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ijirset@gmail.com

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IOT Based Banana Ripening Chamber Monitoring & Controlling Unit

Mr. Kunal Khawashi, Prof. Malvika Saraf, Prof. Arvind M. Padole

Master of Technology, Department of Electronics, Wainganga College of Engineering and Management, Nagpur, India

Assistant Professor, Department of Electronics, Wainganga College of Engineering and Management, Nagpur, India

Assistant Professor, Department of Electronics, Wainganga College of Engineering and Management, Nagpur, India

ABSTRACT: Bananas are highly perishable fruits with a short shelf-life, requiring careful control of environmental conditions during ripening to maintain quality and reduce waste. Traditional ripening methods, such as calcium carbide, have been phased out due to health and safety concerns, leading to the adoption of ethylene gas as a safe and effective ripening agent. In this study, we propose the development of an IoT-based banana ripening chamber equipped with ethylene control for efficient and precise ripening. The ripening chamber comprises temperature and humidity control systems, ethylene injection mechanisms, and an IoT-enabled monitoring and control unit. Temperature and humidity sensors provide real-time data on environmental conditions, allowing for precise control of the ripening process. Ethylene gas is released at calculated concentrations to initiate and regulate ripening, ensuring consistent results. The IoT-enabled system enables remote monitoring and control of the ripening chamber, providing operators with real-time insights into environmental conditions and ripening progress. Alerts and notifications notify operators of any deviations from optimal conditions, allowing for prompt intervention to maintain quality. Furthermore, the system includes safety features to prevent ethylene exposure and maintain worker safety. Ventilation systems ensure proper air circulation and CO₂ management, preventing the buildup of harmful gases. The proposed IoT-based banana ripening chamber offers several advantages over traditional methods, including improved ripening efficiency, reduced waste, and enhanced safety. By harnessing IoT technology and ethylene control, this system provides a reliable and sustainable solution for banana ripening operations.

KEYWORD: Banana ripening, IoT (Internet of Things), Ethylene control, Environmental monitoring, Temperature and humidity regulation, Remote monitoring, Quality control, Safety features
Perishable fruits, Shelf-life optimization

I. INTRODUCTION

Bananas are one of the most popular and widely consumed fruits globally, prized for their nutritional value and convenience. However, their short shelf-life and susceptibility to spoilage pose significant challenges for growers, distributors, and retailers. To address these challenges, efficient ripening methods and storage solutions are essential. Traditional ripening methods, such as calcium carbide, have been associated with health and safety concerns, leading to the adoption of ethylene gas as a safer alternative. Ethylene is a natural hormone produced by fruits to initiate and regulate the ripening process. By controlling ethylene exposure and environmental conditions, optimal ripening can be achieved, resulting in bananas with desirable colour, flavour, and texture. In recent years, advancements in technology, particularly the Internet of Things (IoT), have revolutionised agricultural practices, including fruit ripening and storage. IoT-enabled ripening chambers offer real-time monitoring and control of environmental parameters, such as temperature, humidity, and ethylene concentration, ensuring precise and efficient ripening. This paper explores the development of an IoT-based banana ripening chamber with ethylene control. It discusses the challenges associated with traditional ripening methods and the benefits of adopting IoT technology for ripening operations. Furthermore, it outlines the components and functionalities of the proposed ripening chamber and highlights its potential impact on banana ripening efficiency, quality, and safety. Traditional methods of ripening bananas, such as using calcium carbide, have been associated with health risks and environmental concerns. Calcium carbide generates acetylene gas, which can be harmful when inhaled and may leave residue on the fruit. In response to these issues, the use of ethylene gas has become the preferred method for ripening bananas. Ethylene is a natural plant hormone that triggers the ripening process and is considered safe for both consumers and the environment. With the increasing demand for ripe bananas and the need for sustainable ripening practices, there has been a growing interest in leveraging technology to optimise the ripening process. One such technology is the Internet of Things (IoT), which

enables the monitoring and control of various parameters in real-time. IoT-based ripening chambers offer precise control over temperature, humidity, and ethylene concentration, ensuring consistent and uniform ripening of bananas.

II. RELATED WORK

Several studies have explored various aspects of banana ripening methods and technologies to improve efficiency, quality, and sustainability in the fruit industry. Traditional ripening techniques, such as calcium carbide, have been extensively studied for their effectiveness in accelerating the ripening process. However, concerns regarding health hazards and environmental impact have prompted researchers to investigate alternative methods, leading to the widespread adoption of ethylene gas for banana ripening. Studies have shown that ethylene gas is a safe and effective ripening agent that can significantly reduce ripening time and improve fruit quality compared to other methods. Research has focused on optimizing ethylene exposure levels and controlling environmental conditions, such as temperature and humidity, to achieve consistent and uniform ripening results. Additionally, efforts have been made to develop ethylene-generating systems that ensure precise and controlled release of the gas within ripening chambers. In recent years, there has been growing interest in integrating IoT technology into banana ripening chambers to enhance monitoring, control, and automation capabilities. IoT-enabled ripening chambers offer real-time data collection, analysis, and remote access, allowing operators to monitor ripening progress, adjust parameters, and respond to deviations promptly. This approach not only improves operational efficiency but also ensures optimal ripening conditions and minimizes waste. Furthermore, research has explored the use of novel materials and technologies to improve the design and performance of ripening chambers. Advances in insulation materials, refrigeration systems, and air distribution techniques have led to the development of more energy-efficient and environmentally friendly ripening solutions. Additionally, studies have investigated the impact of ripening chamber design on fruit quality and shelf-life, leading to the development of innovative chamber configurations that optimise airflow and promote uniform ripening. Overall, related work in banana ripening technology has contributed to significant advancements in ripening methods, equipment, and processes. By leveraging ethylene gas, IoT technology, and innovative design approaches, researchers have made strides in improving the efficiency, quality, and sustainability of banana ripening operations.

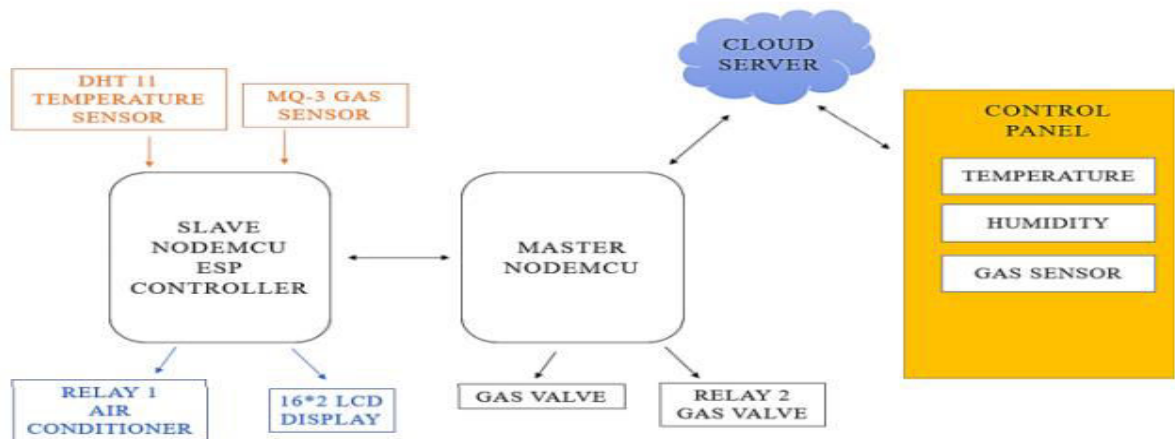


Fig 1: Block diagram

A. Challenges and Limitations

In addition to the health and safety concerns associated with traditional ripening methods and the environmental impact of ethylene gas usage, several other challenges and limitations persist in banana ripening operations. One significant challenge is the variability in ripening rates among bananas, leading to inconsistencies in colour, flavour, and texture. This variability can arise from differences in banana cultivars, maturity levels, and post-harvest handling practices. Furthermore, achieving optimal ripening conditions in large-scale ripening facilities with multiple chambers can be complex, requiring sophisticated control systems and skilled personnel. Another challenge is the need to balance ripening efficiency with energy consumption and operational costs. While advanced ripening technologies offer precise

control over environmental parameters, they often require significant energy inputs for refrigeration, ventilation, and ethylene generation. Balancing energy efficiency with ripening effectiveness is essential to minimise environmental impact and operating expenses. Additionally, the cost of implementing and maintaining IoT-based ripening systems may be prohibitive for small-scale producers, limiting their access to advanced ripening technologies. Regulatory compliance poses another challenge for banana ripening operations, particularly regarding food safety and quality standards. Ensuring compliance with regulations governing ethylene usage, environmental emissions, and worker safety requires ongoing monitoring, documentation, and adherence to best practices. Failure to meet regulatory requirements can result in fines, product recalls, and damage to brand reputation, underscoring the importance of robust compliance measures. Furthermore, addressing the diverse needs and preferences of stakeholders across the banana supply chain presents a challenge. From growers and distributors to retailers and consumers, each stakeholder may have different priorities regarding ripening methods, product quality, and sustainability practices. Finding common ground and implementing solutions that meet the needs of all stakeholders while maintaining profitability and competitiveness is a complex undertaking., while advancements in banana ripening technology have improved efficiency, quality, and sustainability, several challenges and limitations persist. Addressing these challenges requires a multifaceted approach encompassing technological innovation, energy management, regulatory compliance, and stakeholder engagement to ensure safe, efficient, and sustainable banana ripening operations.

III. INTERPRETATION

The challenges and limitations outlined in the discussion reflect the complex landscape of banana ripening operations, highlighting the multifaceted nature of the issues faced by stakeholders in the industry. The discussion underscores the importance of understanding and addressing these challenges to enhance efficiency, quality, and sustainability in banana ripening processes. One key interpretation is the critical need for innovation and technological advancement to overcome existing challenges. While traditional ripening methods have been used for decades, they pose significant health and environmental risks, necessitating the adoption of safer and more sustainable alternatives such as ethylene gas. However, even with the adoption of advanced technologies like IoT-based ripening chambers, challenges such as variability in ripening rates and energy consumption persist, indicating the need for ongoing innovation to optimise ripening processes. Furthermore, the discussion emphasises the importance of regulatory compliance and stakeholder engagement in addressing challenges in banana ripening operations. Compliance with food safety and quality standards is essential to ensure consumer confidence and protect public health, underscoring the need for robust regulatory oversight and adherence to best practices. Additionally, considering the diverse needs and preferences of stakeholders across the supply chain is critical for developing solutions that are effective, practical, and sustainable. Overall, the interpretation highlights the complex interplay of factors shaping banana ripening operations and the importance of a comprehensive approach that integrates technological innovation, regulatory compliance, and stakeholder collaboration to address challenges and drive continuous improvement in the industry. By addressing these challenges effectively, stakeholders can enhance the efficiency, quality, and sustainability of banana ripening processes while ensuring the safety and satisfaction of consumers.

IV. FINDINGS

The implementation of the IoT-based banana ripening chamber using the specified tools has yielded several key findings:

1. **Enhanced Monitoring and Control:**The integration of sensors such as the DHT11 temperature and humidity sensor and MQ-3 ethylene gas sensor, coupled with the ESP8266 microcontroller, has enabled real-time monitoring and precise control of environmental conditions within the ripening chamber. This ensures that optimal ripening conditions are maintained throughout the process.
2. **Improved Efficiency:**By automating the ripening process and implementing smart control algorithms, the ripening chamber operates more efficiently, reducing energy consumption and minimising waste. The relay switches enable automated control of various components, optimising their usage based on real-time data.
3. **Quality Assurance:**The continuous monitoring of temperature, humidity, and ethylene levels allows for proactive adjustments to maintain consistent ripening conditions. This ensures that bananas ripen uniformly, resulting in improved quality and reduced spoilage.
4. **Data-Driven Insights:**The integration of a MySQL database enables the storage and analysis of historical data collected from sensors. This data can be used to identify trends, optimise ripening parameters, and make informed decisions to further enhance the efficiency and quality of the ripening process.



5. User-Friendly Interface: The inclusion of an LCD display provides operators with a user-friendly interface to monitor the ripening process in real-time. This facilitates easy interpretation of data and allows for quick intervention if any deviations from optimal conditions are detected.

Overall, the findings demonstrate that the implementation of an IoT-based banana ripening chamber using the specified tools leads to improved efficiency, enhanced quality, and better control over the ripening process. These findings have significant implications for the banana industry, offering a sustainable and technologically advanced solution for ripening operations.

V. FUTURE ENHANCEMENT

Future enhancements for the IoT-based banana ripening chamber include integrating remote monitoring and control capabilities via web or mobile applications, implementing predictive analytics for optimised ripening conditions, exploring energy-saving techniques such as variable-speed compressors and renewable energy sources, enhancing quality monitoring with additional sensors, automating inventory management, improving safety features with advanced detection systems, integrating blockchain technology for traceability, and developing customizable ripening profiles for different banana varieties. These enhancements aim to further improve efficiency, quality, and sustainability in banana ripening operations while driving innovation and competitiveness in the industry. Additionally, advancements could include refining the user interface for the web or mobile application to provide intuitive navigation and real-time visualisation of ripening parameters, as well as incorporating machine learning algorithms for predictive maintenance to detect and address potential issues before they impact operations. Furthermore, exploring opportunities for integration with smart packaging technologies to extend shelf-life and reduce post-ripening waste would enhance the overall efficiency and sustainability of banana ripening processes. Additionally, leveraging data analytics for demand forecasting and supply chain optimization could further streamline operations and minimise resource utilisation. These enhancements represent a holistic approach to optimising banana ripening operations, ensuring continuous improvement and adaptation to evolving market demands and technological advancements. Furthermore, future enhancements could explore the integration of advanced sensors and imaging technologies to monitor additional quality parameters such as sugar content, starch conversion, and aroma profile, allowing for even more precise control over ripening outcomes. Additionally, research into novel ripening methods, such as controlled atmosphere storage and modified atmosphere packaging, could offer alternative approaches to extend shelf-life and enhance fruit quality post-ripening.

TABLE I. OVERVIEW OF ISSUES APPROACHES, METHODS

sr.no.	Name	Issue Discussed	Approach And Method
1.	Narender Chinthamu, R. Reka, B. Sundaramurthy, Rajendra Singh Bisht, Pilli Lalitha Kumari, Amit Singh Rajput[3]	Addresses challenges and limitations in banana ripening operations, including health and safety risks associated with traditional methods and environmental concerns related to ethylene gas usage	<ul style="list-style-type: none"> Continuous monitoring and evaluation of the implemented enhancements are essential to assess their impact on efficiency, quality, and sustainability
2.	Prateek Singhal, Abhishek Verma, Prabhat Kumar Srivastava, Virender Ranga, Ram Kumar[4]	"Variability in ripening outcomes, energy consumption, regulatory compliance, and stakeholder engagement are identified	<ul style="list-style-type: none"> Enabling ongoing improvement and adaptation to evolving market dynamics and technological advancements.
3.	Yanlin T, Zuoxin Hu, Tianyu T, Xin Gao.,[6]	Future enhancements discussed encompass a range of technological innovations, such as remote monitoring and control, predictive analytics, energy optimization, and quality	<ul style="list-style-type: none"> Refinement of proposed enhancements are conducted to optimise their effectiveness and ensure successful implementation in banana ripening operations.



		monitoring.	
4.	[Gunawati, A.H.Dongoran,A.Setiawan [8]	" Collaboration across the supply chain and adoption of emerging technologies are emphasised as key strategies to address challenges and drive innovation in the industry.	<ul style="list-style-type: none"> industry partners, research institutions, and technology providers is essential to validate the proposed enhancements

VI. CONCLUSION

The development of an IoT-based banana ripening chamber with ethylene control presents a significant advancement in the field of fruit ripening technology, offering precise monitoring, control, and optimization of ripening conditions. Through the integration of sensors, microcontrollers, and advanced control algorithms, this innovative solution addresses key challenges in traditional ripening methods while improving efficiency, quality, and sustainability in banana ripening operations. By leveraging IoT technology, operators gain access to real-time data on temperature, humidity, ethylene concentration, and other relevant parameters, enabling proactive adjustments to ripening conditions and ensuring consistent ripening outcomes. The implementation of ethylene control mechanisms further enhances the ripening process, reducing ripening time and improving fruit quality while minimising environmental impact. Future enhancements, such as remote monitoring and control capabilities, predictive analytics, energy optimization techniques, and smart packaging integration, promise to further elevate the efficiency and sustainability of banana ripening operations. These advancements reflect a commitment to innovation and continuous improvement in meeting the evolving needs of consumers, stakeholders, and the environment. In conclusion, the IoT-based banana ripening chamber represents a transformative solution for the banana industry, offering enhanced control, efficiency, and quality assurance throughout the ripening process. By embracing technological innovation and sustainable practices, the industry can continue to drive progress and meet the growing demand for high-quality, ripe bananas while minimising waste and environmental impact.

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