RESEARCH PAPER

Agripass - A Digital Passport for Agricultural Products Using AI-Based Quality Assessment

Dr.G.Neelamegam [1*], S.T.Poojaa [2*], S.Roshni priya [3*] , R.Rubitha [4*]

[1*] Assistant Professor, Department of Computer Science and Engineering, V.S.B College of Engineering Technical campus, kinathukadavu, Coimbatore, Tamilnadu, India.

[2*] UG Scholar, Department of Computer Science and Engineering, V.S.B College of Engineering Technical campus, kinathukadavu, Coimbatore, Tamilnadu, India

[3*] UG Scholar, Department of Computer Science and Engineering, V.S.B College of Engineering Technical campus, kinathukadavu, Coimbatore, Tamilnadu, India.

[4*] UG Scholar, Department of Computer Science and Engineering, V.S.B College of Engineering Technical campus, kinathukadavu, Coimbatore, Tamilnadu, India.*Abstract*—Agripass is an AI-driven farm-to-fork traceable system that aims to improve the safety and integrity of the farm to fork food supply chain. The system provides a secure digital chain for every consignment of produce right from the harvesting stage itself. The farmers are required to provide all the required information of the produce such as type of produce, soil type, pesticide use, date of harvesting, location, and images of the produce through a role-based web interface. An AI-driven module is also integrated into the system to analyze the uploaded image and provide a quality grades A, B, C to enable a quick and impartial assessment at the source level itself. After the successful completion of the registration process, the system provides a unique QR code that acts as a digital passport for the produce. As the produce passes from distributors to retailers, each handler scans the QR code and records details about how the items were transported, stored, and handed over. Because of this step-by-step update, the journey of the product stays clear. Buyers can scan the same QR code on their phones to quickly check the product's background, including its main details, movement through the supply chain, and the quality score given by AI. Going forward, Agripass may be upgraded by introducing blockchain to better protect stored records from unauthorized changes. The system could also work with IoT sensors and more refined AI techniques to keep track of product conditions in real time and improve the reliability of quality assessment.

Keywords—Farm–to-fork Traceability, AI-Based Quality Assessment, QR Code Tracking, Food Safety and Transparency, Blockchain in Agriculture, Smart Agriculture Systems.

How to cite this article: Neelamegam G, Poojaa ST, Roshni priya S, Rubitha R. Agripass - a digital passport for agricultural products using AI-based quality assessment. Int J Drug Deliv Technol. 2026;16(74s): 2057-2062. DOI: 10.25258/ijddt.16.74s.166

I. INTRODUCTION

The increasing complexity of modern agricultural supply chains has created significant challenges in ensuring food safety, transparency, and traceability. As agricultural products move through multiple stages—including cultivation, harvesting, processing, transportation, and retail—maintaining accurate and reliable records becomes essential for ensuring product quality and consumer trust [1]. Traditional traceability systems often rely on manual documentation and fragmented data storage, which can result in inefficiencies, lack of interoperability, and increased risk of data manipulation. Recent studies highlight the importance of digital traceability systems in improving visibility and coordination across agri-food supply chains [2].

With the advancement of smart technologies, agriculture is undergoing a significant digital transformation through the adoption of Internet of Things (IoT) and data-driven systems. IoT-based frameworks enable real-time monitoring of environmental conditions such as temperature, humidity, and pollution levels, which directly influence crop health and productivity. A real-time environmental monitoring system using IoT and remote sensing technologies demonstrates how large-scale environmental data can be effectively collected and utilized for improving agricultural decision-making [3]. Furthermore, the integration of artificial intelligence (AI) with IoT enhances system intelligence by enabling predictive analysis and automated decision-making, thereby improving efficiency, sustainability, and resource optimization in agriculture [4], [18].

In addition to environmental monitoring, maintaining consistent and objective quality assessment of agricultural produce is a major challenge in traditional systems. Manual inspection methods are often time-consuming, subjective, and prone to human error [5]. Recent advancements in machine learning and deep learning techniques have enabled automated quality evaluation using image processing methods [9]. AI-based analytical models have been successfully applied for agricultural product quality prediction, enabling more accurate and efficient grading systems, [17]. Similarly, image processing techniques have been used for detecting and grading fruits based on visual characteristics, improving reliability in quality assessment processes [6], [10].

Deep learning approaches, particularly convolutional neural networks (CNN), have shown significant potential in analyzing crop images for classification and grading tasks

[11]. A CNN-based approach for freshness classification of fruits and vegetables demonstrates high accuracy in identifying quality variations using visual features such as color, texture, and shape [20]. In addition, advanced machine learning frameworks integrating optimization techniques have been proposed to enhance predictive performance and improve decision-making capabilities in complex environments.Alongside AI and IoT technologies, ensuring the security and integrity of traceability data is crucial for building trust among stakeholders. Blockchain technology has emerged as a reliable solution for maintaining tamper-proof and transparent records in distributed systems. It ensures data immutability and secure data sharing across multiple entities in the supply chain. Studies have demonstrated the effectiveness of blockchain in agricultural traceability and food supply chain management systems [14], [19]. Additionally, blockchain-based systems have been successfully applied in secure applications such as electronic voting, where data integrity and transparency are critical requirements, further validating its reliability in sensitive systems [13].

Moreover, the integration of AI and blockchain technologies has shown promising potential in improving transparency, automation, and trust in agri-food systems. These integrated approaches enhance system reliability by combining intelligent data analysis with secure data storage mechanisms [15].

Despite these technological advancements, most existing solutions focus on individual components such as IoT-based monitoring, AI-driven quality assessment, or blockchain-based traceability independently. However, the lack of integration among these technologies limits the overall efficiency and scalability of agricultural traceability systems. Therefore, there is a growing need for a unified framework that combines real-time monitoring, intelligent quality evaluation, and secure data management to ensure a transparent, reliable, and efficient agricultural supply chain. The remainder of this paper is organized as follows. Section II presents the related work, discussing existing research on agricultural traceability, artificial intelligence–based quality assessment, and blockchain-enabled systems. Section III describes the proposed methodology of the Agripass framework, including system architecture, implementation details, and the algorithm used for AI-based crop quality grading. Section IV presents the results and discussion, highlighting the performance of the system through experimental evaluation and analysis. Finally, Section V concludes the paper by summarizing the key contributions and outcomes of the proposed system.

II. RELATED WORKS

Recent advancements in agricultural monitoring systems have emphasized the integration of Internet of Things (IoT) and data-driven technologies to improve environmental awareness and decision-making. A real-time environmental monitoring framework proposed by K. Manivannan et al. demonstrates how IoT and remote sensing technologies can be used to collect and process environmental data such as temperature, humidity, and pollution levels in real time, thereby improving agricultural monitoring and system responsiveness [3]. Furthermore, the integration of artificial intelligence (AI) with IoT technologies has significantly enhanced agricultural productivity and sustainability by enabling predictive analytics and intelligent automation, as discussed by K. Manivannan et al. [4].Artificial intelligence techniques, particularly deep learning models such as convolutional neural networks (CNN), have been widely applied for agricultural product quality assessment. A CNN-based approach for freshness classification of fruits and vegetables proposed by K. Manivannan et al. demonstrates the ability to accurately analyze visual features such as color, texture, and shape, enabling automated and consistent grading of produce [11]. In addition, integrative machine learning models combining optimization techniques, as presented by I. Nandhini et al., improve prediction accuracy and system performance in complex environments, highlighting the effectiveness of advanced AI-based approaches [12].

In terms of data security and transparency, blockchain technology has emerged as a reliable solution for maintaining tamper-proof records in distributed systems. The application of blockchain in secure systems such as electronic voting, as demonstrated by P. A. Mary et al., ensures data integrity and prevents unauthorized modifications, thereby making it suitable for enhancing trust in digital traceability systems [13].

Beyond these core technologies, several studies have explored digital traceability frameworks to improve visibility and coordination across agri-food supply chains. Research by S. Rossi et al. and M. Ben-Daya et al. highlights the importance of digital traceability systems in ensuring transparency and efficiency in agricultural supply chains [2]. Additionally, the integration of AI, IoT, and blockchain technologies for smart agricultural monitoring has been explored by Y. Liu et al. and M. A. Ferrag et al., demonstrating improved system intelligence and data security [9], [16].

Moreover, AI-based analytical models and image processing techniques have been extensively used for quality detection and grading of agricultural products. Studies by L. Cheng et al., W. Zhang et al., and R. Kumar et al. demonstrate the effectiveness of machine learning and image processing methods in improving the accuracy and consistency of quality assessment processes [5], [6], [10]. Similarly, AI-driven food quality assessment using computer vision techniques has been explored by J. Singh et al., further enhancing automated grading systems [17]. Deep learning-based classification approaches for fruit quality analysis have also been investigated by S. Patel et al., showing improved performance in identifying quality variations [20].

To enhance consumer interaction and accessibility, QR code-based systems have been widely adopted for providing product information. Research by Y. Qian et al. and H. Bao et al. demonstrates how QR codes can be effectively used for enabling consumers to access product traceability information such as origin, quality, and supply chain history [7], [8]. Furthermore, blockchain-enabled traceability frameworks proposed by C. Gonçalves et al. and L. Gomez et al. ensure secure and transparent data sharing across supply chain participants, thereby improving system reliability and trust [14], [19].

IoT-based monitoring combined with machine learning techniques enables continuous tracking of environmental conditions and product handling throughout the supply chain [18].

Artificial intelligence has gained significant attention in agricultural applications, particularly for crop monitoring and quality assessment. Cheng et al. presented AI-driven analytical models for predicting agricultural product quality using machine learning techniques [5].

Despite these advancements, most existing solutions focus on individual technologies such as IoT-based monitoring, AI-driven quality assessment, or blockchain-based traceability independently. However, the lack of integration among these technologies limits the overall effectiveness of agricultural traceability systems. Studies by S. A. Burburi et al. emphasize the need for integrating AI and blockchain technologies to improve transparency, automation, and trust in agricultural systems [15].

Recent studies have further improved these approaches by applying deep learning models for automated fruit quality grading and freshness detection [17], [20].

Another important direction in traceability research involves consumer-accessible systems that allow individuals to verify product origin and supply chain history. QR code technology has been widely adopted as a simple and effective mechanism for linking physical products to digital information systems.

Qian et al. proposed a QR-based traceability system that enables consumers to access detailed product information through mobile scanning applications [7]. Bao and Bao further explored the use of two-dimensional QR codes for agricultural product identification and traceability applications [8].

More recently, blockchain technology has been investigated as a solution for improving data security and preventing tampering in agricultural supply chains. Blockchain-based traceability systems allow product information to be recorded in distributed ledgers, ensuring transparency and reliability of supply chain records [16]. Similarly, blockchain-enabled frameworks have been proposed to strengthen traceability and product authenticity within agricultural supply networks [19].

Therefore, there is a need for integrated digital systems capable of capturing agricultural product information at the source, monitoring product movement across distribution stages, and providing transparent product information to consumers.

III. PROPOSED METHODOLOGY

A. Overview

Agripass is a framework designed to ensure transparent farm-to-fork traceability of agricultural products by integrating digital data collection, AI-based quality assessment, and QR code identification. Product information is captured at the harvesting stage and continuously updated as it moves through supply chain participants such as distributors and retailers. The system architecture consists of modules for farmer data registration, AI-driven quality grading, QR code generation, supply chain tracking, and consumer information access, collectively maintaining a digital record of product movement and quality as illustrated in Fig. 1. The Agripass system operates as a centralized digital platform where farmers initiate the process byregistering product details and uploading crop images through a web-based interface, after which the AI module evaluates product quality and assigns a score. A unique QR code is then generated for each product batch, acting as a digital passport that enables stakeholders to retrieve information and update logistics records, thereby creating a continuous and transparent traceability chain across the supply chain.

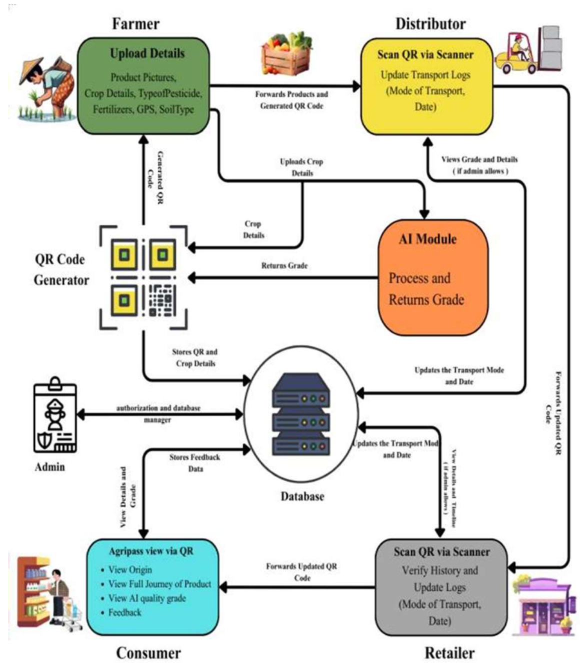


Fig. 1. Agripass AI-driven farm-to-fork traceability system.

B. Farmer Data Registration

The traceability process begins when farmers upload product information through a role-based interface. Farmers provide essential details such as crop type, soil characteristics, pesticide usage, harvest date, and geographic location of the farm. In addition to textual data, farmers also upload images of the harvested crops.

This information forms the initial digital identity of the agricultural product and is stored in the system database. Recording product data at the source ensures accurate traceability and helps maintain transparency in agricultural supply chains.

C. AI-Based Quality Grading

The uploaded crop images are processed using an AI-based image analysis module that evaluates visual characteristics of the agricultural produce. The system performs image preprocessing operations such as resizing and normalization before extracting visual features including color distribution, texture patterns, and shape characteristics.

A machine learning model analyzes these features and generates a quality score for the product. Based on the predicted score, the system classifies the crop into predefined quality grades such as Grade A, Grade B, or Grade C. The predicted quality grade is stored in the database and becomes part of the product's traceability record.

D. QR Code Generation and Product Identification

After product registration and quality grading are completed, the system generates a unique QR code for each product batch. The QR code contains encoded information that links the physical product to its corresponding digital record stored in the system database.

Farmers can download and attach the generated QR code to product packaging. As the product moves through the supply chain, stakeholders can scan the QR code to retrieve product information and update logistics data. QR-based identification provides a simple and efficient mechanism for tracking agricultural products throughout the supply chain.

E. Supply Chain Data Logging

During the distribution process, distributors and retailers update product handling information by scanning the QR code and entering logistics details such as transportation method, shipment date, and storage conditions. Each update is stored in the database as a supply chain log entry.

These logs form a chronological record of the product journey from the farm to the retail outlet. Maintaining such records helps ensure transparency, improves accountability, and allows quick identification of issues such as improper handling or transportation delays.

F. Consumer Information Retrieval

At the final stage of the Agripass system, consumers can scan the QR code using a mobile device to access detailed product information. The system retrieves data from the database and displays information such as product origin, farming details, supply chain journey, and AI-generated quality grade.

Providing consumers with access to this information increases trust in agricultural products and allows buyers to make more informed purchasing decisions.

G. System Implementation

The Agripass framework is implemented using a multi-tier architecture consisting of a web-based frontend, a backend server, and a centralized database. The backend services are developed using Spring Boot, which provides RESTful APIs for handling user authentication, product registration, and supply chain updates.

The frontend interface is developed using Angular, enabling role-based dashboards for farmers, distributors, retailers, and consumers. The system uses a MySQL database to store product records, supply chain logs, and user information. The AI-based quality grading module is implemented using a Python microservice that processes crop images and returns predicted quality grades to the backend system.

The Agripass framework incorporates an AI-based grading mechanism to evaluate agricultural product quality using image analysis. The algorithm processes crop images uploaded by farmers, extracts relevant visual features, and assigns a quality grade based on the predicted score.

H. Algorithm

Algorithm 1: AI-Based Crop Quality Grading
Input: Crop image uploaded by farmerOutput: Product quality grade (A / B/ C)

1. Receive crop image farmer upload interface.
2. Perform image preprocessing operations such as
3. resizing, normalization, and noise removal.
4. Extract visual features including color distribution, surface texture, and shape characteristics.
5. Feed extracted features into the trained machine learning model.
6. Predict the quality score of the agricultural product.
7. If quality score ≥ 85 → assign Grade A.
8. If quality score is between 70 and 84 → assign Grade B.
9. If quality score < 70 → assign Grade C.
10. Store the predicted quality grade in the system database.
11. Link the predicted grade with the product's QR code for traceability.

IV. RESULTS AND DISCUSSION

The Agripass system was implemented and evaluated to demonstrate its effectiveness in providing transparent farm-to-fork traceability for agricultural products. The system enables multiple stakeholders, including farmers, distributors, retailers, and consumers, to interact with the platform through role-based dashboards while maintaining a continuous digital record of product movement across the supply chain. The evaluation focuses on the performance of the AI-based grading module and the traceability mechanism enabled by QR codes.

A. Product Registration and QR Code Generation

The product registration module allows farmers to upload crop information and images through a web-based interface. After the successful submission of product details, the system generates a unique QR code associated with the product batch. This QR code serves as a digital identifier that links the physical product to its corresponding traceability record stored in the database.

The generated QR code enables quick retrieval of product information when scanned by supply chain participants. Distributors and retailers can scan the QR code to access the product details and update logistics information such as transportation method, delivery date, and storage conditions. This mechanism ensures that every stage of product movement is recorded in the system.

The use of QR-based identification significantly simplifies product tracking compared to traditional manual documentation systems. It provides a convenient and cost-effective solution for maintaining supply chain transparency and reducing the risk of data inconsistencies.

B. AI-Based Quality Grading Results

The AI-based grading module evaluates agricultural products using image analysis techniques that examine visual features such as color, texture, and shape. These features are extracted from the crop images uploaded by farmers during the product registration stage. The machine learning model then processes these features and generates a quality score representing the overall visual quality of the product.

Based on the generated score, the system classifies the product into predefined grading categories such as Grade A, Grade B, or Grade C. The grading results produced by the AI model for different agricultural products are illustrated.

TABLE I. AI-based quality assessment results with product grades

Product Id	Product Name	Color Quality	Size Quality	Texture Quality	AI Quality Score (%)	Grade	Status
101	Tomato	Good	Medium	Smooth	92	A	Generated
102	Mango	Excellent	Large	Smooth	95	A	Generated
103	Potato	Average	Medium	Rough	78	B	Generated
104	Apple	Good	Medium	Smooth	85	B	Generated
105	Onion	Average	Small	Rough	65	C	Generated
106	Carrot	Average	Medium	Smooth	70	C	Generated

The results indicate that the AI model effectively evaluates agricultural produce by considering multiple visual quality factors. Products with balanced color, texture, and size characteristics achieve higher quality scores and are classified under Grade A. Conversely, products with lower visual quality indicators receive lower grades.

C. Product Quality Score Distribution

To further analyze the grading results, the predicted quality scores of the evaluated products are represented using a bar chart as shown in Fig. 2. This graphical representation highlights the variation in quality levels among different agricultural products analyzed by the system.

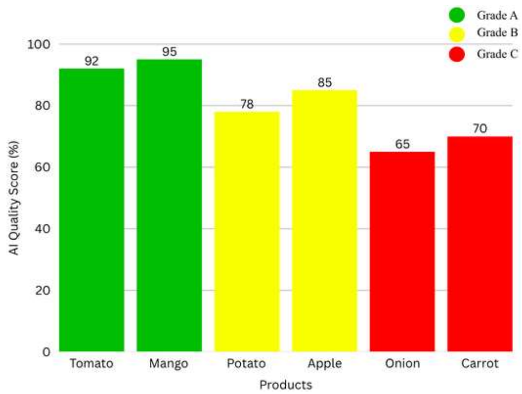


Fig. 2. AI-based quality assessment scores for agricultural products.

The bar chart clearly illustrates the distribution of quality scores across different product categories. Products with higher visual quality indicators obtain higher scores, while products with lower visual characteristics receive lower scores. The visualization helps demonstrate the ability of the AI model to distinguish between varying quality levels of agricultural produce.

Such graphical representations also help stakeholders understand the grading outcomes more easily. Farmers andsupply chain participants can use these insights to improve product handling practices and maintain better quality standards.

D. AI-Based Product Grading Summary

The final grading results and associated product characteristics are summarized in TABLE. I-, which presents the AI evaluation results along with product attributes such as color quality, size quality, and texture quality.

The grading summary provides a comprehensive view of product quality evaluation and demonstrates how AI can assist in maintaining consistent grading standards across agricultural supply chains.

Fig. 3. AI-based quality score and grade classification of agricultural products.

As shown in Fig. 3, agricultural products such as tomato and mango achieve higher quality scores and are classified under Grade A, indicating superior visual quality and freshness. Products such as potato and apple fall within the Grade B range, representing moderate quality levels suitable for standard market distribution. Crops such as onion and carrot receive relatively lower scores and are categorized as Grade C, indicating lower visual quality or possible defects. The AI-based grading system enables early identification of product quality before the produce enters the distribution stage. This helps farmers and distributors make informed decisions regarding product handling and market distribution.

E. System Transparency and Benefits

The implementation results demonstrate that Agripass improves transparency and traceability within agricultural supply chains. By integrating AI-based quality evaluation with QR-enabled product tracking, the system enables stakeholders to maintain accurate records of product handling throughout the distribution process.

The implementation results demonstrate that Agripass improves transparency and traceability within agricultural supply chains. By integrating AI-based quality evaluation with QR-enabled product tracking, the system enables stakeholders to maintain accurate records of product handling throughout the distribution process.

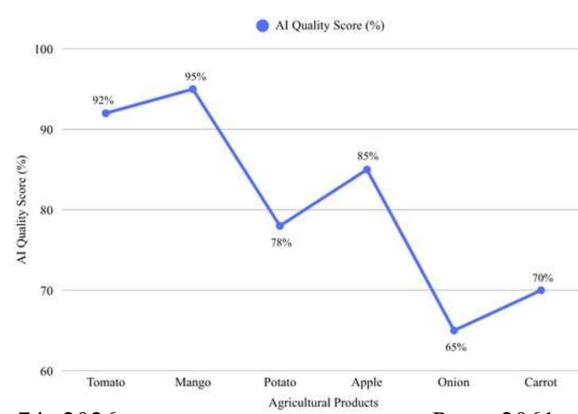
Overall, the experimental results indicate that the Agripass framework successfully combines digital traceability technologies with automated quality evaluation, providing an effective solution for improving monitoring and transparency in modern agricultural supply chains.

F. Comparative Discussion and System Impact

The results obtained from the Agripass system demonstrate the advantages of integrating artificial intelligence with digital traceability technologies in agricultural supply chains. Traditional agricultural monitoring systems often rely on manual quality inspection and paper-based record keeping, which can lead to inconsistencies and limited transparency. In contrast, the Agripass framework automates quality grading and maintains digital records of product movement, enabling more reliable monitoring of agricultural products.

The integration of AI-based quality grading allows the system to evaluate product quality objectively by analyzing visual characteristics of agricultural produce. This approach reduces human error and ensures consistent grading standards across different product batches. Additionally, the use of QR codes simplifies product identification and allows stakeholders to access traceability information quickly through mobile devices.

Another important benefit of the proposed system is improved consumer awareness. By scanning the QR code, consumers can view detailed product information including origin details, supply chain journey, and AI-generated quality grades. Such



transparency strengthens consumer trust and encourages responsible agricultural practices among producers and distributors.

Furthermore, the digital traceability mechanism implemented in Agripass enables easier identification of supply chain issues such as improper handling or delays during transportation. By maintaining chronological records of product movement, stakeholders can monitor supply chain activities more effectively and take corrective actions when necessary.

Overall, the results demonstrate that the Agripass framework provides a practical solution for improving agricultural traceability, product quality monitoring, and consumer transparency within modern food supply chains.

V. CONCLUSION

The Agripass framework presented in this paper provides an effective solution for improving transparency and traceability in agricultural supply chains by integrating digital product registration, AI-based quality grading, and QR-enabled tracking mechanisms. The system enables continuous monitoring of agricultural products from the harvesting stage to the consumer level, ensuring accurate recording of product information and supply chain activities. The AI-based grading module enhances the reliability of quality assessment by analyzing visual features such as color, texture, and shape, thereby reducing dependency on manual inspection. In addition, QR-based traceability allows stakeholders and consumers to access detailed product information, improving trust and accountability within the supply chain. The results demonstrate that the proposed system can significantly improve product monitoring and decision-making processes in modern agricultural systems. As part of future work, the system can be further enhanced by integrating blockchaintechnology to ensure tamper-proof data storage, incorporating IOT sensors for real-time environmental monitoring during transportation, and improving the AI model using larger datasets and advanced deep learning techniques to achieve more accurate and robust quality classification.

REFERENCES

[1] S. Rossi., “Agri-food traceability today: Advancing innovation towards digital food supply chains,” Trends in Food Science & Technology, 2025.

[2] M. Ben-Daya, E. Hassini, and Z. Bahroun, “Internet of Things and digital traceability in agri-food supply chains,” Computers and Electronics in Agriculture, 2024.

[3] K. Manivannan, S. K. Kumar, N. Anand, Y. Perwej, and R. Kamra, “A real-time environmental pollution monitoring framework using IoT and remote sensing technologies,” International Journal of Environmental Sciences, vol. 11, no. 7s, pp. 1064–1075, 2025.

[4] K. Manivannan., “Enhanced agricultural methods and sustainable farming through IoT and AI technology,” in Proc. IEEE ICoICI, 2024.

[5] L. Cheng, Q. Wu, and Z. Zhao, “Artificial intelligence-based analytics for agricultural product quality prediction,” Computers and Electronics in Agriculture, 2024.

[6] W. Zhang, L. Li, and X. Zhou, “Quality detection and grading of peach fruit based on image processing techniques,” Computers and Electronics in Agriculture, 2024.

[7] Y. Qian, K. Zhang, and H. Chen, “QR-code based agricultural product traceability system for consumer transparency,” Journal of Food Engineering, 2021.

[8] H. Bao and Y. Bao, “Two-dimensional QR code identification for food supply chain traceability,” International Journal of Agricultural Technology, 2022.

[9] Y. Liu, H. Zhang, and J. Wang, “Integrating AI, IoT and blockchain technologies for smart agricultural monitoring systems,” IEEE Access, 2025.

[10] R. Kumar, A. Singh, and S. Patel, “Machine learning based image analysis for fruit quality detection,” Journal of Agricultural Informatics, 2023

[11] K. Manivannan, M. Benila, S. Rithika, Y. Vinitha, and S. Yagavi, “A CNN-based approach for freshness classification of fruits and vegetables,” in Proc. IEEE Global Conf. Advancement in Technology (GCAT), 2025.

[12] I. Nandhini, V. Dankan Gowda, B. N. Purushothamma, K. S. Yogi, and V. Hariram, “Foundations of Integrative Machine Learning and Optimization for Disease Prediction,” 2025.

[13] P. A. Mary, R. Saranya, S. Dharanitha, S. Dhanya, D. Anushiya, and S. Anugeetha, “E-Voting System Enhanced by Blockchain Integration for Ensuring Electoral Integrity,” in Proc. IEEE Global Conf. Advancement in Technology (GCAT), 2025.

[14] C. Gonçalves , “Blockchain-enabled traceability in the rice supply chain,” Foods, 2025.

[15] S. A. Burburi, “Role of AI and blockchain technology in enhancing transparency in agri-food supply chains,” 2025.

[16] M. A. Ferrag, L. Maglaras, and H. Janicke, “Blockchain and artificial intelligence for secure food supply chain management,” IEEE Access, 2024.

[17] J. Singh, R. Kumar, and A. Sharma, “AI-driven food quality assessment using computer vision techniques,” Computers and Electronics in Agriculture, 2024.

[18] H. Wang, Y. Li, and X. Chen, “Smart agriculture monitoring system using IoT and machine learning,” Sensors, 2025.

[19] L. Gomez, P. Garcia, and D. Torres, “Blockchain-enabled traceability framework for agricultural supply chains,” Journal of Food Engineering, 2025.

[20] S. Patel, A. Mehta, and R. Gupta, “Deep learning based fruit quality classification for smart agriculture,” IEEE Transactions on Artificial Intelligence, 2026.