

ONION-SHIELD: SMART ONION STORAGE SYSTEM

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Abstract- Agricultural production of onion still faces a lot of difficulties in preserving the crop after harvesting because of the loss of onion due to unsuitable storing conditions. Changes in temperature, too much humidity and not enough air flow can speed up the spoilage process of onions (sprouting, decay, microbial growth) leading to decrease in quality and shelf life of stored onions. These challenges were addressed by designing and implementing a Smart Onion Storage System that continuously monitors and controls the important storage parameters. The system utilizes sensors to detect the temperature, RH (relative humidity) and air quality parameters in the storage space and offers real-time data for monitoring and analysis. The system has an **ATmega328P** microcontroller that controls the interfacing and data acquisition from the sensors, and a **Broadcom BCM2710A1** processor to process the data and provide monitoring in the cloud. It collects the sensor readings and provides an effective monitoring of the storage conditions, allowing corrective actions to be taken at a suitable time if needed. Evaluation during experimentations was performed under various storage conditions and the results showed the capability to achieve a suitable environment for onion storage. The proposed solution will help to decrease the manpower requirement for manual inspection, improve storage efficiency and minimize post-harvest losses. In summary, the developed system provides an effective, feasible, and eco-friendly solution to enhance onion storage management using IoT-based technologies that can reduce expenses for farmers.

Keywords: Smart Onion Storage System, IoT, Arduino Uno R3, Raspberry Pi 02W, DHT11 Sensor, MQ-135 Sensor, Temperature Monitoring, Humidity Control, Air Quality Monitoring, Automation, Relay Control, Exhaust Fan, Heating Bulb, Cloud Monitoring.

I. INTRODUCTION

The storage of onions after harvesting presents a major difficulty for farmers, mainly due to the sensitivity of the crop to environmental conditions. Excess moisture, temperature changes, and lack of airflow are common causes for quality loss, such as sprouting and decay. In many instances, traditional storage techniques are not able to provide the necessary conditions to store the produce and result in significant post-harvest losses, particularly in less resourced areas. To overcome these challenges, the Smart Onion Storage System is proposed as a technology-driven approach for improving storage efficiency. The system is designed to monitor important parameters like the temperature, humidity and air circulation with appropriate sensors. The adjustments (necessary modifications) are

automatically made based on continuous data collection, in order to keep the internal environment stable and fit for onion storage.

The entire system consists of sensors, a control module, and airflow and moisture control mechanisms. These elements work in unison to form an intelligent storage solution, minimizing the need for constant human oversight. The design is designed to be simple, cost-effective, and versatile, allowing for easy integration into both small and large-scale agricultural systems. [1], [2], [6], [7].

A. Working of Smart Onion Storage System

The Smart Onion Storage System works by constantly monitoring and controlling the internal storage environment to ensure suitable conditions for onion quality preservation. The system is primarily concerned with control of three main factors, temperature, humidity and air movement, which are important factors in onion shelf life. A series of environmental sensors are used to measure the humidity and temperature levels within the storage unit at the heart of the system. The sensors are connected to a microcontroller that serves as the control unit for the system. This data is sent to the microcontroller which compares it to the optimum values set for safe onion storage. If the sensed values go out of the range, control mechanisms are automatically activated. If the humidity rises above the specified value, for example, a ventilation fan is started to circulate air and dry the air. Likewise, when the temperature increases, cooling or air movement mechanisms are activated to return it to a desired temperature. In some designs; exhaust systems or air ducts are used to provide adequate ventilation. The system is a closed-loop system, meaning that there is a continuous feedback loop between the sensing, processing, and control functions to maintain environmental stability. This automation eliminates the need for manual monitoring, and also decreases human error. Moreover, the system can be made with display unit or wireless module to watch the data remotely. This enables them to see the storage situation and the performance of the system in real time.

Overall, the operating principle of Smart Onion Storage System is based on integrated principle of sensing, decision making and automatic control, which is responsible for an efficient storage and reduction of post-harvest losses. [1], [2], [3].

II. LITERATURE REVIEW

Various researches have pointed out the significance of appropriate storage to minimize post-harvest losses of onions. Conventional storage techniques are unable to control temperature, humidity and air movement effectively which causes spoilage and degradation in quality. The latest developments are in the area of sensor-based and automated systems that monitor various environmental parameters and ensure the storage conditions are optimal. While these smart solutions are efficient and reduce the need for manual work, there is a need for affordable and scalable solutions that can be widely adopted.

1. Traditional onion post-harvesting Techniques.

Onion postharvest practices are simple and inexpensive, so traditional practices are widely used. Once harvested, onions are usually cured by sun drying for a few days to help lower moisture on the surface and extend their shelf-life. This process is beneficial in improving the outer skin and reducing the risk of microbial infection during storage. After curing, onions are often kept in sheds or temporary storage facilities constructed from local materials, including bamboo, wood, or mesh. Once cured, onions are typically stored in sheds or temporary structures like bamboo, wood, or mesh, which are made from locally available resources. These storage techniques involve using the natural air circulation to regulate moisture and heat. Platforms or racks may be built on by farmers at times, for better ventilation and to avoid contact with the ground. Here are the traditional methods, and some disadvantages of these methods. They have no specific control over environmental conditions (temperature and humidity) which may result in spoilage, sprouting or loss of weight of the stored onions, especially under poor climatic conditions. This implies that a significant amount of losses can be incurred in post-production, and improved and more stable storage systems are required. [6] [7], [8].

2. Solar-Powered Smart Onion Storage Innovations

The development of smart onion storage systems which are solar-powered has been developed to resolve the limitations of traditional storage, particularly in places where electricity is unreliable. Such systems harness solar power to drive components like fans, sensors and control units and are able to run continuously and at lower cost. The sensors measure different parameters like temperature and humidity, and an air flow is managed by solar-operated mechanisms to keep the storage conditions adequate. Adjustment is automatically done using the microcontroller-based control, thereby minimizing the moisture damage as well as the chances of sprouting and spoilage, based on real time data. While these systems provide energy efficiency and sustainability, there are some challenges like start-up cost and maintenance. Even so, the innovations related to solar

powered storage offer viable options to enhance the storage of onions and minimize losses after harvest. [5].

3. Cost-Effective Smart Onion Storage Technologies

The development of the cost-effective smart onion storage technologies is a cost-effective solution to ensure proper storage conditions. The systems incorporate cheap sensors, microcontrollers and basic ventilation systems to regulate and measure the humidity and temperature. They need less energy and investment and bring less to the table in terms of weight loss, sprouting and spoilage as compared to traditional cold storage. They are simple to use and can be used in small scales as well as larger storage applications. The technologies though may lack in accuracy; they are still useful and cost-effective for enhancing onion storage and reducing post-harvest losses. [1],[2],[3].

A. Comparison and Analysis of Literature Review

When comparing the various storage methods for onion, it is found that the traditional methods are low cost but are not properly controlled environmentally giving rise to increased losses. More complex systems such as cold storage provide improved preservation, but are costly. Smart storage solutions offer a balance that improves efficiency at a more affordable cost through the use of sensors and automation. Overall, these systems are more appropriate for the contemporary requirements of agriculture.

- Traditional Onion preservation system vs. Modern Automated

Onion preservation systems used traditionally involve sun drying, open air and ventilated structures. The following methods are low-cost, easy to implement, but provide little control of environmental conditions and increase susceptibility of onion to spoilage, sprouting and loss of quality. The other systems, the automated systems, use sensors, micro controllers and ventilation systems to track and regulate temperature, humidity and air flows. These systems provide improved storage conditions and reduce the amount of post-harvest losses while increasing the shelf life. Conventional approach is simple and cost-effective, but modern automated approach provides better efficiency and reliability. But they can come with a hefty price tag. In conclusion automated systems offer a better solution for maintaining quality in onion long-term storage. [1], [2], [3].

- Solar-Powered Solutions vs. Electricity-Powered Solutions

Solar based storage systems are powered by energy derived from sunlight, which is beneficial in areas where standard electricity isn't available at all times. They can aid in reducing long-term costs, but their effectiveness varies with weather conditions, and they can require supplemental

assistance. Electricity-powered systems, on the other hand, can operate continuously and reliably, ensuring the maintenance of optimal storage conditions. They can, however, raise the operating costs and require a constant electricity source. Solar systems are sustainable and electric systems are consistent. [5].

• Cost-Effective Technologies vs. Consistent Performance

Cost effective storage technologies are those that require a simple component design and use energy efficient designs to ensure that expenses are kept to a minimum, which is suitable for farmers who have limited resources. These systems, however, don't always keep things perfectly stable. Systems that are designed to be consistent offer better control of the environment, including temperatures and humidity, which results in a reliable storage environment, however these systems typically have higher costs. So, there is a compromise between cost and having consistent storage performance. [1], [3], [5].

B. Overall Analysis

A general assessment of the different storage methods shows that there are significant differences in the efficiency, cost and reliability of them. Traditional techniques are simple to practice and inexpensive, but they do not ensure sufficient control over the environment leading to a greater risk of spoilage, sprouting and loss in quality. Advanced storage systems have a better control of temperature, humidity and ventilation, which extends the storage period and improves the quality of the stored products, but they are more expensive;

Today's smart storage solutions bring sensor-based monitoring and automated control to the mix in order to strike a balance between performance and affordability. Solar-powered systems improve feasibility in areas with poor power supply and the cost-effective designs make the technology more attractive to smaller and medium-sized farmers. The systems conserve man power, utilize storage space and prevent post-harvest losses overall [1] [2] [3] [6]. Based on the aforementioned analysis, it is concluded that smart onion storage systems offer a viable and sustainable solution to the problems of traditional storage systems, giving more control, flexibility and long-term benefits.

III. PROPOSED SYSTEM

A. Simulation Diagram

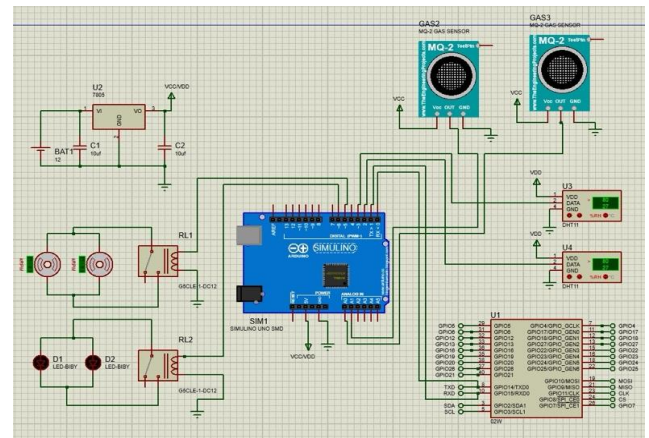


Fig.1 Circuit diagram

Smart Onion Storage System (S.O.S.S.) is a combination of sensors, automation and remote monitoring that create a controlled storage area. It is designed to keep the temperature, humidity and air quality at an appropriate level to minimize onion spoilage and shelf life.

The DHT11 sensor is used to measure the temperature and humidity, and the MQ-2 sensor is used to detect the unwanted gases. The sensor data is then processed with arduino using the ATmega328p microcontroller. Relay modules regulate an exhaust fan and heating bulb for better storage conditions if the readings are outside the specified range.

With a BCM2710A1 chipset, the Raspberry Pi makes it possible to connect to the cloud so that users can control the storage environment remotely, in real time. The power is provided by the battery, and the voltage regulator provides a stable voltage to the components.

The system automatically senses, process and takes corrective actions. It decreases human labour and offers a technology driven solution to enhance the onion storing process and minimize post-harvest losses.

B. 3D Design of the Storage Chambe

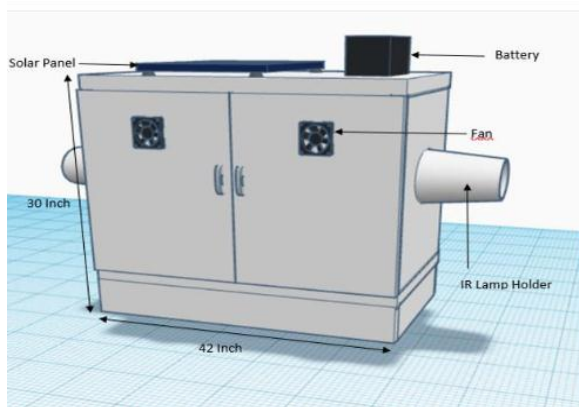


Fig.2 Outside Structure

Figure. 2 The second is the proposed Smart Onion Storage System for providing a controlled storage system to ensure quality and lessen post-harvest losses of onions as shown in figure 2. The system comprises of a storage chamber, which is closed off, and includes environmental control and monitoring devices. The roof of the structure is covered with a solar panel, which is the main source of energy for the system. The energy produced is stored in a battery so as to provide uninterrupted energy supply during the low sun periods. One or more ventilation fans are fitted over the chamber to ensure adequate ventilation, temperature and humidity control and to avoid excessive moisture build-up inside the storage. Additional heating is provided by incorporation of an IR lamp holder to support temperature management. The storage chamber is about 42 in long by 30 in high which is sufficient for onion storage. The closed configuration shields stored onions from the unwanted environmental changes and provides more control over the inside environment. The proposed system incorporates renewable energy sources, ventilation systems, and environmental monitoring technologies, creating a sustainable and efficient solution for the preservation of onions. The design will optimize the use of storage space, prolong the shelf life of the product, and reduce losses due to poor storage conditions.

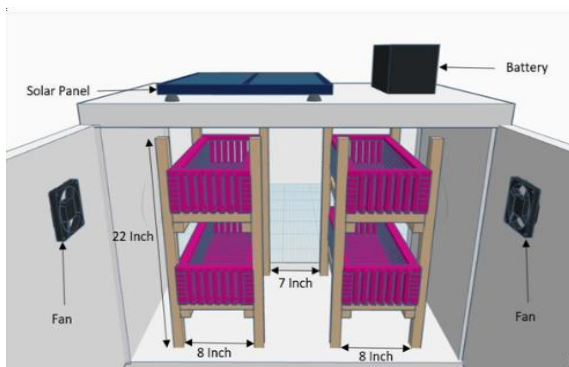


Fig.3 Inside Structure

Figure. 3 shows the internal arrangement of the proposed Smart Onion Storage System. The chamber contains two racks with multiple trays for storing onions. The trays are arranged vertically to make better use of the available space, while the gaps between them allow air to circulate freely. Each rack is approximately 8 inches wide, with a 7-inch gap between the two rack sections to support the distribution of air throughout the chamber.

Ventilation fans are fitted on both side walls to maintain airflow and help regulate temperature and humidity. Proper ventilation can reduce moisture buildup and lower the risk of onion spoilage, sprouting, and microbial growth. A solar panel mounted on the top of the chamber supplies energy, which is stored in a battery to support system operation. The chamber is 22 inches high and is designed to provide sufficient storage space without restricting airflow. Overall, the design combines efficient space utilization and ventilation to support better onion preservation and reduce post-harvest losses.

C. Onion Storage Trays



Fig.4 Onion Holding Tray

Figure.4 The proposed Smart Onion Storage System uses a perforated plastic tray to store onions within the storage system. There are several openings in the base and side walls of the tray to allow for airflow to pass around the onions stored in the tray. Ventilation is necessary for appropriate storage conditions to prevent buildup of moisture and reduce the chances of spoilage, sprouting and fungal growth. The tray has a lightweight plastic body which is easy to handle, clean and set up inside the storage chamber. The perforated design also ensures even delivery of the air blown by the ventilation fans, so that all onions in storage are subjected to the same conditions. The tray design is therefore an important aspect to enhance the storage efficiency and quality of onion during the storage period.



Fig. 5 Storage Capacity of Onion Trays

The storage capacity assessment of a single onion tray which is used in the proposed Smart Onion Storage System is shown as in Figure.5. To find out how many onions can be put into one tray so that the airflow and storage efficiency of the scale will not be affected, a digital weighing scale was used. The weight measured was about 5 kg, the maximum weight which was chosen for each tray. This plant's capacity helps to provide adequate spacing between onions to allow for proper air circulation throughout the storage chamber. The total storage capacity of the system is about 20 kg as it is composed of four trays. This design of the tray can help maximize storage space and provide adequate conditions for the storage of onions and minimize spoilage in the storage area.

D. Monitoring Parameters

Table. 1 Environmental Parameters Monitored in the Proposed System

Parameter	Ideal Range for Onion Storage	Monitored in Proposed System
Temperature	25°C – 30°C	DHT11 Sensor
Relative Humidity	65% – 75% RH	DHT11 Sensor
Air Quality	0-50 AQI	MQ-135 Sensor

Proper environmental conditions are vital to good storage quality and shelf life of onions. One of the most important factors is temperature; too high temperatures will hasten sprouting and spoilage. So, DHT11 is always monitoring the temperature within the recommended range of 25°C–30°C. The DHT11 sensor is also used to monitor the relative humidity level, which is kept between 65%RH-75%RH to avoid moisture loss and avoid fungal growth. An MQ-135 sensor is also installed to monitor air quality to determine the storage environment and to detect the presence of unwanted gases. The Air Quality Index (AQI) 0-50 means

good AQI, good ventilation, and maintaining good air quality is essential for good storage environment. These parameters are monitored continuously, so that the proposed system can help in the effective preservation of onions and minimize post-harvest losses. [3], [6], [8].

E. Flowcharts

A) System Flowchart

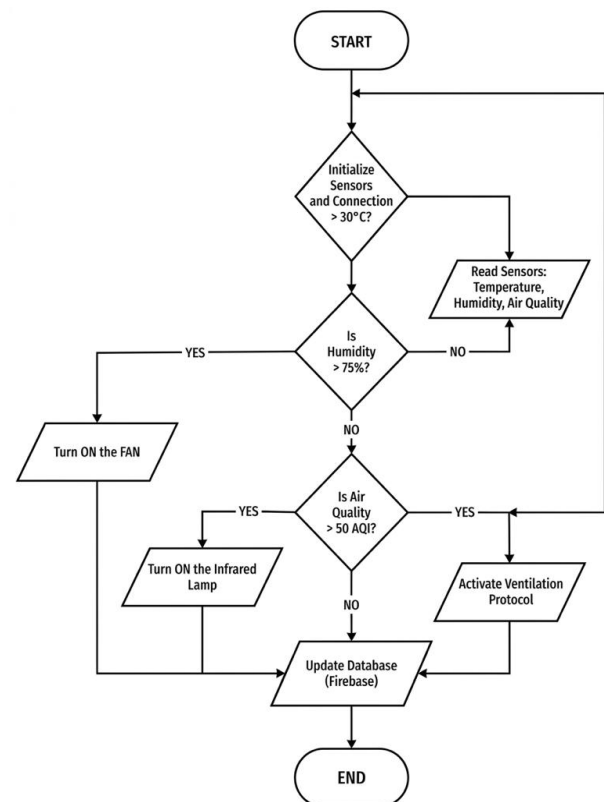


Fig. 6 Flowchart

The Smart Onion Storage System (Fig.6) works by constantly monitoring and controlling the major environmental factors that influence onion storage such as temperature, relative humidity, and air quality. The sensors and the communication modules are first switched on to start recording the data in the storage space. The sensor data acquired is continuously analyzed to assess the storage conditions. If the humidity has been passed 75%, the ventilation fan will automatically be switched on improving the ventilation and reducing the amount of excess moisture present in the chamber. This will avoid undesirable conditions that can cause spoilage. It is also capable of air quality monitoring with MQ-135 air quality sensor. When air quality value is > 50 AQI, a ventilation protocol is activated to ensure the proper environment for the storage. Furthermore, an infrared lamp is employed to guarantee optimal preservation conditions if a temperature control is needed.

Once the required control actions are executed, the sensor data and system status is uploaded to the cloud database built with firebase. This allows you to monitor and access storage information in real time, remotely. This entire process is repeated continuously, so that the system can react quickly to the changes in the environment and thus keep the conditions advantageous for onion preservation.

B) System Block Diagram

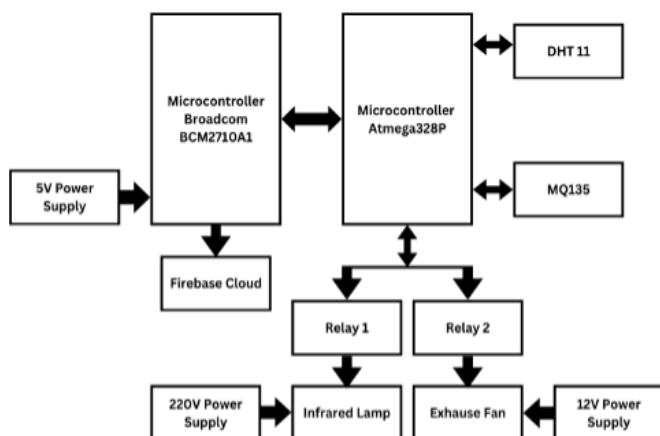


Fig. 7 Block Diagram

The block diagram (Fig.7) is a representation of the structure of the Smart Onion Storage System and interaction between its components. The sensors and control units are powered by a 5V power supply. The main controller of the system is an **Arduino Uno R3 (ATmega328P)** and the cloud data is transmitted through a **Raspberry Pi (BCM2710A1)**. This sensing unit is made up of two sensors, **DHT11** which is used for measuring temperature and humidity and **MQ-135** which is used to detect air quality. These sensors will continuously transmit data to the Arduino, which will compare the data to the set limits and take appropriate action. Arduino controls two relays depending on the conditions. A single relay is used for the infrared heating lamp, which is powered by a 220V supply to remove moisture, while the second relay powers a 12V exhaust fan for heat removal and ventilation. The **BCM2710A1** uploads data to the Firebase cloud, for remote monitoring. In general, the system provides proper control of environment and efficient management of onion storing. [1], [2], [3], [4].

IV. RESULTS

The findings of the Smart Onion Storage System show that real-time monitoring and data-transmission is possible with the help of cloud integration. The system continuously collects data from environment using sensors and uploads that data to Firebase database, which is accessible remotely. The observed results showed that the air quality measured by the sensor MQ-135 was about 24-38, which represents

the condition of the storage environment. The humidity was observed to be around 25% and 36% and the temperature was approximately 32.5°C and 32.6 °C in the DHT11 sensors. These values validate the fact that the system can accurately measure the environmental parameters and display the values in real time on the cloud platform. From these readings, the **ATmega328P** clearly can control the exhaust fan and heating bulb to provide appropriate storage conditions. Combining Raspberry Pi with Firebase creates a continuous data flow so that users can track the storage environment remotely. The overall outcomes confirm the correct functionality of the system in terms of sensing, processing and cloud monitoring.

Table.2: Comparison of Recommended Storage Conditions and Measured Values

Parameter	Suggested Range	Sensor 1 Reading	Sensor 2 Reading
Temperature	25–30°C	28°C	28°C
Humidity	65–75%	69%	69%
Air Quality	0-50 AQI	42AQI	42AQI

Table.3: Comparison with Traditional Onion Storage

Features	Traditional Onion storage	Smart Onion Storage System
Working	Manual	Automatic
Sensor Monitoring	No	Yes
Air Quality Detection	No	Yes (MQ-135)
Temperature Control	Limited	Controlled
Humidity Control	No	Yes
Ventilation System	Natural	Exhaust Fan (Automatic)
Moisture Control	No	Heating Bulb Used
Remote Monitoring	No	Yes (Cloud via Raspberry Pi)
Cost	Low	Moderate
Supervision Required	Yes	Minimal
Efficiency	Low	High

Table.3 The proposed Smart Onion Storage System monitored the environmental parameters during the experimental period, which are presented in this figure. Both the sensors gave a temperature reading of 28°C and is within the recommended range of 25–30°C for storage of onion. Appropriate temperature control can minimize the chances of sprouting and loss in quality. The relative humidity of both the sensors was 69 % which lies within the desired range of 65-75 per cent. This will stop excessive moisture loss and minimize the risk of rotten growth and spoilage. Both sensors measured AQI readings of 42, which is considered good air quality. The readings indicate proper ventilation was provided, which would have helped to keep harmful gases from building up and would have helped provide a proper environment for onion preservation.

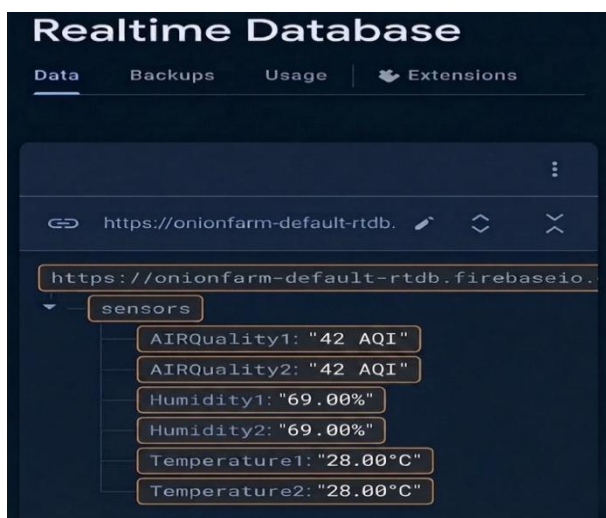


Fig.8 Data Showcased on Google Firebase



Fig.9 Prototype of the Working System

The prototype is designed as a collection of four trays, which is placed on two wood racks to store onions in a controlled environment. It is heated by an internal heating bulb, and the electronic components and wiring power up the system. The

prototype is intended to ensure proper conditions for the storage and to aid in decreasing the losses of post-harvest.

V. CONCLUSION AND FUTURE SCOPE

In conclusion, the Smart Onion Storage System offers a practical solution for automated monitoring and control, ensuring optimal storage conditions for onions. DHT11 and MQ-135 sensors are used to continuously monitor the temperature, humidity and air quality of the storage area. This data is then passed on to the Arduino Uno R3 which controls devices such as the exhaust fan or the heating bulb that help maintain an appropriate environment. With the inclusion of Raspberry Pi, it is possible to send real-time data to the cloud, enabling control of storage conditions remotely. It is proven to be efficient in reducing moisture, air-flow and post-harvest losses. Moreover, solar energy can be utilized in rural and low-resource regions, so it is more applicable for those regions.

Future scope

Future improvements to Smart Onion Storage System may involve greater sophistication of monitoring and mobile interface to warn the user when the environmental conditions are out of the safe zone.

Intelligent control techniques can be used to automatically regulate the airflow, humidity and temperature of the system, which can effectively improve the efficiency and reduce energy consumption.

It can also be adapted for other agricultural commodities like fruits and vegetables, thus expanding the scope of its use.

Can also be used to store other agricultural products such as fruits and vegetables. Looking forward, further advancements can be directed towards optimizing the solar energy harnessing efficiency and battery performance, ensuring reliable operation in regions with limited power availability.

The system could be further developed to include the features of IoT data analysis and cloud-based platforms to provide valuable insights that can help with better storage management and decision-making.

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Biography



Chirag Yogesh Zope is an Electronics and Telecommunication Engineering graduate with experience in network operations. His Smart Onion Storage System project was presented at the Avishkar Project Competition organised by SPPU. He plans to pursue an MS degree overseas to advance his technical knowledge.



Vishal Tukaram Kale has completed his Bachelor's degree in Electronics and Telecommunication Engineering. He is currently working as an Audit Officer at Quess Corp Limited, where he is gaining professional experience and developing his analytical and auditing skills.