

Smart Onion Segregation and Storage System

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Abstract— Onions are staple crop in agriculture, and is widely consumed in food throughout the world because of its nutritional and commercial value. But, postharvest losses causing due to improper segregation and storage of onions is still a very big challenge which leads to high economic losses. Efficient segregation and storage of onions is very important. Proper Sorting of Onions based on their size, defects, quality is very important to provide high quality and high value onions in the market. Along with Sorting, storage of onions hold equal importance to minimize spoilage. Storage of Onions at specific temperature, humidity is very important for increasing their shelf life. This review paper explores current methodologies and technologies employed in onion segregation and storage systems, emphasizing automation, humidity, and temperature control. It also includes comparative analyses based on critical parameters like economic feasibility, efficiency, storage longevity, and technological integration. The objective is to provide an in- depth understanding of the advancements in onion storage systems, offering insights into how automation and innovative solutions can enhance storage effectiveness and sustainability.

Keywords— Segregation, Sorting, Storage, IOT in Agriculture, Climate Controlled, Image Processing, AI-based Sorting, Sensors, Machine Learning, Shelf life, Humidity Controlled, Automation, Real-time monitoring.

I. INTRODUCTION

Through its high output quantity that meets demand for both domestic and overseas activities, India is held as one of the top producers of onions in the world. Onions are an indispensable household ingredient for the Indian people, just as much as they are a major sector of the Indian agricultural market. Due to the unorganized storage systems, inadequate segregation methods as well as poor handling techniques, the country suffers major post-harvest losses from high onion production. Inadequate infrastructure coupled with low technology applications result in enormous post-harvest losses which reduce farmers income levels and also endangered India's food security. The top end of the life of onions exposes them to the forces of nature i.e. temperature variation plus humidity plus inadequate air circulation. Unfavourable climate conditions end in seed sprouting combined with spoilage together with weight reduction that leads to market value decreases and financial losses. Adequate implementation of storage and segregation measures will be the way to bridge raw material shortages and maintain quality in post- harvest. It categorizes onions by their dimension as well as their mass and visual features, plus their overall quality metrics.

The manual sorting process is labour-intensive, tedious, and prone to human errors. This creates a cascading cycle of poor storage conditions that results in higher spoilage rates and inconsistent result patterns.[2]

More recent automated systems for sorting onions are leveraging state-of-the-art technologies based on image processing, weight sensors and AI-driven indoor mechanisms to generate expected results in no time. The systems also reduce workforce requirements, allowing for consistent results with minimized segregation processing. Strictly following this method conserves a lot of space in terms of storage. Oiling onions of the same size and stovoid quality (i.e., have the same skin and meat smoothness, freshness, and jaw and head polish) in similar storage units is the best solution as it permits raw environmental management while facilitating simple observation techniques and ganely. In addition, proper segregation of produce would minimize produce contamination risk and prolong the storage serpentine. The optimal conditions for ontario heat preservation are achieved by sensors and automated process controls in modern storage equipment, which maintain the temperature and humidity of storage for onions. Modern technology linked agricultural storage systems are a critical developmental step in sustainable agriculture practices. Automated storage systems bring great economic benefits with the help of minimum loss, good distortion, and high market value. Automated storage systems minimizes manual labour force in agricultural production solving the current labour shortage issues.[2]

The Paper examines various approaches as well as technical methods being used for storage of onions. In this paper, an economic performance and efficiency and adaptability to the environment comparison study is conducted between conventional and modern methods of onion storage systems. The primary goal of is to find the best storage practices in onion production to reduce the loss during storage as well as improve sustainability along with ensuring storage longevity. Modern technology adoption coupled with innovative solutions enables the agricultural field to minimize both post-harvest loss rates and boost national food security levels. This paper presents research findings which offer stakeholders beneficial information about modern storage systems to promote better agricultural result.[3]

II. LITERATURE REVIEW

TABLE I: LITERATURE REVIEW

Ref. Year	Paper Title	Method	Contributions	Future Scopes
[1] 2024	IoT-Based Onion Storage System: A Review Paper	IoT storage system	Summarizes existing storage technologies and IoT applications	Integration with blockchain for secure storage
[2] 2024	Early Detection of Onion Spoilage Utilizing IoT and AI During Storage and Transportation	AI and IoT- based detection system	Develops an AI- based system for early detection of onion spoilage	Faster and more accurate detection using ML models
[3] 2024	A Comprehensive Review on Recent Advances in Postharvest Treatment, Storage & Quality Evaluation of Onion	Review- based study	Analyzes recent technological advancements in post- harvest treatment and storage	Exploring nanotechnology for storage improvements
[4] 2024	Implementation of IoT & Fuzzy Logic Driven Real-time Smart Storage Monitoring System	IoT and fuzzy logic	Proposes a fuzzy logic- based approach for better decision-making in onion storage	Optimizing real-time decision- making processes
[5] 2024	IoT-Based Efficient Storage System for Sustainable Agriculture	IoT- enabled storage system	Develops an IoT- based sustainable storage system for agricultural products	Large- scale deployment and automation improvements
[6] 2024	Machine Vision- Based Real- Time Onion Classification and Sorting Using YOLO v8 Model	AI-based YOLO v8 deep learning model	Implements a machine vision- based AI model for real-time onion sorting	Implements a machine vision- based AI model for real-time onion sorting
[7] 2024	Onion Smart Storage System Using IoT (Humidity Sensor DHT11, Gas Sensor MQ-6)	IoT- based storage with sensors	Uses IoT sensors to monitor onion storage conditions	Enhanced sensor- based spoilage detection
[8] 2023	Automate d Quality- Based Onion Using Raspberry Pi	Raspberry Pi- based automation	Develops an automated system using Raspberry Pi for onion sorting	Enhanced automation and scalability
[9] 2023	An Onion Quality Analyzer & Sorter Device Using Random Forest Classifier	AI- based Random Forest model	Utilizes machine learning (Random Forest) for quality- based onion sorting	Combining multiple AI models for better accuracy

[10] 2023	SORT: Blockchain & Onion Routing-Based Secure Telesurgery Framework for Healthcare IoT	Blockchain technology	Introduces blockchain and onion routing for secure data transmission	Implements a machine vision-based AI model for real-time onion sorting
[11] 2023	Application of AI in the Food Industry – A Guideline	AI implementation in food tech	Reviews AI applications in food safety and sorting	Improve automation, enhance speed, and accuracy
[12] 2023	Development of IoT Enabled Vegetable Stockpile Warehouse Monitoring System to Support Farmers	IoT-based monitoring system	Designs a system for warehouse monitoring using IoT	Real-time predictive analytics for better storage
[13] 2023	Development of Smart Machine for Sorting Deceased Onions	Automated sorting machine	Develops an automated system for sorting defective onions	Improved sensor technology for better accuracy
[14] 2022	Post-Harvest Management in Onion: Deserve Concern	Post-harvest management study	Discusses key post-harvest management challenges and solutions	Addressing supply chain challenges in onion storage
[15] 2022	Effect of Temperature & Relative Humidity on Onion Farms and Its Monitoring Using IoT-Based Smart Farming System	IoT and climate monitoring	Examines temperature and humidity effects on onion farms with IoT	AI-driven climate prediction for onion farming
[16] 2021	Belt Conveyor System for Smart Onion Sorting Machine	Belt conveyor mechanism for sorting	Develops a belt conveyor-based automated sorting machine	Improve automation, enhance speed, and accuracy
[17] 2020	Smart System for Onion Storage	IoT-based storage system	Designs an IoT-based onion storage system for better shelf life	Integrating AI for better spoilage prediction
[18] 2020	Classifying Quality Grading and Size of Allium Cepa	Digital image processing	Uses image processing algorithms for onion	Advanced AI models for classification

The above literature review table provides an in-depth summary of recent studies aimed at smart onion segregation and storage systems. It brings together 18 academic papers published between 2020 and 2024, reflecting the swift development of technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and machine learning in agricultural post-harvest management. The process of onion segregation and storage comes under a multidisciplinary field that involves post-harvest technology, agriculture automation, and smart farm systems. The post-harvest period is critical in establishing the ultimate quality and economic worth of farm produce, and for onion, a very perishable crop, losses can be high if proper handling cannot be assured. Traditional methods relying on manual separation and natural storage are time-consuming and climate-dependent. Human judgment and variability in climate control result in these being unreliable and inconsistent.[6] The transition of this process to automated and intelligent systems brings significant engineering disciplines as follows:

A. Internet of Things (IoT)

Facilitates real-time measurement and regulation of environmental parameters (temperature, humidity, gas output) within storage compartments. Internet of Things sensors such as DHT11, MQ-6, and smart actuators serve as the spine of intelligent onion storage systems.[5]

B. Artificial Intelligence (AI)

It facilitates automatic onion segmentation into groups of the same shape, size, color, and other surface defects, which standardizes the quality for subsequent processing. There is ample scope for real-time classification, with YOLOv8 and Random Forest algorithms being highly accurate and fast.[6]

C. Fuzzy Logic and Automation

Fuzzy logic systems can be utilized for making decisions where uncertainties are involved, such as adjusting ventilation, humidity, and temperature based on current conditions in a storage environment.[6]

D. Digital Image Processing

This is focused on segregation and grading, based on identification of external features using Digital Image Processing. Used in conjunction with sensors, this enables precise classification and mitigates spoilage risk.[6]

E. Climate-Controlled Storage Systems

Data-driven storage systems using sensors and feedback loops to keep onions from sprouting, rotting or drying out. This significantly increases long term storage and quality retention. [6]

III. METHODOLOGY

A. Manual Segregation and Traditional Storage

Manual segregation is a traditional and widely used method where onions are sorted based on visual inspection and manual handling. It is suitable for small-scale farmers and local markets. Labour-intensive manual sortation and conventional storage techniques arrange onions by size and weight and look before transferring those things to ventilated buildings or unprotected places with natural ventilation. The unsorted network is less costly to reach smallholder farmers but labour intensive to run and results in uneven segregation and also encourages spoilage and limited environmental management.

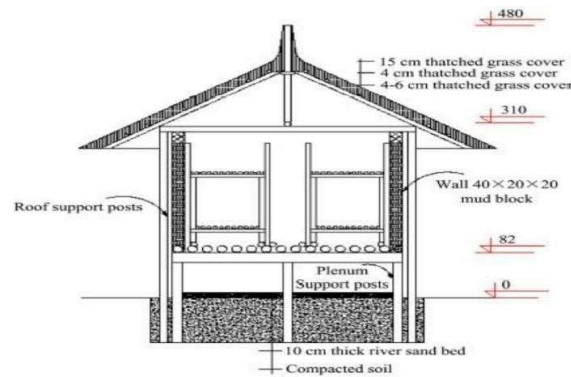


Figure 1 Traditional Storage

B. Automated Segregation with Mechanical System

Onions are sorted by size, weight, quality, and flaws using automated segregation systems that use machinery and technology. Medium- to large-scale farming operations adopt these techniques because they increase accuracy and efficiency while lowering labor expenses. Manual Automation systems currently utilize conveyor belts and weight sensors to identify and segregate onions, relying on rollers for mechanical separation when programmed to do so. While automated systems with optimised workflow enable accurate sorting and require fewer humans and operate more quickly, they are limited in their ability to perform adaptive quality-based sorting.



Figure 2 Mechanical Sorting

C. AI-Driven Sorting and Automated Storage System

To maximize onion segregation and storage, AI-driven sorting and automated storage systems leverage cutting-edge technology including computer vision, Internet of Things sensors, robots, and machine learning. Large-scale commercial farming and processing facilities use these technologies to increase productivity, cut waste, and uphold high standards of quality. AI algorithms, machine learning technology, and image processing are utilized in both types of solutions to evaluate onion characteristics and monitor the storage environment through IoT technology. These systems have very accurate sorting but come with high initial costs and need skilled personnel to operate while providing low product decay and accurate storage environments, as well as system remote monitoring. Uses high-speed cameras and AI algorithms to analyze onion size, shape, color, and defects in real time.

D. Sensor Based Segregation and climate-controlled Storage System

Sensors ensure accurate division of materials using moisture and size for storing onions in complete temperature and humidity conditions. Though sensor-based segregation requires costly maintenance and operation complexity, it allows to keep up longer storage duration along with reduced losses. Sensor-based segregation and climate-controlled storage use advanced sensing technologies to automatically grade onions and maintain ideal storage conditions. These systems help large-scale farms, processing units, and warehouses reduce spoilage, improve efficiency, and ensure consistent quality. Identifies size, weight, defects, and internal damage. Smart climate control prevents fungal growth and sprouting. Sensor- Based Segregation Systems 1) Optical & Infrared Sensors 2) Weight & Pressure Sensors 3) Moisture & Gas Sensors

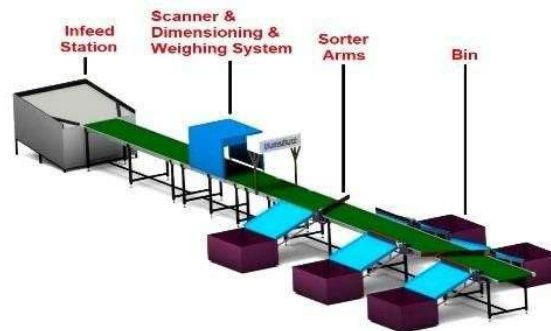


Figure 3 Sorting Conveyor Belt

E. Hybrid Segregation and Storage System

To maximize onion sorting and storage, a hybrid segregation and storage system integrates mechanical, AI-driven, sensor-based, and manual methods. This method balances accuracy, scalability, and cost-effectiveness, making it perfect for medium- to large-scale operations. Hybrid segregation and storage systems unite manual product inspection with automatic systems and partial automation storage structures to achieve optimal efficiency and cost-effectiveness. The hybrid systems combine moderate capital costs with options for different operational sizes and lower staff requirements yet fail to match the efficiency of complete automation and offer restricted remote control functions. Uses manual labor where needed, automation where beneficial. Combines sorting and storage methods for better results. Can be adapted for small, medium, or large farms.[9]



Figure 4 Hybrid Sorting System

IV. COMPARATIVE ANALYSIS

Smart Storage and Sorting Systems for Onions advanced considerably because of artificial intelligence (AI) and machine learning (ML) combination with Internet of Things (IoT) technology coupled with sensor-based monitoring and image processing methods. These technological developments aim to improve both product sorting precision as well as reduce postharvest waste and boost warehouse operational effectiveness. Onion segregation and storage are crucial for the maintenance of post-harvest quality and reducing economic losses. Manual storage and segregation are time-consuming and open to inconsistency, leading to reduced efficiency and higher spoilage. Automated solutions apply advanced technologies such as AI-based segregation

mechanisms, humidity and temperature control, and optimized storage conditions to enhance onion preservation and reduce wastage.[10]

Following is a comparative analysis between automated and manual onion storage and sorting systems based upon key factors such as efficiency, precision of segregation, economic feasibility, and scalability.

TABLE II: DIFFERENCE BETWEEN MANUAL SEGREGATION AND STORAGE AUTOMATED SEGREGATION AND STORAGE

Parameter	Manual Segregation and storage	Automated segregation and storage
Efficiency	Lower due to human error and inconsistencies	Higher with precision sorting and consistent environmental control
Storage Longitivity	3-4 months, prone to faster spoilage	8-10 months with optimized storage conditions
Humidity control	Relies on natural ventilation, less precise	Controlled using sensors and actuator for optimal levels
Temperature regulation	Manual adjustments based on experience	Automated Systems maintain consistent temperatures

V. CONCLUSION

The study of Smart Storage and Sorting Systems for Onions has seen significant advancements in recent years, with the integration of IoT, machine learning, computer vision, and sensor-based technologies playing a crucial role in improving efficiency, reducing postharvest losses, and optimizing storage conditions. A comprehensive analysis of 19 research studies reveals that automated sorting mechanisms using deep learning (YOLOv8, Random Forest), image processing, and machine vision have demonstrated high accuracy (up to 97.7%) in classifying onions into different quality categories. Artificial Intelligence delivers smart storage solutions with MQ-6 and CO₂ and Ammonia gas sensors together with DHT11 humidity sensors which improve spoilage prevention and storage duration through real-time environmental feedback. This review demonstrates that accuracy directly relates to cost and scalability requirements. The precision of AI sorting technology comes at an expensive cost for small farmers who need to invest in high computational capabilities and extensive training data collections. IoT-based storage solutions monitor in real-time while keeping costs low although sensor quality and connectivity determine their operational effectiveness. The combination of AI sorting technology with IoT storage monitoring demonstrates effective benefits for producers since it enables accurate decisions before spoilage becomes apparent. Researchers need to overcome a few key limitations in current advancements. Current solutions primarily focus individually on sorting or storage with no established systems yet for unified solutions between sorting, spoilage detection and optimization of long-term storage. Infrared spectroscopy along with NIR-based defect detection systems deliver thorough knowledge about onion internal quality but these systems remain unreachable to small-scale farmers because of their expensive setup costs. Better research should create affordable smart storage and sorting technology which uses several sensor systems to boost accuracy and operational reliability while being energy efficient and scalable.

An AI-IoT hybrid system with complete self-managing capabilities represents the most promising approach to upgrade onion storage and sorting methods. The agricultural sector has the potential to minimize postharvest losses while upgrading onion quality and boost farmer sustainability through the combination of computer vision-based quality assessment technology with real-time environment monitoring and predictive analytical capabilities. Additional interdisciplinary research and practical field tests are necessary to optimize these technologies for general application in onion farming and storage management.

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