Development of Onion-Storage Facility for better Shelf Life

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Abstract - Owing to a lack of infrastructure, variability in Indian climatic conditions and climate changes, farming sector is experiencing huge financial distress. So, farmers are unable to contribute to the economic growth of our country as per their potential. A majority of the population is involved in farming but many of them are struggling in fulfilling their basic necessities. The major problem in the farming sector is the low shelf life of the crops i.e they are perishable in nature. Even if the shelf life is good enough, due to the deterioration of quality of crops, their valuation decreases. There are several cold storage structures are available, but they are not affordable to small farmers. Onion is one of the major crops in Maharashtra state and is one of the most sensitive crop. So, in this work, a novel design of a cost-effective storage system for onions is proposed with the motive to increase the shelf life of crops and maintain the quality of crops.

Index Terms - Onion, storage structure, shelf life, sprouting, black mold, neck rot, internet of things, sensors, shaded pole induction motor, speed control, Vedic plaster, solar thermal application

I. Introduction

Farming in India has a substantial impact on the national economy and the financial well-being of growers and consumers. India is set to break records in the year 2017 with an onion (Allium Cepa L) output exceeding 20.6 million tons, making it the world's second-largest onion producer. However, India's fluctuating climate leads to significant onion spoilage during storage, resulting in the annual wastage of about 4 million tons. (Sathiyabama. N, 2017). Onion is harvested during the rabi season, accounting for 65% of onion production and reaching the market from April to May. The same crop must continue to meet consumer demand until the months of October and November each year before the kharif crop is harvested and brought to market. As a result, storing onion is critical to maintaining a consistent supply. It has been observed that approximately 30-40% of the crop is lost during storage for a variety of reasons, including physiological weight loss, rotting, sprouting, and so on. (government sources). The importance of onion storage systems cannot be underestimated.

Proper storage structure significantly prolongs the shelf life of onions and maintains their market value. Rotting of onion can be reduced by controlling humidity and providing adequate ventilation. This quality preservation not only ensures the preservation of the flavor and nutritional value of onions but also reduces post-harvest losses, benefiting both growers and distributors. There are few more problems that farmers face like black molding, weight loss and sprouting but these problems can be minimized by maintaining the proper temperature and relative humidity of the storage structure. Effective storage structure allows onion availability across seasons, which is critical for areas with seasonal growing patterns and for maintaining a steady supply during off-seasons. Such storage facility will also reduce the chances of price rise in onion. Proper storage also facilitates onion exports, as it ensures compliance with international quality standards. It supports value-added manufacturing industries by providing a good quality of onions to maintain product quality. Storage structure should be cost effective so that, farmers have easy accessibility. Also, efficient storage structure ensures a stable supply of this essential crop with required nutrients throughout the year and reduces the wastage. In this way, it can be availed at good market price and farmers will also get better profit margins out of it.

India's climate has exhibited heightened variability across seasons, leading to unanticipated fluctuations in temperature and humidity. These conditions increase the susceptibility of onions to spoilage, primarily due to fungal growth, culminating in bacterial rot, sprouting, and weight loss. (V.G Wagh, 2016). The highest rates of sprouting (67.25%) and rot (17.78%) were observed in onions stored at 13˚C. (Mouluda Sohany, 2016).

Sathiyabama et.al. have attempted to prevent onion from weight loss, sprouting and rotting by evaluating health of onion bulb using ammonia gas and carbon di oxide gas emission data and further use this data to control temperature. V.G. Wagh et.al. attempted the same method of detection of gases for monitoring the health of onion bulb and further take action to maintain the temperature using different control strategy. But both of them did not elaborate on the cooling system employed for temperature control. R.P. Murumkar et. al. suggested natural ventilation technique using PVC pipes for enhancing shelf life of onion bubls and reduce post-harvest losses. Pavankumar R. Sonawane et.al. suggested a noval technique i.e vapour compression cycle based onion preservation system in which they are maintaining the temperature in the range of 5ºC -10 ºC using refrigeration process. This might be an effective method but a costly affair which small and marginal farmers might not afford.

The contribution of this work is listed as follows:

1) Storage structure is designed on CAD software by using the concepts of green building which will help to maintain the temperature with minimum possible power input. CAD modeling (Computer Aided Design) is an essential tool in the design of storage structures, whether for warehouses, industrial facilities, or architectural applications. It enables engineers and designers to create highly detailed, accurate and scalable 3D representations of the storage system.

2)In this work, temperature is being maintained without using any refrigeration process as it is an energy intensive method of maintaining the temperature. Instead, forced ventilation is employed with the help of bidirectional control of fan. In this method losses in onion does happen but it is minimum which make it an optimal solution. This approach save huge amount of power and money in terms of energy bills. This approach is a cost effective solution which make further it affordable to even small farmers.

3) This whole system work on IOT setup which will help in automatic speed control of fan in order to implement the concept of solar thermal application.

II. Losses in Onion

Onion bulbs are very sensitive to temperature and relative humidity. Onion is a highly perishable crop as the temperature and humidity vary throughout the year in a wide range. Due to unavailability of sufficient storage facility, the post harvest losses (both qualitative and quantitative) in onion are very high. The targeted temperature and relative humidity for onion storage is 25ºC-30ºC and 65%-70% respectively (recommended by national cooperative development corporation).

Figure 1. Sprouting in Onion

Sprouting in onion: A combination of natural growth mechanisms and storage conditions leads to the sprouting of onions. As biennial plants, onions have a two-year life cycle. If they are kept in storage for a long time, they may sprout since they will go through their normal growth phase. Crucial factors include storage conditions; onions that are kept in warm, humid circumstances are more likely to sprout. Sprouting can also result from physical damage sustained during handling, harvesting timing, and varietal characteristics. Onions should not be stored next to potatoes since the gasses from the potatoes can hasten the sprouting process. Instead, onions should be kept in cool, dry locations with adequate air circulation. Onions that have sprouted can still be eaten, however their flavor may be softer than that of the onion overall.

Rotting in onion: A number of things, including too much moisture, inadequate ventilation, and bacterial or fungal diseases, can cause onions to rot. During storage, high humidity and insufficient air movement can foster the growth of bacteria that cause rot. Pathogens may also enter through mechanical damage sustained during harvesting, handling, or storage. The risk of decay is further increased by storage in unclean or wet environments. Onion rot can be avoided by properly storing them in a cool, dry location with plenty of airflow. Furthermore, separating harmed or diseased onions prior to storage contributes to preserving the general durability and quality of the onion supply.

Black Moulds in onion: A fungal infection, most frequently Aspergillus niger, is the usual cause of black mold on onions. This fungus can infect onions during growth, harvest, or storage. Its spores flourish in warm, humid environments. Due to the fungus's ability to penetrate surface wounds, onions that are bruised or damaged are especially vulnerable. Black mold grows as a result of improper storage conditions, such as excessive humidity and inadequate ventilation. The onion appears blackened as the mold becomes infected and releases dark-colored spores. Black mold on onions can be avoided with good agronomic and storage practices, such as handling onions gently to limit damage and providing enough air to reduce humidity. Moreover, storing onions in a cool, dry environment.

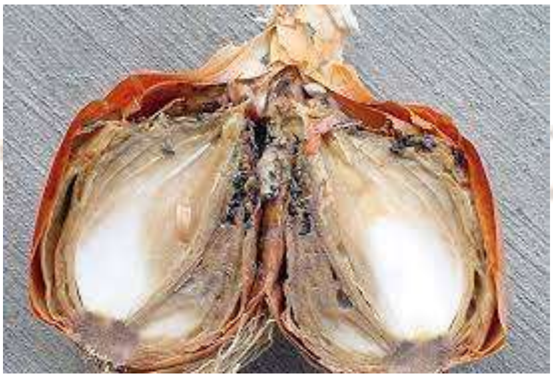

Figure 2. Rotting in Onion

Figure 3. Black Moulds in onion

Physiological weight loss in onions: Onions' weight is mostly determined by a number of elements pertaining to their production and growth. Important factors influencing bulb size and weight are soil quality, growth length, and onion variety. Larger and heavier onion bulbs develop more fully when given enough light, water, and nutrient-rich soil. The growing season's weather and other external elements are also very important. When conditions are ideal, onions typically grow larger, heavier bulbs. Onion weight and quality are also influenced by harvesting and storage techniques, including appropriate handling throughout these phases. Onions' weight is essentially the result of a combination of environmental influences, genetic factors, and cultivation techniques used throughout the course of their life cycle.

Total soluble solid(TSS): TSS indicate the amount of soluble solid in any crop. TSS value affect the taste of the crop as it consist of sugar content, protein, amino acids and other organic materials. It is also an important factor for judging the quality of onion. As per standard set by Government of India, TSS should lies between 10-12 %

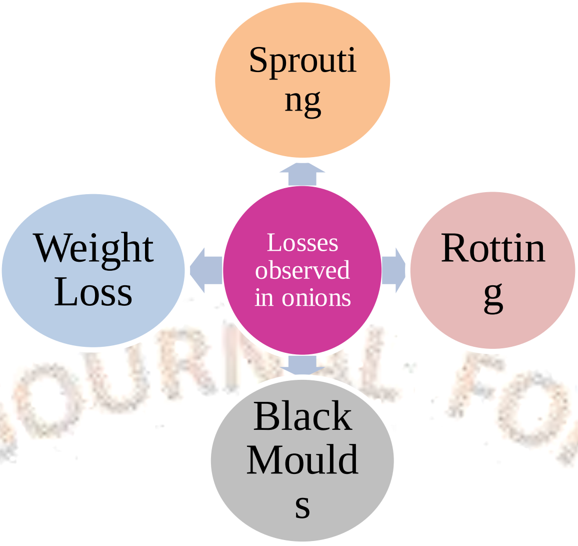

Figure 4. Various losses observed in onions

III. ONION AND ITS STORAGE STRUCTURES

Onions are one of the oldest bulb crops known to man. It is a key ingredient in many cuisines from all cultures and religions. It is valued for its distinctive pungent odour and numerous health benefits. India cultivates approximately 30 onion varieties. Crops are sensitive to temperature and rainfall pattern; northern India grows onion in rabi season (November-April), whereas Tamil Nadu, Andhra Pradesh, Karnataka, Gujarat, and Maharashtra grow both in rabi and kharif (June-October). **(E.P. Banuu Priya).** Storage Structure plays a vital role in onion segment. Different storage structures are already proposed. Farmers in India practise a variety of storage methods. Charches are one type of storage method used in India's Ladakh and Odisha regions. In this method, freshly harvested onions are tied in bunches and hung from the ceiling with support from long sticks. (**SudaRshan Bhalshankar)**. This method is suitable for short period of storage.

Figure 5. Charches method of storage

Vengaya Pattarai: In this type of storage system, big rectangular blocks are placed in a geometrical manner. An overlying structure is laid over these stones. The base of the structure is made up of neem wooden board. The three lateral sides and the roof are covered with the help of coconut thatches which help not only to reduce the exposer to rainwater but it also protects the crops from excessive sunlight which can potentially damage the crops. The fourth side can be covered either with jute gunny bags or bamboo sheets.

Kanda chawl: These structures are mostly found in Maharashtra (state of India which is the leading producer of onion). This structure is stationed on a raised platform to prevent onion bulbs direct contact to ground moisture and dampness. The roof of the structure has increased centre height and more slopes at the end to allow good air circulation. It uses shade on the roof to avoid direct exposure to sunlight. The structure can be made cost effective by using locally available construction material.

Ventilated Storage: In this storage technique, crops are kept under natural ventilation on all sides of the structure. An onion can be stored for as long as 4 month with 4-8% losses. If we use forced ventilation, the duration can be increased upto 10 months with 2-4% losses. The total losses in low cost bottom ventilated structure are much lower than other types. The cases of black mould and sprouting is also lower as reported.

Cold Storage: These are concrete structures with refrigeration process used to moderate the temperature to required level set by operator. This is the most efficient method of storing onion with lowest possible losses but on the other hand operating and initial cost is very high**.**

IV. System Description

Storage structure: Storage structure is the most important component in onion storage, so this work start with design of storage structure. This structure is designed in such a manner so that temperature can be modulated just by air circulation. It is easy to either increase the temperature or decrease the temperature inside the storage by just changing the direction of air. One small opening at the bottom of one side wall and one opening at the upper part of other side wall is provided. If the air moves from lower opening towards upper opening, the temperature inside the structure will decrease and if the direction of air reverses i.e from upper opening on one side wall towards lower opening, the temperature will increase. The air circulation in either direction can be maintained with help of fan with bidirectional motion control. This method of temperature regulation is also known as solar thermal application. The dimensions of storage structured designed is 9ftsx9ftsx8fts. This structure is designed for the storage capacity of 2.5 tons. The storage structure consists of three racks; these are latticed racks which will facilitate natural ventilation among them.

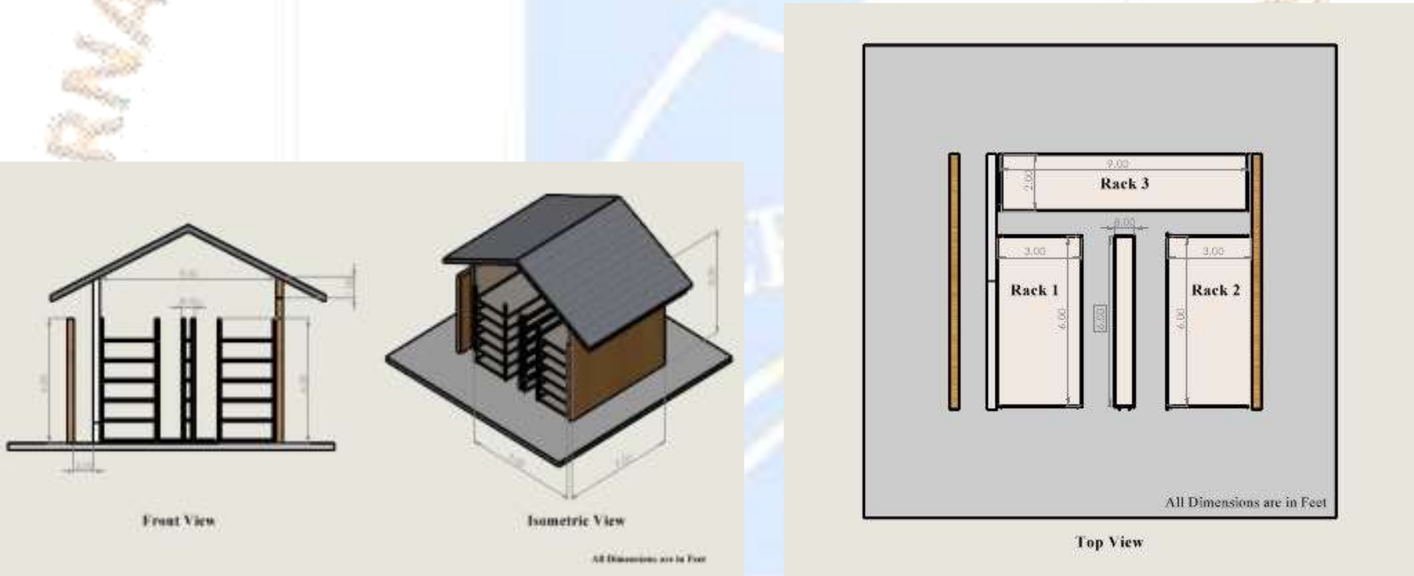

Figure 6. 3D CAD Model Designs

Figure 7. Prototype of Storage System

Vedic Plaster: Vedic plaster is created by combining natural resources like gypsum and cow dung ash in the right proportions. This eco-friendly alternative reduces environmental pollution, which can result from cement and its derivatives. The versatile vedic plaster composite finds numerous applications, particularly in areas where lightweight, cost-effective, and non-load-bearing materials are needed. (Deepak Meshram, 2021)

Cow dung retains water when mixed with other components. After the finishing process, the water gradually interacts with the plaster. Lime also stores and releases water as needed. The goal is to create lightweight samples with improved thermal properties for enhanced comfort in traditional construction. (Borade Mansi, 2020)

Figure 8. Vedic Plaster

Advantages:

• Vedic Plaster requires no curing after application which saves up on all that water.

• Vedic Plaster is very light weight and total strength is achieved in air.

• Due to low thermal conductivity of Gypsum and Cow Dung, it keeps house warm during the cold months (Winter Season) and cool during the warm month (Summer Season).

• ensures energy and power saving in the buildings.

Table 1. Vedic Plaster Properties

Property	Description
Composition	- Primary ingredients: Gypsum and Cow Dung Ash
Mixing Ratio	- Proportion mix, precise ratios may vary
Environmental Impact	- Reduced environmental impact compared to cement
Uses	- Non-load-bearing, lightweight, cost-effective
Thermal Performance	- Improved thermal properties, varies with formulation
Application	- Traditional construction for walls, ceilings, etc.
Thermal Conductivity	- Specific thermal conductivity values may vary
Fire Resistance	- Generally fire-resistant due to gypsum content
Workability	- Offers good workability for application
Aesthetics	- Provides a traditional and natural appearance

Cooling Fan with Motor: This project's outcome relies heavily on control of air circulation in both directions in order to implement the concept of solar thermal application wherein if air moves from ceiling to ground the temperature increases and if the direction of air reverses the temperature decreases. This can be done by bidirectional speed control of fan the speed and direction of an induction motor, which relies on AC power for operation Speed is altered by adjusting the AC power through an AC driver circuit. This is achieved using a microcontroller from the Atmega family, which provides PWM power to an opto-coupler. The opto2-coupler, in turn, controls a TRIAC that regulates power to the induction motor. (Md. Abdullah Al Rakib, 2022)

When it comes to ventilation in a storage structure, self-starting induction motors are the best option because they start up automatically and don't require external starting mechanisms or human intervention. Self-starting motors also guarantee continuous ventilation in storage facilities, where air circulation is essential for preserving product quality, managing environmental factors, and avoiding the buildup of hazardous gases.
The technical Specification of the fan used is as per following table: -

Table 2. Cooling Fan with Motor Properties

Rated Voltage Volt/Hz	230 V/ 50 Hz
Air throughout Unimpeded airflow	55/ 66 m^3/h
Axial fan	Self starting shaded pole motor
Rated Current	0.12 A/ 0.11 A
Nominal output	19 W/ 18 W
Noise level	46/49 dB

Advantages :
1.Simple and rugged construction, leading to high reliability and low maintenance requirements.
2.No need for additional starting devices or circuits, as the motor is self-starting.

Figure 9. Cooling Fan with Motor

DHT11 Sensor :-

Figure 10. DHT11 Sensor

Table 3. DHT11 Properties

Property	Specification
Type	Digital Humidity and Temperature Sensor
Model	DHT11
Operating Voltage	3.3V – 5.5V
Humidity Measurement Range	20% - 90% RH
Temperature Measurement Range	0°C - 50°C (32°F - 122°F)
Humidity Accuracy	±5% RH
Temperature Accuracy	±2°C (±0.5°F)
Resolution	1% RH (Humidity), 1°C (Temperature)
Sampling Period	1 reading every 2 seconds
Output Signal	Digital signal (Single-Wire, 1-wire)
Interface	3 pins (VCC, Data, GND)
Response Time	1 - 2 seconds
Dimensions	15.5mm x 12mm x 5.5mm
Applications	'eather stations, HVAC systems, Indoor climate monitoring, etc.
Special Features	Low cost, easy to use, compact design

The DHT11 temperature sensor is a widely used digital sensor designed for measuring temperature and humidity in various electronic projects. Developed by Aosong Technology, this sensor is known for its simplicity and affordability, making it a popular choice for hobbyists and professionals alike. The DHT11 utilizes a resistive humidity element and a thermistor to measure humidity and temperature, respectively. It operates on the principle that the resistance of these elements changes with variations in humidity and temperature. The sensor provides digital output in a specific format, making it easy to interface with microcontrollers and single-board computers. With a temperature measurement range of 0 to 50 degrees Celsius and a humidity range of 20% to 90%, the DHT11 is suitable for a wide range of applications, including weather stations, climate control systems, and IoT (Internet of Things) devices. While the DHT11 is reliable and cost-effective, it is worth noting that it may have limitations in terms of accuracy and precision compared to more advanced sensors. Nonetheless, its simplicity and accessibility make it an excellent choice for entry-level projects where moderate accuracy is acceptable.

Advantages:

• One of the primary advantages of the DHT11 is its low cost, making it accessible for hobbyists, students, and budget-conscious projects.

• The sensor is easy to use and doesn't require complex calibration procedures. It provides a simple digital signal output that can be easily interfaced with microcontrollers or single-board computers.

• The DHT11 operates on low power, making it suitable for battery-powered or energy-efficient projects.

The sensor has a decent temperature measurement range (0 to 50 degrees Celsius) and humidity range (20% to 90%), making it suitable for a variety of environments and applications.

Arduino Uno:

In the robotics and electronics communities, the Arduino Uno is a well-liked microcontroller board that is frequently used for prototyping and developing various projects. As its foundation, the Atmel ATmega328P microcontroller powers the Arduino Uno. In order to program the board and communicate serially with the microcontroller, the Arduino Uno can be linked to a computer over a USB port. With a clock speed of 16 MHz, it can handle a lot of programs with enough processing power. Six of the board's fourteen digital input/output pins may be utilized as PWM (Pulse Width Modulation) exits. It also includes six pins for analog input. The board has two power options: it can be supplied via the USB connection or an external DC power supply (7–12V).

The bootloader takes up about 2 KB of the 32 KB of flash memory on the ATmega328P microcontroller. The board contains one KB of EEPROM (Electrically Erasable Programmable Read-Only Memory) and two KB of SRAM (Static Random-Access Memory).

Because the Arduino Uno has a bootloader pre-loaded, users can program it via a USB connection and the Arduino IDE. The Arduino Uno's design and specifications are publicly available since it is a component of the open-source hardware and software ecosystem.

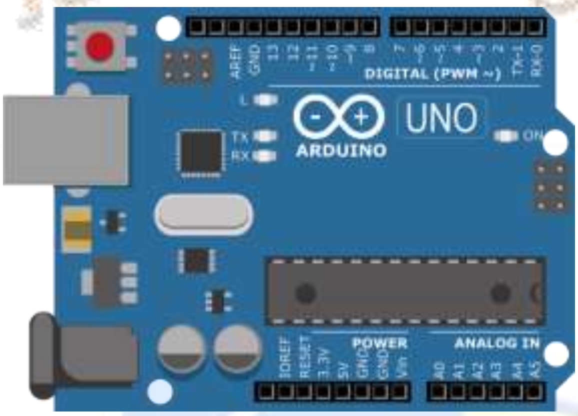

Figure 11. Arduino UNO

The Arduino Integrated Development Environment (IDE), which makes writing, compiling, and uploading code easier, is used to program the board. An Arduino Uno may be expanded using a range of expansion boards known as "shields," which simply slide on top of the board to provide more features. With a sizable and vibrant community, Arduino offers a wealth of information, guides, and discussion boards for users to ask questions and exchange project updates.

Advantages:

• Arduino Uno is relatively affordable compared to other microcontroller platforms, making it accessible to a wide audience, including students, hobbyists, and professionals.

• Both the hardware and software of Arduino Uno are open-source, allowing users to access and modify the design to suit their needs.

• Arduino Uno is widely used in educational settings to teach electronics and programming due to its simplicity and hands-on approach.

• Arduino Uno is excellent for rapid prototyping, allowing users to quickly test and iterate on their ideas. The straightforward programming environment facilitates a quick development cycle.

Table 4. Arduino UNO Properties

Property	Specification
Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (Recommended)	7-12V
Input Voltage (Limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P)
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length x Width	68.6 mm x 53.4 mm
Weight	25 g
Operating Temperature	0°C to 70°C
USB Connector	Type B Mini-USB

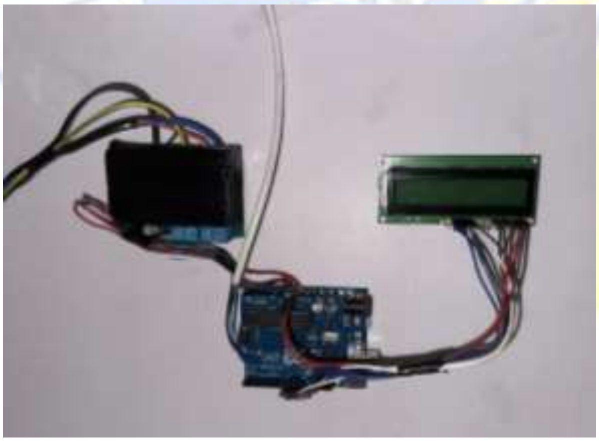

Figure 12. Automation Circuit

V. METHODOLOGY AND CALCULATIONS

The process starts with temperature sensor which help in temperature measurement. Now, there are two cases:

Case1: When the temperature inside storage structure is greater than the set temperature DHT11 sensors were strategically placed throughout the onion storage facility to continuously monitor the ambient temperature. These sensors collect real-time temperature data, which is then transmitted to a microcontroller for analysis. Relay modules are connected to the microcontroller and the bidirectional fan, allowing for temperature-based automated fan direction control. When the temperature inside the storage facility exceeds the upper limit of 30 degrees Celsius, the microcontroller triggers the relay module to change the direction of the bidirectional fan to anticlockwise. This rotation direction promotes airflow and facilitates heat dissipation, helping to regulate the temperature within the desired range.

Case2: When the temperature inside storage structure is less than the set temperature

When the temperature inside the storage facility falls below the lower limit of 25 degrees Celsius, the microcontroller instructs the relay module to switch the bidirectional fan to clockwise.

Figure 13. Automation Flow Chart

This rotational direction helps redistribute warm air trapped near the ceiling downwards, resulting in more uniform heating throughout the storage area and preventing cold spots where temperature-sensitive goods may be negatively impacted.

In the first case study, bidirectional fans rotating in the anticlockwise direction effectively reduced heat buildup, ensuring compliance with regulations and preserving onion quality.

In the second case study, when temperatures dropped below the lower limit, the flexibility of the bidirectional fan control system, with a capability to rotate clockwise, aided in the redistribution of warm air, reducing the risk of cold damage to stored onions.

The energy required by the bidirectional fan to bring down the temperature from 45˚ C to 25˚C is calculated with the help of formula which is derived from the principles of thermodynamics and heat transfer.

The formula is as following,

$E = V \times \rho \times k \times \Delta T$ (1)

Where,

- Volume (V) is the amount of space occupied by the substance. It could refer to the volume of a storage facility or a specific material.
- Density (ρ) refers to the mass per unit volume of a substance. It describes how densely packed the particles are within that volume.
- Specific Heat Capacity(k): This property describes the amount of heat energy required to raise the temperature of a unit mass of a substance by one degree Celsius (or Kelvin). The SI unit for specific heat capacity is J/(kg·K) or J/(kg·°C).
- Temperature Difference (ΔT): Determines the temperature change. Whether the system gains or loses heat, the difference has a significant impact on overall energy transfer.

Secondly, the time required for the fan to bring down the temperature within the standard temperature limit is calculated,

$\text{Time} = E \times \text{Air flow rate} \times \rho$ (2)

Where,

- Airflow rate(m^3/min)= $\frac{\frac{\pi}{4} \times d^2 \times N}{60}$
- D= diameter of fan and N fan speed in RPM

Next the total power consumed by the fan in this operation is calculated.

kWh = W x t / 1,000

- Fan Wattage(W): This is the power rating of the fan, which is usually measured in watts (W). Wattages vary among different types of fans.
- Duration of Use (t): This is the number of hours the fan functions.

VI. Results And Discussion

Calculation:

The energy (E) required to heat or cool the room is determined by the formula:

$E = V \times \rho \times k \times \Delta T$

Given values:

Volume (V): 27 cubic meters

Density (ρ): 1.2 kg/m³

Specific Heat Capacity (C): 1.005 kJ/kg

Temperature difference (ΔT): 45°C - 25°C = 20°C

E=180.9kJ or 0.05kWh/cycle

Time Calculation:

The time required to achieve this energy change is determined by the formula:

Time= E ×Air flow rate × ρ

Airflow rate is specified on fan, and energy value is calculated previously. Substituting the energy value and airflow rate into the formula,

Time ³=9.86 min/ cycle

Therefore, the fan used in this project must take for 9.86 minutes to bring down the temperature from 45ºC to 25ºC. Also, it would consume 0.05kWh of electricity for the same. These calculations provide insights into the energy requirements and associated power consumption for maintaining specific temperature conditions in the given room volume.

The precision attained by the project, in line with precision agriculture principles, is one important topic of discussion. An intelligent and focused approach to onion storage is demonstrated by the dynamic adjustments and real-time monitoring made possible by the Arduino Uno and DHT11 temperature sensors. As this project shows, precision agriculture not only guarantees the best possible conditions for the produce that is stored, but it also represents a paradigm shift in how technology can be used to meet the unique requirements of agricultural practices.

The effective temperature control and airflow management made possible by the DHT11 sensors and DC fans show how precisely technology can meet the unique requirements of onion storage. The technology greatly increases the shelf life of onions by inhibiting sprouting and deterioration, which has a direct effect on the profitability of onion farming. Reducing post-harvest losses increases returns for farmers and other stakeholders, strengthening the agricultural sector's sustainability and resilience.

Economically, the success of the project is evident in the extended shelf life of onions, contributing directly to the economic viability of onion farming. By mitigating post-harvest losses, farmers stand to benefit from increased yields and reduced waste, resulting in a more sustainable and profitable agricultural venture. This economic impact extends beyond individual farmers to the broader agricultural supply chain, influencing market dynamics and ensuring a more reliable and consistent supply of onions to consumers.

VII. CONCLUSIONS

In conclusion, an important development in agricultural technology has been made with the integration of Arduino Uno, DHT11 temperature sensors, and fans in the construction of an onion storage facility. Post-harvest management is changing as a result of this comprehensive strategy that combines intelligent control mechanisms, accurate temperature monitoring, and energy-efficient ventilation.These technologies work together to not only solve the unique problems related to storing onions, but also to provide a paradigm-shifting example of sustainable agriculture.

The use of AC fans in the storage facility is critical for effective climate control. AC fans, known for their high performance and ability to handle large amounts of air, ensure proper airflow in the storage environment. This is critical for preventing sprouting and maintaining humidity and temperature. AC fans, with their consistent and continuous operation, help to maintain uniform conditions within the storage space, preventing moisture buildup, which can lead to decay and fungal growth. The durability of AC fans ensures that they can operate efficiently in a variety of conditions, contributing significantly to the overall stability of the storage environment.

The DHT11 temperature sensor is the watchful administrator of ideal storage circumstances. This sensor, which is positioned strategically inside the storage facility, continuously measures the outside temperature and provides real-time data that is essential for making climate control decisions. The storage facility can proactively address temperature fluctuations and reduce the risks of sprouting and decay thanks to the precision and responsiveness of the sensor. In addition to helping to maintain onion quality, the DHT11 is a prime example of how to successfully combine old knowledge with modern technology, which is a crucial component of sustainable agriculture.

This technological ensemble is centered around the Arduino Uno microcontroller. The Arduino Uno, the system's brain, coordinates the cooperative efforts of the DHT11 temperature sensors, DC fans, and additional actuators. Because of its programmable nature and versatility, control logic can be customized to meet the specific requirements of onion preservation, resulting in a storage environment that is optimally tuned. The Arduino Uno is a key player in the development of precision agriculture because its function goes beyond simple automation. It is an embodiment of adaptability.

The advantages of this integrated system go beyond the immediate benefits of preserving onions. Using technology to improve storage conditions raises the effectiveness of farming practises. A decrease in post-harvest losses benefits farmers and other agricultural supply chain participants monetarily. The model's sustainability in terms of energy use and environmental effect fits in with the growing global narrative of ethical and sustainable farming methods.

A new era in agriculture is essentially being heralded by the creation of a storage facility that makes use of AC fans, DHT11 temperature sensors, and Arduino Uno. This era will see innovation meet the basic need for sustainable and ethical food production. In light of the ever-growing global demand for both environmental sustainability and food security, the incorporation of these technologies into smart storage facilities is a remarkable demonstration of human resourcefulness. It symbolises a peaceful coexistence in which technology turns into a crucial ally in the age-old quest to protect crops and support local populations.

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