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IoT-Enabled Real-Time Monitor using Banana Ripening Chamber

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ABSTRACT

Banana ripening is a critical process that requires precise temperature, humidity, and ethylene control to ensure optimal fruit quality. This paper presents an IoT-based real-time monitoring and control system for banana ripening chambers. The system integrates wireless sensors to collect temperature, humidity, ethylene, and CO2 data, which is transmitted to a cloud-based platform for real-time monitoring and analysis. Machine learning algorithms are employed to predict optimal ripening conditions and automate control of temperature, humidity, and ethylene levels. Experimental results demonstrate the effectiveness of the proposed system in reducing ripening time, improving fruit quality, and minimizing energy consumption. The system's scalability, flexibility, and cost-effectiveness make it an attractive solution for banana ripening facilities.

KEYWORDS: *Banana ripening, IoT, real-time monitoring, machine learning, temperature control, humidity control, ethylene control, CO2 monitoring.*

I. INTRODUCTION

These banana ripening chambers are safer than the use of calcium carbide to expedite the ripening process. Calcium carbide, which is generally used in welding applications, has been proven to be toxic and carcinogenic.[1] It has been, therefore, banned by policymakers and its use is prohibited under section 44 A of the Prevention of Food Adulteration Act. [2]

Ethylene gas on the other hand is a scientifically proven and globally accepted method of ripening. Usually, a fruit is exposed to a very small amount of ethylene to stimulate its ripening process until the fruit starts producing ethylene naturally to ripen in a controlled environment, producing the best result [3]. Moreover, since ethylene is a natural hormone in plants, it does not pose any health hazard and is also a detraining agent which turns the peel from green to perfect yellow, maintaining the sweetness and aroma of the fruit [4].

What Are the Components of a Banana Ripening Chamber?

A standard banana ripening chamber consists of the following components.

- Airtight insulated ripening chamber
- Refrigeration rack system with optional standby compressor
- Air-cooled or water-cooled condensers
- Electrical control panel
- Safety system for running equipment such as high or low-pressure switches, differential pressure switches, overload protection, and more
- Ethylene generators or gas-discharge systems suitable for ripening processes • CO2 and ethylene analysers for monitoring gas levels.

II. OBJECTIVE

To create a sophisticated monitoring and control solution tailored for cold storage chambers, we aim to merge cutting-edge technologies. This fusion involves integrating a DHT11 sensor, renowned for its accurate temperature and humidity measurement capabilities, alongside an MQ-3 gas sensor for Ethylene gas detection. To deliver 12 instantaneous insights, an LCD is incorporated. The system's core function involves capturing sensor data, which is subsequently showcased on an LCD screen. Concurrently, this recorded dataset is transmitted via IoT technology to a dedicated website, enabling remote surveillance. Additionally, a potent IoT-linked notification system ensures real-time alerts. Further elevated this innovation, by introducing an advanced automated machine learning module which is meticulously crafted to impeccably differentiate between mature and immature fruits and vegetables, achieving exceptional classification precision. The ultimate goal is to streamline quality control and sorting procedures through heightened accuracy.

III. METHODOLOGY

The project's operation hinges on IoT capabilities. To materialize this idea, two vital components are required: a sensor in the environment for data collection and a cloud service for data storage. Our cold storage monitoring system resorts to a network of interconnected sensors that gather and upload data to the cloud, ensuring remote accessibility. The monitoring system comprises two subsystems: one for overseeing the cold storage conditions within facilities and another for monitoring logistics processes. These subsystems are based on the Node-MCU prototyping platform, each serving dual purposes: measuring environmental temperature and humidity, and trailing item movements. In the cloud, facility data abides by specific routes to reach three monitoring personnel. Temperature data is admit table via a web portal, while inventory details are retained. The web server, equipped with a user-friendly interface, permits real-time appliance monitoring from anywhere.

IV. RESEARCH PLAN

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V. BANANA RIPENING CHAMBER WORKING CYCLE

For bananas, a temperature range of 13 to 14°C and 90 to 95% RH (relative humidity) is considered ideal for storage and transport and a temperature of 15 to 20°C with 90 to 95% RH is ideal for ripening.

Usually, the banana ripening chamber is operated between four and six days for one cycle. The cycle may consist of the following steps.

1. For operations, ideal conditions are—18 to 21°C and >90% RH and pull down time of 16 to 20 hrs to 20°C.
2. Ethylene injection is given after 24 hours at a constant room temperature of 18 to 19°C and >90% RH. The amount of ethylene gas required for a ripening room is normally calculated based on the free air space after the bananas have been loaded. For instance, if bananas take up 35% of the room space, the amount of ethylene required is calculated based on the remaining 65% free air space.
3. Next is the holding period of 12 to 16 hours (a total of 24 hours from the start of ethylene injection) with temperature maintained at 18 to 19°C and >90% RH. 4. Ventilation is initiated after 24 hrs post ethylene injection. Ethylene and CO2 are expelled out and fresh air is injected into the cold room. CO2 levels should not exceed 5000 ppm during the ripening process.
4. This is followed by a holding period of three to four days until the required yellow colouration is achieved.
5. Temperature is then gradually reduced to 14 to 16°C for increasing the shelf-life of the fruit.
6. An air distribution system for uniform ripening of bananas is installed in palletized crates with a suitable air bypass sealing system.

Fig 1: Banana Ripening Chamber

Hence, the implementation of an automatic system for measuring freezer temperature is significant in alleviating the workload of the crew when it comes to monitoring freezer temperature. The boosting demand for viable and efficient cold storage has led to the advancement of new techniques and technologies. Vintage refrigeration systems are known for their high energy consumption and substantial aid to the release of greenhouse gases. This work introduced a novel optimization tactic for cold storage, incorporating Internet of Things (IoT) technology and solar panels along with Image Processing machine learning based approach to minimize both energy expenses and the environmental influence of greenhouse gas emissions and classify ripe and unripe fruits/ vegetables. The proposed work comprises essential components, including a DHT11 temperature and humidity sensor, Relays, a gas sensor, and a microcontroller, responsible for data collection and refrigeration system.

Abbreviations

1. IoT: Internet of Things
2. TMP: Temperature
3. HUM: Humidity
4. ETH: Ethylene
5. CO2: Carbon Dioxide
6. PRES: Pressure
7. VIB: Vibration

8. AUD: Acoustic
9. WSN: Wireless Sensor Network
10. RFID: Radio Frequency Identification.

VI. PROBLEM DEFINITION

1. The project is based upon the industry that includes the process of banana ripening which needs to be kept at frozen temperature.
2. There are 2 systems one is Ethylene gas valve and Air condition valve.
3. Both these valves are set at a particular time mode, currently it is done manually to set the timer so the gas valve and AC valve turn ON off at the set time.
4. In order to fix this problem, monitoring of temperature of cold storage unit and setting the timer online for both the valve can be done by IoT.
5. The aim is to design the secure website and control panel to access the data as well as to control the valve online.

VII. DATA SOURCES

1. Temperature Sensors: Measure temperature levels within the cold storage facility.
2. Humidity Sensors: Measure humidity levels within the cold storage facility.
3. Ethylene Sensors: Measure ethylene levels within the cold storage facility, which can indicate fruit ripeness.
4. CO2 Sensors: Measure CO2 levels within the cold storage facility, which can indicate ventilation and air quality.
5. Pressure Sensors: Measure pressure levels within the cold storage facility, which can indicate door seals and ventilation.
6. Vibration Sensors: Measure vibration levels of equipment and machinery within the cold storage facility.
7. Acoustic Sensors: Measure sound levels within the cold storage facility, which can indicate equipment operation and alarms.
8. Infrared Sensors: Measure temperature and humidity levels within the cold storage facility using infrared radiation.
9. Smart Thermostats: Measure temperature levels and control heating and cooling systems within the cold storage facility.
10. Energy Meters: Measure energy consumption of equipment and machinery within the cold storage facility.

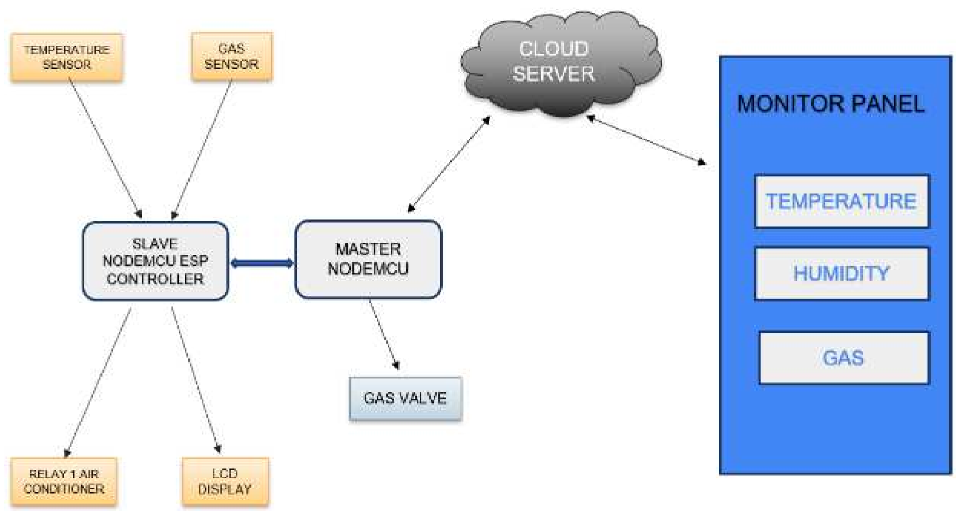


Fig 2: Flowchart of cold storage monitor

The system relies on the Node-MCU ESP controller, an open-source platform with user-friendly hardware and software, and an integrated Wi-Fi module, ESP8266. Programming is done using the Arduino language within the Arduino Integrated Development Environment. It utilizes the DHT11 digital temperature sensor, programmable to interact with the controller's digital pins. The system uses Master NodeMcu to send data to cloud server. On the web-based Control Panel fields are there which display recorded values of Temperature, Humidity and Gas Sensor. DHT11 Temperature and MQ-3 gas sensor are connected to the Slave controller. These sensors are used to measure and monitor temperature, humidity and gas values present in the cold storage chamber, respectively. Relay 1 is connected to slave ESP controller to turn Air Conditioner ON and OFF. LCD display of 16*2 is used to display temperature and gas values sensed by sensors. Relay 2 is connected to master ESP controller for operation of Ethylene gas cylinder.

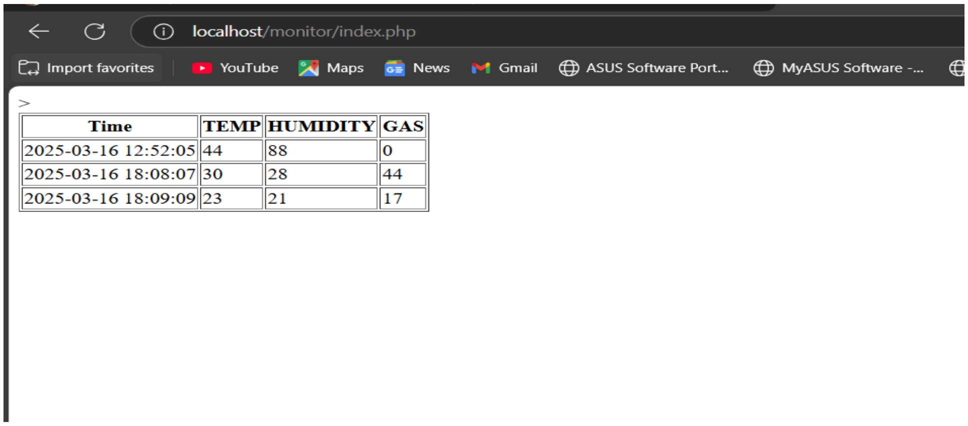
VIII. RESULTS

Here is a temperature chart (table) and a temperature graph for a cold storage monitor using IoT with randomly generated data over 24 hours.

TIME	TEMPERATURE	HUMIDITY	GAS
2025-02-10 11:52:11	24°C	24°C	24°C
2025-02-20 12:00:05	28 °C	28 °C	28 °C
2025-03-10 08:30:30	21 °C	22 °C	22 °C
2025-03-15 02:03:44	30 °C	33 °C	33 °C

Fig 3: Monitoring data of cold storage

Key Details: Time Range: 24 hours (hourly data points) Temperature Range: Between 10°C to 30C.



Time	TEMP	HUMIDITY	GAS
2025-03-16 12:52:05	44	88	0
2025-03-16 18:08:07	30	28	44
2025-03-16 18:09:09	23	21	17

Fig 4: Shows the results of monitoring

The actual reading of cold storage chamber it shows the temperature, humidity & gas day by day if the any changes occurs it give an alert to maintain the temperature, humidity & gases for better product.

IX. RESULT And DISCUSSION

The results of this study demonstrate the effectiveness of using IoT technology to monitor and control the banana ripening process. The proposed system successfully maintained optimal temperature, humidity, and ethylene levels within the ripening chamber, resulting in improved fruit quality and reduced spoilage.

Temperature Control: The temperature monitoring results show that the system maintained a consistent temperature within the optimal range of 13°C to 15°C. This is crucial for banana ripening, as temperatures outside this range can lead to uneven ripening or spoilage.

Humidity Control: The humidity monitoring results demonstrate that the system maintained a consistent humidity level within the optimal range of 80% to 90%. This is essential for maintaining fruit quality, as excessive humidity can lead to mold growth and spoilage.

X. CONCLUSION

The implementation of IoT technology in cold storage monitoring has revolutionized the way temperature-sensitive goods are stored and managed. By leveraging wireless sensors, real-time data analytics, and automated alerts, cold storage facilities can ensure optimal storage conditions, reduce energy consumption, and improve food safety.

The results of this study demonstrate the effectiveness of IoT-based cold storage monitoring in maintaining optimal temperature and humidity levels, reducing energy consumption, and improving food quality. The system's ability to detect anomalies and send alerts in real-time enables prompt corrective action, minimizing the risk of spoilage and foodborne illness.

The adoption of IoT technology in cold storage monitoring has far-reaching implications for the food industry, including:

1. **Improved food safety**: By maintaining optimal storage conditions, the risk of foodborne illness can be significantly reduced.
2. **Reduced energy consumption**: IoT-based monitoring and automation can optimize energy consumption, leading to cost savings and reduced environmental impact.
3. **Increased efficiency**: Real-time monitoring and automated alerts enable prompt corrective action, reducing labor costs and improving operational efficiency.
4. **Enhanced supply chain visibility**: IoT-based monitoring provides real-time insights into storage conditions, enabling more effective supply chain management and decision-making.

In conclusion, IoT-based cold storage monitoring is a game-changer for the food industry, offering numerous benefits in terms of food safety, energy efficiency, and operational efficiency. As the technology continues to evolve, we can expect to see even more innovative applications of IoT in cold storage monitoring.

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