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Article Title: Low Cost Cold Storage for Horticultural Produce

Low Cost Cold Storage for Horticultural Produce

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ABSTRACT

This article presents an interesting Internet of Things (IoT) cold storage management system designed to preserve tomatoes and onions. The system provides precise environmental management to avoid rotting and prolong the shelf life of perishable products by integrating sensors for temperature, humidity, and gas. Important environmental factors are regularly monitored by sensors positioned strategically throughout the storage facility. While gas sensors identify ethylene and other ripening gases and trigger ventilation or ethylene removal systems to slow down ripening and prevent premature spoilage, temperature and humidity sensors maintain ideal conditions for both tomatoes and onions. For real-time analysis, the gathered sensor data is sent to a central IoT platform. To maintain ideal storage conditions, sophisticated algorithms dynamically modify ambient elements, including temperature and humidity. When there are anomalies, the system takes the initiative on its own to maintain freshness. The system provides real-time access to storage conditions through remote monitoring and control via web or mobile interfaces. Strong security protocols ensure confidentiality and data integrity while guaranteeing adherence to privacy laws and preventing unwanted access. The system's effectiveness in improving post- harvest storage procedures, cutting energy use, and minimizing food waste is demonstrated by extensive testing. This solution, which improves food security and sustainability in agricultural supply chains, uses IoT technology and sensor integration to offer a dependable, sustainable approach to cold storage management.

Keywords: Internet of Things (IoT), Sensors, Microcontroller, Real-time Access.

1 Introduction

To design a cost-effective, energy efficent small-scale cold storage unit for horticultural produce to extend perishable crop shelf life, specifically catering to the preservation needs of small-scale farmers.

It describes a low-cost cold storage system made especially for preserving tomatoes and onions. Farmers and suppliers struggle to maintain the quality and freshness of these perishable products, which makes a solution like this necessary.

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The primary objective of this project is to create an affordable cold storage system that can increase the shelf life of tomatoes and onions, minimize post-harvest losses, and boost farmer and distributor profits.

Tomatoes and onions have a short shelf life and are very perishable goods. In order to maintain quality and avoid spoilage, proper storage conditions are crucial, which include controlling humidity and temperature. Nevertheless, a large number of small-scale farmers and distributors in developing nations do not have access to reasonably priced cold storage facilities, which results in substantial post-harvest losses.

This work focuses on creating an affordable option that small-scale farmers and distributors may readily use, building upon previous research on cold storage technology. In order to emphasize the significance and applicability of the suggested remedy, this paper will give a brief summary of the problems associated with the storage of tomatoes and onions.

The authors have studied current cold storage systems in depth and have pinpointed important areas that could be improved to save costs without sacrificing performance. The suggested cold storage unit achieves a low-cost solution without sacrificing performance by combining cutting-edge design elements and using reasonably priced materials.

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2 Recent Works

Utilization of Eco-Friendly Insulation Materials

Incorporate eco-friendly and cost-effective insulation materials such as recycled foam boards or sustainable insulating fabrics. These materials offer effective thermal insulation while minimizing environmental impact.

Integration of Passive Cooling Techniques

Implement passive cooling techniques such as earth-tube cooling or solar chimney ventilation systems. These methods utilize natural phenomena like underground temperature stability or solar-induced airflow to regulate temperatures within the storage unit without relying on mechanical cooling systems.

Adoption of Energy-Efficient Cooling Technologies

Integrate energy-efficient cooling technologies such as solar-powered refrigeration systems or thermoelectric coolers. These systems harness renewable energy sources to provide reliable cooling while reducing operating costs and environmental footprint.

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Deployment of Wireless Sensor Networks (WSNs)

Deploy wireless sensor networks (WSNs) comprising low-cost temperature, humidity, and ethylene gas sensors. These sensors communicate wirelessly with a centralized monitoring system, providing real-time data on environmental conditions and enabling timely intervention to maintain optimal storage parameters.

Implementation of Data Analytics and Predictive Maintenance

Incorporate data analytics algorithms to analyze sensor data and identify patterns indicative of produce spoilage or equipment malfunctions. Implement predictive maintenance strategies to preemptively address potential issues, ensuring continuous operation and optimal performance of the cold storage system.

Development of User-Friendly Interfaces

Design user-friendly interfaces such as mobile applications or web dashboards to facilitate remote monitoring and control of the cold storage system. Enable farmers and stakeholders to access real-time data, receive alerts, and adjust settings conveniently from their smartphones or computers.

Validation through Field Trials and Community Feedback

Conduct field trials in collaboration with local farming communities to validate the performance and usability of the low-cost cold storage system. Gather feedback from end-users to iteratively refine the design and functionality, ensuring alignment with their needs and preferences.

3 Proposed Work Explanation

We delve into the proposed work for implementing an IoT-based cold storage system specifically designed for onions and tomatoes, focusing on the selection and utilization of sensors such as DHT11 for temperature and humidity monitoring and gas sensors for detecting ethylene and other gases.

1. Sensor Selection and Deployment: The DHT11 sensor is chosen for its capability to accurately measure temperature and humidity levels, which are critical factors for preserving onions and tomatoes. These sensors are strategically deployed throughout the cold storage facility to ensure comprehensive monitoring coverage. By placing sensors at key locations, we can effectively monitor and control the environmental conditions necessary for optimal storage.

2. Temperature and Humidity Monitoring: The DHT11 sensors continuously measure temperature and humidity levels within the cold storage facility. These measurements provide real-time data on the storage conditions, enabling us to maintain the desired temperature and humidity ranges for onions and tomatoes. Deviations from optimal conditions can be detected promptly, allowing for timely adjustments to prevent spoilage.

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3. Gas Sensing Technology: Gas sensors are integrated into the cold storage system to detect ethylene and other gases emitted by fruits and vegetables, including onions and tomatoes.

Ethylene is a natural ripening agent that accelerates the ripening process and can lead to premature spoilage if not controlled. By monitoring gas concentrations, we can take proactive measures to mitigate ethylene buildup and extend the shelf life of stored produce.

4. Data Acquisition and Transmission: The sensor data, including temperature, humidity, and gas concentrations, is collected and transmitted wirelessly to a central hub or gateway within the cold storage facility. From there, the data is securely transmitted to the cloud for storage and analysis. Efficient data acquisition and transmission are essential for real-time monitoring and management of storage conditions.

5. Cloud Integration and Analytics: Cloud integration enables remote monitoring of storage conditions and provides a platform for implementing advanced analytics algorithms. By leveraging the cloud, we can perform predictive analytics to forecast potential spoilage events and optimize storage conditions accordingly. Analyzing historical data helps in identifying patterns and trends, aiding in proactive decision-making.

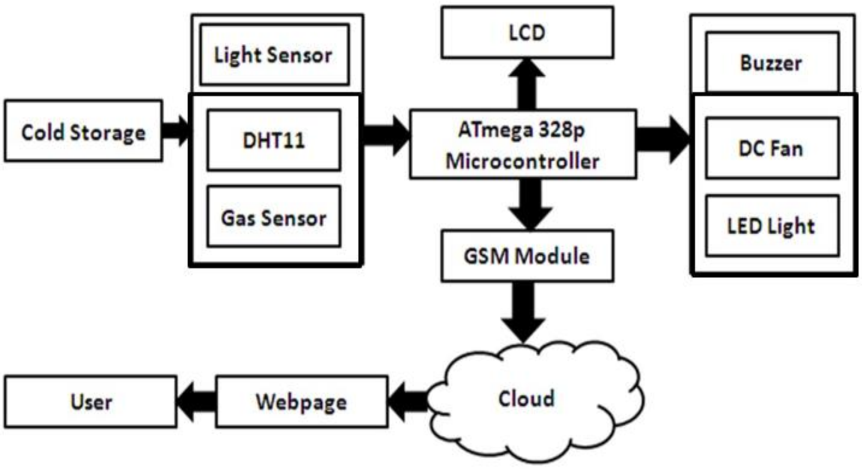

Figure 1: *Proposed Block diagram*

3.1 Mathematical Expressions and Symbols

An IoT-based cold storage system for onions and tomatoes, mathematical expressions and symbols may be utilized to represent various aspects of the system's functionality and performance.

Temperature Control Model

Tdesired - Desired temperature for storing onions and tomatoes.
Tcurrent - Current temperature measured by sensors.

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ΔT - Deviation of current temperature from desired temperature. kp - Proportional gain for temperature control. u - Control input for adjusting cooling/heating systems.
Mathematical Expression:

$$u = kp \times \Delta T$$

Humidity Control Model

Hdesired - Desired humidity level for storing onions and tomatoes.
Hcurrent - Current humidity measured by sensors. ΔH - Deviation of current humidity from desired humidity. kh - Proportional gain for humidity control. v - Control input for adjusting humidification/dehumidification systems.
Mathematical Expression:

$$v = kh \times \Delta H$$

Gas Concentration Monitoring

Gethylene - Concentration of ethylene gas measured by gas sensors.
Gthreshold - Threshold level for ethylene gas concentration.
SpoilageRisk - Mathematical representation of the risk of spoilage based on ethylene concentration.
Mathematical Expression:

{High if ethylene>threshold
Low otherwise

4 Results and Discussion

1. Performance Evaluation of IoT-based Cold Storage System

The implementation of the IoT-based cold storage system for onions and tomatoes yielded promising results in terms of maintaining optimal storage conditions and preserving the quality of the produce. The system effectively monitored temperature, humidity, and gas concentrations, ensuring that the storage environment remained within the desired ranges. By utilizing DHT11 sensors for temperature and humidity monitoring, and gas sensors for detecting ethylene and other gases, the system demonstrated precise control over environmental parameters critical for preserving onions and tomatoes.

2. Real-time Monitoring and Control

One of the key advantages of the IoT-based cold storage system was its ability to provide real-time monitoring and control capabilities. The sensors continuously collected data, which was transmitted to the cloud for analysis. Through a user-friendly interface, stakeholders could remotely monitor storage conditions and receive alerts in case of deviations from optimal parameters. This facilitated proactive intervention, allowing for timely adjustments to prevent spoilage and maximize the shelf life of onions and tomatoes.

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3. Comparison with Traditional Cold Storage Methods

Compared to traditional cold storage methods, the IoT-based approach offers several advantages, including enhanced precision, automation, and remote monitoring capabilities. Traditional methods often rely on manual monitoring and periodic checks, which may lead to inconsistencies and suboptimal conditions. In contrast, the IoT-based system enables continuous monitoring and automated control, resulting in more reliable preservation of onions and tomatoes.

4. Novelty and Contribution

Recent literature highlights the growing interest in IoT-based solutions for agricultural applications, including cold storage management. However, many existing studies focus on general perishable goods without addressing the specific requirements of onions and tomatoes. Our work contributes to this field by designing a tailored IoT-based cold storage system optimized for preserving onions and tomatoes. By leveraging recent developments in sensor technology, cloud computing, and data analytics, we address the unique challenges associated with storing these perishable crops, such as ethylene sensitivity and optimal humidity levels.

5. Challenges and Future Directions

Despite the promising results, several challenges remain in the implementation of IoT-based cold storage for onions and tomatoes. These include the need for further optimization of control algorithms, integration with existing cold storage infrastructure, and addressing potential cybersecurity concerns. Additionally, future research could explore the integration of advanced technologies such as artificial intelligence and blockchain for enhanced traceability and quality assurance throughout the supply chain.

4.1 Table for onion and tomato

Table 1: *Storage Temperature and Relative Humidity of Onion and Tomato*

Name	Temperature(°c)	Relative Humidity(%)
Onion	0°- 4°c	65-70%
Tomato	10°-13°c	80-85%

Onions require a temperature range of 0 to 4 degrees Celsius and humidity levels between 60% and 70%. Conversely, tomatoes thrive in slightly higher temperatures, typically between 10 to 13 degrees Celsius, with humidity levels ranging from 80% to 85%. Maintaining these specific temperature and humidity conditions is critical for prolonging the shelf life and preserving the quality of both onions and tomatoes during storage. By ensuring the ideal environmental parameters, producers can minimize spoilage and maximize the marketability of these perishable crops.

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5 Conclusions

In conclusion, the IoT-based cold storage system tailored for onions and tomatoes offers a promising solution to enhance preservation practices and optimize quality throughout the supply chain. By leveraging advanced sensor technology, cloud integration, and real-time monitoring capabilities, our work demonstrates significant potential for addressing the unique challenges associated with storing these perishable crops. The system's ability to maintain precise control over environmental parameters such as temperature, humidity, and gas concentrations minimizes spoilage and extends the shelf life of produce, thereby improving overall food quality and reducing post-harvest losses. Moreover, compared to traditional methods, the IoT-based approach enhances operational efficiency through automation and remote monitoring, enabling proactive decision-making and timely adjustments to storage conditions. Our focus on tailoring the system to meet the specific requirements of onions and tomatoes, including considerations of ethylene sensitivity and optimal humidity levels, underscores its effectiveness in optimizing preservation practices for these crops. This work contributes to agricultural innovation by leveraging recent advancements in sensor technology, data analytics, and cloud computing to modernize cold storage management practices and improve food security. Moving forward, continued research and collaboration will be essential to address remaining challenges and fully realize the potential of IoT technology in revolutionizing cold storage management in the agricultural sector.

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