

An IoT-BASED SMART AUTO-CONTROLLED FRUIT VENTILATION SYSTEM FOR POST-HARVEST PRESERVATION

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Abstract —*Post-harvest fruit spoilage is a major concern in agricultural supply chains due to uncontrolled environmental conditions inside storage units. Factors such as temperature, humidity, and ethylene gas accumulation significantly accelerate ripening and degradation, leading to economic losses for farmers and distributors. This paper presents a smart auto-controlled fruit ventilation system that utilizes Internet of Things (IoT) technologies to continuously monitor storage conditions and automatically regulate ventilation in real time. The proposed system integrates gas sensors, temperature and humidity sensors with a microcontroller-based control unit to detect unfavourable storage conditions. When ethylene gas concentration or environmental parameters exceed predefined safe thresholds, the system automatically activates ventilation mechanisms to restore optimal conditions. Sensor data is processed in real time, enabling timely control actions without manual intervention. To enhance system reliability, adaptive threshold control and continuous monitoring strategies are employed. Experimental evaluation demonstrates improved freshness retention, delayed ripening, and reduced spoilage when compared to traditional manual ventilation methods. The proposed system is cost-effective, energy-efficient, and suitable for small- and medium-scale fruit storage applications, contributing to sustainable post-harvest management.*

Keywords — *IoT, Fruit Preservation, Ethylene Gas Control, Smart Ventilation, Post-Harvest Management, Automated Storage.*

I. INTRODUCTION

Fruits remain biologically active even after harvesting and continue to respire, releasing gases such as ethylene that accelerate ripening and senescence. In enclosed storage environments, the accumulation of ethylene gas, combined with improper temperature and humidity control, leads to rapid spoilage and significant post-harvest losses. According to agricultural studies, a substantial percentage of harvested fruits are lost before reaching consumers due to inadequate storage and preservation methods. Traditional fruit storage practices largely rely on manual inspection and periodic ventilation, which are inefficient and prone to human error. Cold storage facilities, although effective, are expensive and inaccessible to small-scale farmers. As a result, there is a growing demand for affordable, automated solutions that can maintain optimal storage conditions without continuous human supervision. Recent advances in IoT

and embedded systems have enabled the development of smart agricultural solutions capable of real-time monitoring and automated control. By integrating sensors, microcontrollers, and actuators, IoT-based systems can detect changes in environmental parameters and respond instantly to maintain optimal conditions. This paper proposes an IoT-based smart auto-controlled fruit ventilation system that continuously monitors gas concentration, temperature, and humidity, and automatically regulates ventilation to extend fruit shelf life. The proposed system emphasizes real-time responsiveness, low-cost implementation, and ease of deployment, making it suitable for practical agricultural environments.

II. LITERATURE SURVEY

Post-harvest fruit preservation has received significant research attention due to the high levels of spoilage caused by improper storage conditions. Fruits remain biologically active even after harvesting, continuing metabolic processes such as respiration and transpiration. During respiration, fruits consume oxygen and release carbon dioxide, ethylene gas, and moisture. The accumulation of these by-products within enclosed storage environments accelerates ripening, softening, and eventual senescence, thereby reducing both shelf life and market value. As global food demand increases, minimizing post-harvest losses has become a critical objective for the agricultural sector, supply chain managers, and food preservation researchers. Traditional storage techniques typically rely on manual inspection, periodic ventilation, and fixed environmental controls. While these methods have been widely practiced, they are often inefficient and lack the responsiveness required to manage rapidly changing storage conditions. Manual monitoring is labor-intensive and prone to human error, and scheduled ventilation may not align with the actual environmental needs inside the storage facility. As a result, fruits may be exposed to unfavorable temperature, humidity, or gas concentrations for extended periods before corrective measures are implemented. To overcome these limitations, recent research has increasingly focused on sensor-based monitoring systems and IoT-enabled automation, which provide real-time data collection and intelligent control of storage parameters.

Author(s)	Focus Area / Proposed System	Technology & Parameters Monitored	Control Mechanism, Advantages & Limitations
Zhang et al.	Ethylene monitoring for ripening detection	Ethylene gas sensor; ethylene concentration	Monitoring-based control. Adv: Accurate detection. Lim: Temperature-sensitive; needs calibration.
Sujatha et al.	Low-cost gas detection system	MOS sensor + microcontroller; ripening gases	Threshold-based alerts. Adv: Affordable. Lim: Limited parameter monitoring.
Singh & Mehta	IoT cold storage monitoring	IoT sensors; temperature & humidity	Real-time alerts. Adv: Remote access. Lim: Internet dependency.
Lang & Jedermann	Distributed sensor system with edge intelligence	Embedded system; temp, humidity, gas	Edge-level automation. Adv: Reliable offline. Lim: Complex implementation.
Gupta et al.	Automated ventilation control	Multi-sensor system; gas, temp, humidity	Dynamic airflow control. Adv: Energy-efficient. Lim: Sensor integration required.
Aliff et al.	IoT dashboard monitoring	Sensor network; temp, humidity, gas	Remote visualization. Adv: Better decision-making. Lim: Needs stable data transmission.

Several studies have explored the use of gas sensors for monitoring ethylene concentration in fruit storage environments, as ethylene plays a key role in regulating fruit ripening. Zhang et al. investigated the response characteristics of ethylene sensors under varying temperature conditions and demonstrated that continuous gas monitoring can effectively indicate fruit ripening stages. Their research showed that sensor sensitivity and response time are influenced by environmental factors, making proper calibration essential for accurate detection. The findings emphasized that real-time measurement allows storage operators to intervene promptly, preventing premature spoilage and maintaining fruit quality during extended storage periods. Similarly, Sujatha et al. developed a low-cost monitoring system using metal oxide semiconductor (MOS) gas sensors integrated with microcontrollers to detect ripening-related gas emissions. Their work highlighted the practicality of affordable technological solutions for agricultural applications, particularly for small-scale farmers and storage operators with limited resources. The system employed threshold-based control mechanisms that triggered alerts or ventilation when gas concentrations exceeded safe levels. Results demonstrated that cost-effective sensor-based systems can still deliver reliable performance when properly configured, making them suitable for broader adoption across diverse agricultural settings.

IoT-based environmental monitoring systems have been widely applied in agricultural storage and cold chain logistics, where maintaining stable conditions is essential for preserving freshness and nutritional quality. Singh and Mehta proposed an IoT-enabled monitoring framework for cold storage facilities that continuously tracks temperature and humidity levels using connected sensors. Their resultshighlighted that real-time sensing combined with automated alerts significantly reduces storage losses compared to traditional manual inspection methods. The ability to remotely access environmental data also enhances operational efficiency, allowing managers to respond immediately to anomalies and prevent large-scale spoilage.

Lang and Jedermann further reviewed the application of distributed sensors and embedded intelligence in logistics and storage containers. Their study emphasized the importance of edge-level decision-making, particularly in scenarios where network connectivity may be intermittent or unavailable. By enabling local processing and automated responses, edge computing ensures that critical actions—such as activating ventilation or adjusting cooling systems—can occur without delay. This approach enhances system reliability and supports continuous preservation even in challenging infrastructure environments.

Automated ventilation control has also been investigated as an effective strategy for managing post-harvest storage conditions. Gupta et al. demonstrated that sensor-driven ventilation systems outperform traditional timer-based methods by dynamically responding to real-time environmental variations. Instead of relying on predetermined schedules, these systems adjust airflow based on actual gas concentration, temperature, and humidity levels. Their study confirmed that automated airflow regulation helps maintain optimal storage conditions while simultaneously reducing energy consumption, making the approach both economically and environmentally beneficial.

Aliff et al. expanded this concept by integrating IoT dashboards for remote monitoring and management. These dashboards enable storage managers to visualize trends in temperature, humidity, and gas concentration through intuitive graphical interfaces. With access to historical and real-time data, operators can identify patterns, predict potential risks, and take corrective actions proactively rather than reactively. Such visualization tools also improve decision-making by transforming raw sensor data into meaningful insights that support efficient storage management.

Across the reviewed literature, several common conclusions emerge. First, continuous monitoring of ethylene gas, temperature, and humidity is essential for effective fruit preservation because these parameters directly influence ripening and deterioration processes. Second, IoT-based sensor integration enables timely and automated control actions, reducing reliance on manual supervision and minimizing the likelihood of human error. Third, rule-based threshold control provides a reliable and cost-effective solution, particularly for small- and medium-scale storage facilities that require practical yet efficient technologies. Finally, automated ventilation has been consistently shown to significantly reduce spoilage and energy waste when compared to manual or fixed-timer approaches.

Collectively, these findings establish a strong technological foundation for advancing smart storage solutions in the agricultural sector. They highlight the growing importance of integrating sensing technologies, embedded intelligence, and automated control mechanisms to create adaptive storage environments capable of responding to real-time conditions. Building upon these insights, the proposed IoT-based smart auto-controlled fruit ventilation system focuses on real-time sensing, automated decision-making, and energy efficiency. By combining continuous environmental monitoring with intelligent ventilation control, the system aims to enhance fruit preservation, extend storage life, reduce post-harvest losses, and support sustainable agricultural practices.

III. EXISTING METHODOLOGY

Conventional fruit storage and preservation methods primarily depend on manual observation and intermittent control measures, which have been practiced for decades across agricultural communities worldwide. In these traditional systems, farmers and storage operators typically rely on basic instruments such as thermometers and hygrometers to monitor environmental conditions, primarily temperature and humidity, which are critical for maintaining fruit quality. While these instruments provide some guidance, their use is largely dependent on human diligence and frequent manual checking. Ventilation, cooling, or other preservation actions are usually triggered only when visible signs of spoilage—such as discoloration, softening, unpleasant odors, or textural changes—are observed in the stored produce. This reactive approach inherently involves a significant delay between the onset of deterioration and corrective intervention. By the time spoilage indicators become noticeable, substantial physiological and biochemical changes may have already occurred in the fruits, resulting in considerable post-harvest losses and reduced marketability. Such delays in response are particularly problematic in fruits with high respiration rates or short shelf lives, where even minor deviations in storage conditions can lead to rapid quality degradation.

Cold storage facilities have become widely adopted in commercial fruit preservation due to their ability to maintain controlled low-temperature environments. These systems operate by slowing down the metabolic processes and enzymatic activity in fruits, thereby delaying ripening, softening, and senescence. For large-scale commercial operations, cold storage has proven to be highly effective in extending the shelf life of perishable fruits and enabling long-distance transportation while preserving quality. However, despite their advantages, cold storage systems are not without limitations. They require substantial capital investment for construction and equipment, continuous and reliable power supply, and trained personnel to operate and maintain the facilities. Such requirements make these systems expensive and often inaccessible to small- and medium-scale farmers who may lack the financial resources or technical expertise. Consequently, many small-scale producers are unable to take advantage of advanced preservation technologies, which restricts their ability to reduce post-harvest losses and limits their competitiveness in the market.

Moreover, traditional cold storage alone does not address the problem of ethylene gas accumulation—a plant hormone naturally emitted by fruits that accelerates ripening and senescence. When fruits are stored in enclosed environments without adequate gas management or ventilation, ethylene can accumulate to levels that significantly hasten ripening. This can lead to over-ripening, premature spoilage, or loss of desirable quality attributes such as firmness, color, and flavor. Therefore, even in cold storage facilities, additional measures such as ethylene removal or active ventilation are often necessary to ensure optimal preservation. The lack of real-time monitoring and responsive control in conventional systems means that ethylene-related deterioration may go unnoticed until quality degradation becomes evident.

In an attempt to reduce the dependency on continuous manual intervention, some semi-automated storage solutions have been introduced. These systems often employ fixed timers to operate ventilation fans or other preservation mechanisms at pre-

determined intervals. While such timer-based systems represent a step forward in labor efficiency compared to fully manual approaches, they remain far from ideal. Fixed-timer operations are unable to adapt to dynamically changing environmental conditions within the storage environment, such as fluctuating temperature, humidity, or gas concentration levels. For example, during periods of high ethylene emission or elevated temperature, the ventilation fans may not operate frequently enough to mitigate accelerated ripening. Conversely, during cooler periods with low respiration and ethylene production, the fans may operate unnecessarily, resulting in wasted energy, increased operational costs, and suboptimal preservation outcomes.

Overall, existing conventional and semi-automated methodologies exhibit several critical limitations that hinder effective post-harvest preservation. These include their reactive nature, lack of real-time responsiveness, dependence on human monitoring, high energy and operational costs, inability to manage ethylene accumulation adequately, and limited accessibility for small-scale farmers. Such constraints highlight the need for more advanced, intelligent, and automated storage solutions that can continuously monitor environmental conditions, respond dynamically to changes, and maintain optimal preservation parameters with minimal human intervention, ultimately reducing spoilage, extending shelf life, and improving the economic returns for producers.

1. Lack of Real-Time Monitoring: Most traditional and semi-automated storage systems rely on periodic manual inspection or fixed-interval sensing mechanisms. These approaches fail to provide continuous, real-time monitoring of crucial environmental and biochemical parameters such as temperature, relative humidity, ethylene gas concentration, and carbon dioxide levels. Since fruit respiration rates and gas emissions can change rapidly depending on ripening stage and ambient conditions, the absence of real-time data prevents early detection of unfavorable storage environments. As a result, corrective actions are often delayed until the damage becomes visible or irreversible.

2. Reactive Intervention: Existing systems primarily operate in a reactive manner rather than a preventive one. Ventilation or cooling actions are initiated only after noticeable signs of spoilage—such as softening, discoloration, mold growth, or unpleasant odors—are observed. By the time these symptoms appear, fruits may have already undergone significant physiological degradation. This delayed response reduces the effectiveness of preservation measures and leads to higher spoilage rates, particularly for climacteric fruits that are highly sensitive to ethylene accumulation.

3. Inefficient Resource Use: Fixed-timer-based ventilation and cooling systems operate without considering real-time storage conditions. Such systems may activate fans or cooling units unnecessarily during periods of low gas emission or favorable temperature conditions, leading to excessive energy consumption. Conversely, during periods of rapid ethylene production or temperature spikes, fixed schedules may fail to provide sufficient ventilation. This mismatch results in inefficient use of energy, increased operational costs, and suboptimal storage performance without ensuring consistent fruit quality.

4. Limited Adaptability: Conventional storage methods lack adaptability to variations in fruit type, ripening stage, storage duration, and external environmental conditions. Different fruits have distinct optimal storage requirements; however, existing

systems typically apply uniform control strategies regardless of these differences. Additionally, changes in ambient temperature, humidity, or seasonal conditions are not dynamically accounted for, further limiting the system’s ability to maintain ideal internal storage environments. This rigidity reduces the overall effectiveness of preservation across diverse agricultural scenarios.

5. **Increased Spoilage and Waste:** Due to the combined effects of delayed intervention, inadequate monitoring, and inefficient control, spoilage rates remain high in traditional storage systems. Accumulation of ethylene gas accelerates ripening, while improper temperature and humidity promote microbial growth and moisture loss. These factors collectively contribute to increased post-harvest waste, reduced market value of produce, and financial losses for farmers, distributors, and storage operators. In the long term, such inefficiencies negatively impact food supply chains and agricultural sustainability.

In conclusion, traditional fruit storage and semi-automated approaches provide only partial solutions to post-harvest preservation. The lack of integrated real-time sensing, automated decision-making, and adaptive control highlights the urgent need for advanced, smart storage solutions. Technologies that can continuously monitor environmental and biochemical conditions, and automatically adjust ventilation, cooling, or gas control, would significantly reduce spoilage, optimize energy use, and improve shelf life across both small and large-scale operations.

IV. PROPOSED SYSTEM

The proposed automated ventilation system introduces a smart, IoT-enabled solution for regulating environmental conditions in fruit storage facilities to reduce post-harvest losses. Fruits continue to respire after harvesting, releasing ethylene gas, moisture, and heat, which accelerates ripening and spoilage when accumulated in enclosed environments. If these factors are not properly controlled, they can lead to significant quality degradation, weight loss, microbial growth, and reduced market value of the produce.

Traditional storage methods rely heavily on manual inspection and ventilation, which often results in delayed corrective actions and inconsistent preservation. Farmers and storage managers typically depend on periodic checks rather than continuous monitoring, making it difficult to detect sudden environmental changes. This reactive approach increases the risk of spoilage, especially during peak harvest seasons when large quantities of fruits must be stored for extended periods.

To overcome these challenges, the proposed system automates the monitoring and ventilation process using sensors, a microcontroller, and controlled airflow mechanisms. The integration of IoT technology enables real-time data collection and analysis, ensuring that storage conditions remain within the desired range at all times. By eliminating the need for constant human supervision, the system improves operational efficiency while reducing labor requirements.

The system continuously measures ethylene gas concentration, temperature, and relative humidity inside the storage chamber. These parameters play a critical role in determining the ripening rate and overall freshness of fruits. Based on real-time sensor data, intelligent control logic automatically regulates ventilation to maintain optimal storage

conditions. When gas levels or temperature exceed predefined thresholds, the system activates motorized shutters to allow fresh air circulation. Once the environment stabilizes, the shutters close automatically, preventing unnecessary airflow and maintaining internal balance.

This approach minimizes human intervention, reduces energy consumption, and significantly improves fruit shelf life. Maintaining stable environmental conditions not only preserves freshness but also helps retain nutritional quality, texture, and flavor. As a result, farmers can reduce economic losses and ensure better returns in the marketplace.

Unlike conventional cold storage systems that require high capital investment, specialized infrastructure, and continuous power supply, the proposed solution adopts a low-cost and energy-efficient ventilation strategy. Motorized ventilation shutters are used instead of continuous ventilation fans, allowing natural airflow only when required. This selective operation conserves energy and makes the system environmentally sustainable.

Furthermore, the design emphasizes affordability, scalability, and ease of implementation. The system can be installed in existing storage structures without major modifications, making it practical for widespread adoption. Its modular architecture also allows additional sensors or features to be integrated in the future, such as remote monitoring through mobile applications, data logging for predictive analysis, and automated alerts for abnormal conditions.

The system is particularly well suited for small- and medium-scale farmers, decentralized storage units, and rural agricultural environments where access to advanced cold storage facilities is limited. By providing a reliable and intelligent storage solution, the proposed automated ventilation system supports better post-harvest management, enhances food security, and contributes to sustainable agricultural practices. Ultimately, it bridges the gap between traditional storage methods and modern smart farming technologies, promoting higher efficiency and reduced waste across the agricultural supply chain.

V. THRESHOLD INDICATORS

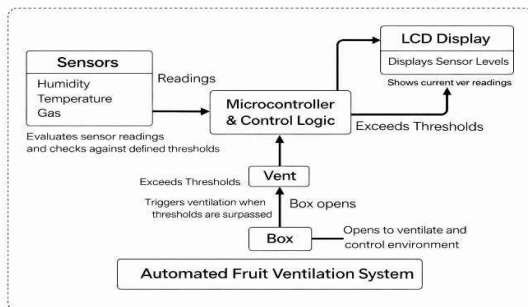
Parameter	Safe Level	Warning Level	Danger Level	Action
Temperature	<27°C	28°C – 35°C	> 40°C	Turn ON ventilation / cooling
Humidity	<40% RH	40% – 55%	> 60%	Dehumidify / increase airflow
Gas	400 – 1000 ppm	500 – 700 ppm	> 800 ppm	Start ventilation immediately

The system categorizes environmental conditions into safe and danger levels based on predefined threshold values for temperature, humidity, and gas concentration. When all parameters remain within the safe range, a **green indicator light** turns ON, signifying that the storage environment is stable and suitable for fruit preservation. During this state, the system continues regular monitoring without activating the ventilation mechanism. However, when any parameter exceeds the safe limit and reaches the danger level, a **red indicator light** is automatically triggered. This visual warning allows users to instantly recognize that the storage conditions have become

unfavorable. Simultaneously, the automated ventilation system starts operating to expel accumulated heat, moisture, and gases, thereby restoring optimal conditions inside the storage chamber. This dual-indicator approach enhances system reliability by combining automation with easy-to-understand visual signals. It reduces the need for constant manual supervision while enabling faster decision-making in critical situations. As a result, the threshold indicator mechanism plays a vital role in preventing spoilage, maintaining fruit quality, and ensuring efficient storage management.

VI. SYSTEM ARCHITECTURE

The automated fruit ventilation system is designed using a modular and layered architecture that seamlessly integrates environmental sensing, automated decision-making, controlled ventilation, and optional IoT-based supervision. This architectural approach ensures reliable operation, scalability, energy efficiency, and ease of maintenance. By dividing the system into clearly defined functional modules, each component can operate independently while coordinating with the others to maintain optimal storage conditions for fruits. The architecture supports real-time monitoring, rapid response to unfavorable conditions, and adaptability to different fruit types and storage environments. The overall system is composed of six major modules, namely the Data Acquisition Module, Sensor Monitoring Module, Control Logic and Decision-Making Module, Ventilation Actuation Module, IoT Monitoring and Communication Module, and the System Feedback and Safety Module. Together, these modules form a closed-loop control system that continuously senses environmental parameters, evaluates storage conditions, and performs corrective actions whenever deviations occur.



A. **Data Acquisition Module:** The data acquisition module forms the foundation of the automated ventilation system, as the accuracy and reliability of control decisions depend directly on the quality of sensor data. This module is responsible for continuously collecting critical environmental parameters from within the fruit storage chamber. Ethylene gas sensors such as MQ-series or MQ-135 sensors are employed to detect the concentration of ethylene and other harmful gases released during fruit respiration, which are known to accelerate ripening and spoilage. Temperature and humidity sensors, such as DHT11 or DHT22, are used to monitor the ambient temperature and relative humidity inside the storage unit. These parameters are crucial for maintaining fruit freshness, preventing dehydration, and minimizing microbial growth. All sensors are strategically placed inside the storage chamber to ensure accurate representation of internal conditions. The collected sensor readings are sampled

at regular intervals and transmitted to the microcontroller for further analysis and processing.

B. **Sensor Monitoring Module:** The sensor monitoring module continuously evaluates the real-time data obtained from the data acquisition module. The microcontroller reads the values of ethylene concentration, temperature, and humidity and compares them with predefined threshold values that represent optimal and safe storage conditions. Each monitored parameter plays a significant role in fruit preservation: elevated ethylene levels accelerate ripening and senescence, high temperatures increase respiration rates and metabolic activity, and improper humidity levels can lead to moisture loss or fungal and bacterial growth. When any of these parameters exceeds its acceptable range, the system identifies the condition as abnormal and flags it for corrective action. Continuous and uninterrupted monitoring enables early detection of unfavorable storage conditions, thereby preventing irreversible damage and reducing post-harvest losses.

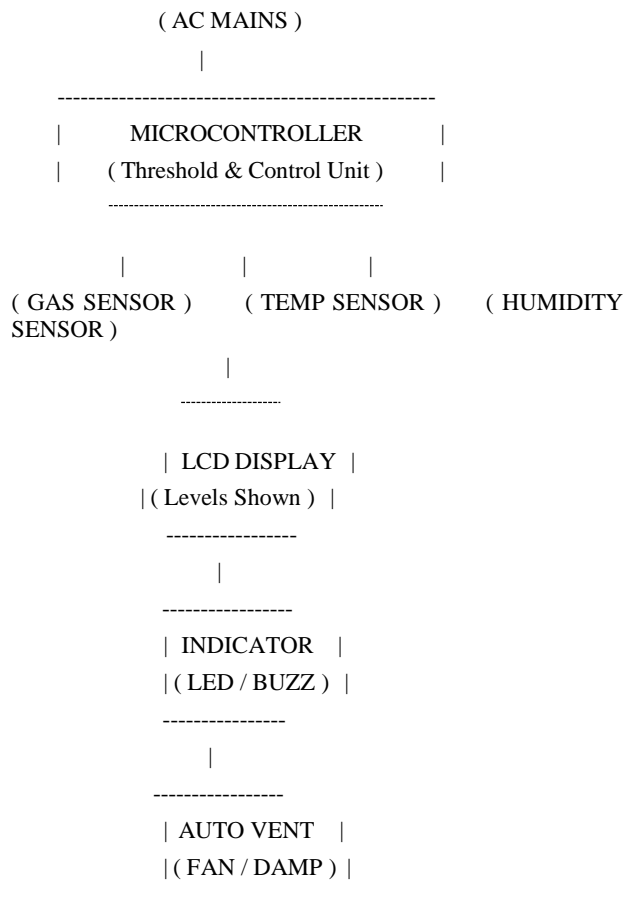
C. **Control Logic and Decision-Making Module:** The control logic and decision-making module acts as the intelligence core of the automated ventilation system. It processes the sensor data received from the monitoring module and determines the appropriate control actions based on programmed decision rules. The decision-making process involves reading real-time sensor values, comparing them with predefined or adaptive threshold levels, assessing the magnitude and severity of deviations, and generating control signals accordingly. The system can be configured with adaptive thresholds to suit different fruit varieties and storage durations. For instance, climacteric fruits with high ethylene sensitivity may require stricter ethylene thresholds, while other fruits may tolerate higher humidity levels. This flexibility and adaptability enhance the system's reliability, effectiveness, and applicability across diverse agricultural storage scenarios.

D. **Ventilation Actuation Module:** The ventilation actuation module is responsible for regulating airflow within the fruit storage chamber based on decisions made by the control logic module. Unlike conventional storage systems that rely on continuously operating fans, the proposed system utilizes motorized ventilation shutters or louvers driven by a servo motor or DC motor. When abnormal environmental conditions are detected, the microcontroller sends appropriate control signals to the motor driver, causing the ventilation shutters to open automatically. This allows ethylene-rich and stale air to exit the chamber while fresh air enters naturally due to pressure differences. Once the sensor readings return to safe and acceptable limits, the shutters close automatically, restoring a controlled internal environment. This passive or semi-passive ventilation strategy significantly reduces energy consumption while ensuring effective regulation of gases and temperature.

E. **IoT Monitoring and Communication Module:** The IoT monitoring and communication module enhances the functionality of the system by enabling remote access and real-time data visualization. An ESP8266 or ESP32 module is used to transmit sensor data wirelessly to a cloud-based platform or a local monitoring dashboard. This module allows users to observe real-time storage conditions, analyze historical data trends, and receive alerts when environmental parameters exceed predefined limits. Remote monitoring eliminates the need for constant physical presence, enabling farmers and storage managers to take timely corrective actions and improve overall operational

efficiency. Additionally, the availability of historical data supports better decision-making and long-term optimization of storage practices. F. System Feedback and Safety Module The system feedback and safety module ensures reliable, safe, and user-friendly operation of the automated ventilation system. Visual indicators such as LEDs and audible alerts such as buzzers are used to notify users when abnormal conditions persist beyond acceptable durations. This module also incorporates essential safety features, including manual override options for emergency ventilation, fail-safe mechanisms to handle sensor malfunctions, and power loss recovery procedures to restore system operation after interruptions. By enhancing fault tolerance and user awareness, this module increases system robustness and builds user confidence in automated operation. G. System Workflow Summary The overall workflow of the automated fruit ventilation system operates as a continuous closed-loop process. Environmental sensors collect real-time data from the storage chamber, which is then analyzed by the microcontroller. The system compares the sensor readings with predefined thresholds and applies decision logic to determine whether ventilation is required. Based on this decision, the ventilation shutters are opened or closed automatically. The system continuously monitors and updates environmental conditions, ensuring optimal storage parameters are maintained at all times. This closed-loop feedback mechanism enables continuous optimization and effective control of fruit storage conditions.

FLOW DIAGRAM



IMPLEMENTATION RESULTS

The proposed IoT-based smart fruit ventilation system was

implemented using a microcontroller-based control unit integrated with environmental sensors and automated ventilation mechanisms. Ethylene gas concentration, temperature, and humidity levels were continuously monitored inside the fruit storage chamber using gas sensors and temperature-humidity sensors. The system operated based on predefined threshold values corresponding to optimal storage conditions. When sensor readings exceeded these limits, the control unit automatically activated the ventilation shutters to expel ethylene-rich air and regulate internal conditions. Once the parameters returned to acceptable ranges, ventilation was stopped automatically, ensuring efficient energy usage. Experimental testing was conducted under controlled storage conditions using selected fruit samples. The results indicated improved freshness retention and delayed ripening when compared to traditional manual ventilation methods. Continuous monitoring reduced the need for manual inspection, and automated ventilation ensured timely corrective actions. The system demonstrated reliable operation, low power consumption, and effective regulation of storage conditions. These results confirm that IoT-based automated ventilation can significantly reduce post-harvest spoilage and improve fruit shelf life in a cost-effective manner.

VII. CONCLUSION AND FUTURE WORK

This paper presented an IoT-based smart auto-controlled fruit ventilation system designed to improve post-harvest fruit preservation by regulating ethylene gas concentration, temperature, and humidity in storage environments.

By integrating environmental sensors, a microcontroller, and automated ventilation shutters, the system ensures optimal storage conditions without continuous human intervention. The proposed solution offers a low-cost, energy-efficient alternative to conventional cold storage systems, making it suitable for small- and medium-scale farmers. Real-time monitoring and automated control significantly reduce spoilage, extend shelf life, and improve storage efficiency. Future work may focus on integrating cloud-based data analytics for long-term monitoring, mobile application support for remote alerts, and the incorporation of data-driven optimization techniques to further enhance ventilation strategies based on historical sensor data.

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