



# IOT-Enabled Smart Onion Preservation System for Post - Harvest Loss Reduction

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**Abstract** - Post-harvest onion losses due to inadequate storage conditions continue to pose a major challenge in the agricultural sector, particularly for small and marginal farmers. Improper ventilation, excess humidity, and temperature fluctuations often lead to sprouting, rotting, and significant economic losses. To address this issue an IoT-based Smart Onion Preservation System has been developed to maintain optimal environmental conditions within the storage unit. The system continuously monitors temperature and humidity levels with help of DHT11 Sensor and placed inside the storage chamber. Based on real-time data the system automatically controls with ESP32 Microcontroller to automate 60 W incandescent bulb to regulate airflow and maintain suitable temperature levels. The exhaust fan helps remove excess moisture and heat while the bulb provides controlled warmth when required. Additionally, natural materials such as river sand, charcoal powder and dry coconut leaf fibers are incorporated to enhance moisture absorption, improve air quality and reduce odor. This integration of IoT technology with eco-friendly materials ensures energy efficiency, low operational cost and reliable performance. The system is compact, affordable and particularly suitable for small-scale onion storage applications in rural areas.

**Keywords** - IoT, Preservation System, ESP32, DHT11, Sustainable Agriculture, Post Harvest

## Introduction

Onion post-harvest losses occur due to improper storage conditions such as excess humidity, temperature variation and poor air circulation. These unfavorable conditions lead to sprouting, rotting, fungal growth and weight loss, resulting in significant economic losses for farmers. Using ESP32, sensors and exhaust fans the system automatically maintains optimal conditions and enables remote monitoring to extend onion shelf life. The system also includes a natural environmental control core made of river sand, charcoal powder, dried onion outer layers and coconut leaf fibers. which helps in humidity absorption, odor control and air purification inside the storage chamber.

## II. Literature Survey

Attkan et al (2021) proposed onion slices were dried in a low-humidity air-assisted hybrid solar dryer. Drying occurred in the falling rate period and the drying rate was attenuated with the initial moisture content of the samples. The effects of different drying air temperatures (50, 60, 70°C) and KMS pre-treatments (0.1, 0.3, 0.5%) on drying characteristics of onion slices were also studied. Eight thin layer drying mathematical models viz. Newton, Page, Modified Page, Exponential, Asymptotic, Logistic, Wang and Singh and two-term exponential were investigated and the results were compared to their goodness of fit in terms of coefficient of correlation ( $r$ ), standard error ( $es$ ) and the mean square of the deviation  $\chi^2$ .



Fernandes et al (2022) proposed the design of a user-friendly solar food dryer intended for domestic over-production. The system focused on simplicity, low cost and ease of operation while maintaining effective drying performance.

Horticulture Statistics Division et al (2017) presented comprehensive data on onion production, area, and productivity in India. The report highlights the importance of proper post-harvest management to reduce losses and improve storage infrastructure.

Gopinath et al (2022) developed and tested a thermal energy storage-based solar dryer system for seeded grapes. The system incorporated sensible heat storage materials to extend drying operations during low solar radiation periods. Performance results showed improved drying continuity, reduced drying time and better product quality, highlighting the advantages of integrating thermal energy storage into solar drying systems.

Krabch et al. (2022) designed and experimentally evaluated an indirect solar dryer with a single drying compartment for pear drying. The system aimed to ensure uniform airflow and temperature distribution. Results indicated improved drying efficiency and better color retention of dried pears, validating the effectiveness of indirect solar drying for sensitive food products.

Kushwah et al (2023) optimized drying parameters for banana slices using a hybrid indirect solar dryer with response surface methodology. The study evaluated the effects of temperature, air velocity and slice thickness on drying efficiency and product quality. The optimized results demonstrated reduced drying time and enhanced moisture removal efficiency, confirming the suitability of hybrid solar dryers for banana processing.

Lad et al (2023) conducted a numerical study on a phase change material-assisted indirect solar dryer. The inclusion of thermal storage stabilized temperature fluctuations and improved drying performance. Findings indicated enhanced energy utilization, reduced drying duration and improved food quality during intermittent solar radiation conditions.

Malakar et al (2021) designed and experimentally evaluated an evacuated tube solar dryer that achieved higher drying air temperatures and improved thermal efficiency. Although demonstrated for garlic cloves, the drying characteristics are similar to onion dehydration. Results showed reduced drying time and improved product quality, indicating the system's suitability for onion drying applications.

Sandali et al (2019) reviewed various techniques to enhance thermal performance of solar drying systems. The study discussed improvements such as thermal energy storage, airflow optimization and design modifications. The review highlighted innovative approaches to increase efficiency, reduce drying time and improve product quality in solar drying technologies.

Saxena et al (2020) evaluated drying kinetics of hygroscopic crops using a vacuum tube-assisted hybrid solar dryer. The system demonstrated improved temperature control and moisture removal.

Singh et al (2022) experimentally investigated a mixed-type solar dryer integrated with thermal energy storage for apple slices. The study analyzed drying kinetics and system performance.

Suherman et al (2023) examined solar drying of tomato slices and evaluated drying characteristics under controlled conditions. The study demonstrated effective moisture reduction and acceptable product quality. Results confirmed solar drying as a sustainable low-cost method for food preservation suitable for small-scale agricultural applications.

### **Description of Existing System**

Existing onion storage systems such as split bamboo structures, Vengaya Pattarai and bottom-ventilated sheds are commonly used as alternatives to conventional heap storage. These methods provide partial natural ventilation and help reduce physiological weight loss, sprouting and rotting to some extent. However under tropical climatic conditions their performance remains limited. Inadequate control of internal temperature and humidity often leads to moisture accumulation especially during high ambient humidity and rainfall periods. Uneven airflow within the storage structures causes localized heating, accelerating sprouting and fungal growth. Most existing systems lack effective moisture-absorbing mechanisms and proper thermal insulation, resulting in significant post-harvest losses. As a result, onion losses in these storage methods can still reach 35–40%, highlighting the need for further improvement in storage design and environmental control.



Fig.1.Split bamboo storage structure

### **Description of Proposed System**

The proposed work focuses on developing a low-cost, naturally ventilated onion storage structure using locally available materials such as a bamboo frame, dry sand layer and coconut-leaf thatch roof. Traditional storage systems like split bamboo stores, Vengaya Pattarai and bottom-ventilated sheds have shown reduced physiological weight loss sprouting and rotting compared to conventional heap storage however losses still reach 35–40% under tropical conditions. The proposed design adopts a raised bottom-ventilated structure with split bamboo sides to ensure natural airflow.

An internal dry sand layer is incorporated to absorb excess moisture while a thick coconut-leaf thatch provides thermal insulation and protection from direct sunlight and rain.

**Block Diagram:**

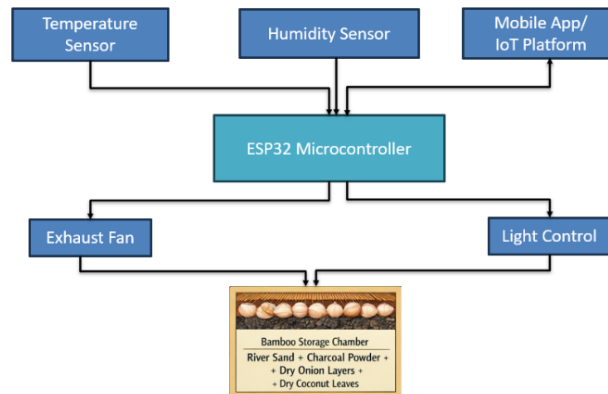


Fig.2. Block Diagram of the Proposed System

**Flow Chart:**

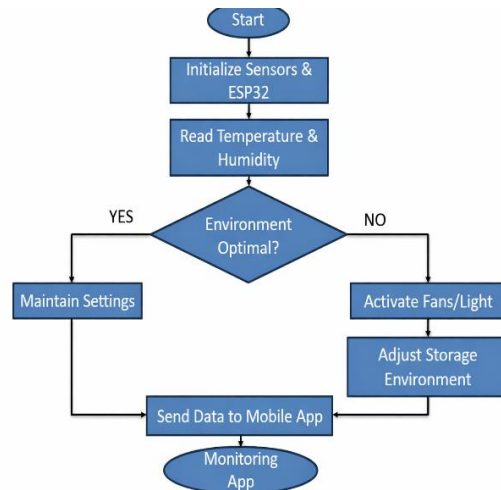


Fig.3. Flow Chart of the Proposed System

**Hardware Implementation:**

The IoT-based Smart Onion Preservation System is a fully automated solution designed to reduce post-harvest losses by maintaining optimal storage conditions. It uses temperature and humidity sensors, exhaust fan, AC 60 W incandescent bulb and a microcontroller to regulate airflow and temperature without human intervention.

**Hardware Components:**

(i) Exhaust Fan: The exhaust fan is used to expel warm and humid air from the storage structure thereby maintaining proper ventilation.



Fig.4. Exhaust Fan

(ii)ESP32 Microcontroller: The microcontroller serves as the central control unit of the system. It processes sensor inputs and controls the exhaust fan and incandescent bulb accordingly enabling automated.



Fig.5. ESP32 Microcontroller

(iii) DHT11 Sensor: The DHT11 sensor is used to continuously monitor the temperature and relative humidity inside the onion storage chamber. Maintaining these parameters within permissible limits is essential to reduce sprouting, moisture accumulation and spoilage.

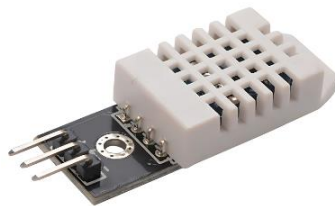


Fig.6. DHT11 Sensor



(iv) AC 60W Incandescent Bulb: An AC 60 W incandescent bulb is used as a controlled heat source inside the storage system. The bulb helps regulate internal temperature during low ambient temperature conditions.



Fig.7. AC 60W Incandescent Bulb

Table 1: Specifications

Name of the Components	Specifications
Exhaust Fan	12V DC
Microcontroller	ESP32 (3.3V)
Temperature & Humidity Sensor	DHT11 (3.3V)
Bulb	AC 60W

**Control Logic:**

- If Temperature > 30°C
  - Exhaust fan ON
  - Heating bulb OFF
- If Humidity > 70% RH
  - Exhaust fan ON
- If Temperature < 25°C
  - Heating bulb ON
  - Exhaust fan OFF
- If Temperature and Humidity within optimal range
  - Both fan and bulb OFF

**III. Results and Discussion**

The proposed IoT-based Smart Onion Preservation System demonstrates effective stabilization of storage conditions under tropical environments. The results indicate that integrating real-time monitoring with passive natural materials significantly improves

moisture and thermal regulation which are critical challenges in onion storage. Unlike conventional low-cost ventilated structures the inclusion of sand, charcoal and coconut fibers provides enhanced humidity buffering and air purification. The automated airflow control further minimizes conditions that lead to sprouting and rotting. Compared with recent onion storage approaches that rely solely on passive ventilation the proposed hybrid system offers improved environmental stability without increased energy consumption highlighting its novelty as a sustainable low-cost solution for extending onion storage life.

#### **Description of the Making Model**

The developed low-cost onion storage structure uses a bamboo frame with split bamboo side walls for natural ventilation. The raised base prevents ground moisture contact while the open lattice design supports airflow and heat dissipation. This structure forms the foundation for integrating natural moisture-absorbing materials and IoT monitoring components.



Fig.8.Making Model

#### **Implementation of the Proposed System**

The model was constructed using a strong bamboo frame elevated above the ground to ensure proper ventilation and prevent direct contact with soil moisture. The side walls were designed with gaps to promote continuous natural airflow. Inside the structure onions were arranged in layers separated by river sand, charcoal powder and dry coconut leaf fibres to enhance moisture absorption and maintain a balanced internal environment. Temperature and humidity sensors were installed to continuously monitor storage conditions. When environmental changes are detected the system automatically activates exhaust fans and airflow control mechanisms.



Fig.9.Implementation of the Proposed System

#### IV. Conclusion

The IoT-based Smart Onion Preservation System minimizes post-harvest losses by continuously monitoring temperature and humidity and automatically regulating ventilation, airflow and lighting. It prevents sprouting, rotting, and excess moisture buildup by maintaining optimal storage conditions. Natural materials such as river sand, charcoal powder and dry coconut leaf fibers enhance moisture absorption and air purification. The system is energy-efficient, cost-effective and highly suitable for small and marginal farmers.

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