

# AI Based Fruit and Vegetable Quality Detection Using Image Analysis

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**Abstract:** Fruit production in India amounts to 44.04 million tons per year. This creates an enormous opportunity for fruit grading for quality inspection testing from farm to consumer dispatch. A fruit's size, volume, and level of hydration must all be considered while grading it. For fruit grading, spectroscopic techniques are used with a variety of sensors, mostly based on the optical properties at near-Infrared levels. For in-house examination, fruits stored in stock houses and piles require more advanced robotic manipulators. Algorithms for grading and image processing techniques use the sensor or inline camera readings as input. Neural network and fuzzy-based classifiers are just a couple of examples of these. The techniques and procedures employed are covered in this review.

**Index Terms**—IoT(Internet of Things), ESP32 C3, Methane Gas Sensor (MQ-4), Embedded System, Machine Learning (ML).

## I. INTRODUCTION

A balanced diet must include fruits because they are a great source of macro- and micronutrients like fiber, vitamins, and minerals. But fruit's freshness and shelf life—which are influenced by a number of variables like temperature, humidity, and microbe exposure—are what really determine how good the fruit is. When fruits start to decay, they not only lose their nutritional value but also serve as havens for deadly fungi and bacteria that could endanger human health. After harvest, up to but excluding the retail stage of the supply chain, about 14% of the world's food is lost, and an additional 17% is wasted at the retail and consumer levels. Food waste and loss account for 8–10% of the total. global greenhouse gas emissions, which are linked to extreme weather occurrences including droughts and flooding as well as an unpredictable climate. Global per capita food waste at the retail and consumer levels, as per SDG 12, Target 12.3 of the 2030 Agenda for Sustainable Development.

Fungi, bacteria, and other microbial organisms cause a significant amount of food spoiling during various stages of the food preservation process [2]. It is feasible to economically preserve more food items if spoilage is identified in the early post-harvest stage. Therefore, this paper's innovative strategy is to provide an IoT-based system for early decay detection and food quality inspection while reducing costs to prevent food loss, thereby guaranteeing food freshness and sufficient food preservation to fulfill future demands. With the use of cutting-edge technology including sensors, data storage, and machine learning (ML) algorithms, the suggested system offers a viable method for keeping an eye on fruit deterioration and precisely projecting its expiration date. While an IoT-based system may provide helpful insights, it should also be utilized in conjunction with suitable handling, storage conditions, and excellent agricultural practices to maintain fruit quality along the supply chain.

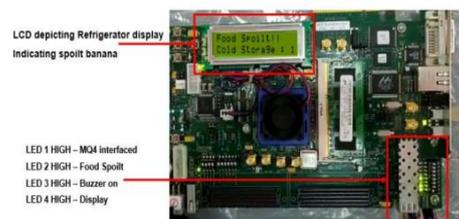


Fig. 2. Existing Model of Food Quality Detection System

When it comes to fruit decay detection, the suggested method's success rate is more than 75% accurate. This suggested method's scalability, affordability, and user-friendliness make it perfect for fruit storage and transportation, which is one of its main advantages. Conclusively, the suggested approach for detecting and forecasting fruit degradation represents a noteworthy advancement in food safety and preservation, enhancing precision and dependability. It can be expanded to include additional perishable goods, offering a complete solution for the safety and preservation of food.

## II. TECHNOLOGICAL ACHIVEMENT

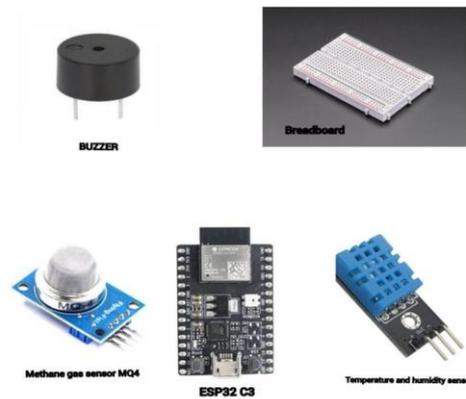
Many researchers have proposed their novel approaches for detecting food freshness using several machine learning algorithms or sensors. Li et al [3], represented and analyzed 300 'Xuxiang' kiwifruit in order to observe the lifespan including the rotting process in cold storage (2°C) using RGB recognition software. Kathirvelan et al [4], highlighted IR thermal emission based ethylene gas sensor detects ethylene accurately by absorption of IR across the fruit's wavelength. Chakraborty et al. [5], proposed a model to prevent the propagation of rottenness using CNN, on a Kaggle data set for achieving the highest accuracy rate of 99.46%. Megalngam et al. [6], used artificial intelligence along with image processing by CNN, k cluster algorithm, and HSV that can detect the spoilage percentage of food. Goel et al [7], develop an algorithm that combines three algorithms of MFA, PSO, and GSA to detect rotten food and this hybrid algorithm contains an 83.33% accuracy rate. Tian et al. [8] proposed a new technology called Hyperspectral Transmittance Image to detect early decaying process caused by Penicillium Spp. In another research paper, Hemamalini et al. [9] used image processing techniques with k-means clustering, Support Vector Machine (SVM) and Gaussian elimination method to remove noise from collected.

## III. PROPOSED SYSTEM METHODOLOGY

A rotten fruit emits gasses, Methane and Ethylene, the decay rate also depends on some parameters such as temperature, humidity. If all these values are recorded, then a prediction of how long the fruit will last by applying the decay rate formula is possible to detect. As fruit decay, it starts to emit Methane gas, the amount of emission of Methane gas is increased with the decayed percentage of the fruit, there is an initial amount of emission when the fruit starts to decay and a final constant rate of emission when the fruit is completely decayed, and the decay rate no longer increases. The decay rate of a rotten fruit is determined by the amount of methane it emits, increasing with the decayed percentage. Figure 3 represents the block diagram of the proposed system.

DHT11 sends humidity and temperature information to IoT based app, which is connected to a micro-controller ESP32 C3. The IoT based app stores the data in a database and to calculate the life expectancy applies the Machine Learning (ML) algorithm. The IoT based app then shows the raw data and lifespan. Sensors are connected to ESP32 C3 to measure temperature and humidity. To measure Methane gas

emission, MQ-4 sensor can be used to detect the amount of gas that is emitted. Also, DHT-11 sensor is used to measure the temperature and humidity. These two sensors are connected to the Raspberry Pi Pico module, also The Machine Learning (ML) algorithm. The IoT based app then shows the raw data and lifespan. Sensors are connected to ESP32 C3 to measure temperature and humidity. To measure Methane gas emission, MQ-4 sensor can be used to detect the amount of gas that is emitted. Also, DHT-11 sensor is used to measure the temperature and humidity.



## IV. SYSTEM DESIGN AND SIMULATION

The core principle of the proposed system is to introduce a cost-effective method that can detect the shelf life of fruits and vegetables both inside and outside of cold storage. By accurately identifying the ripeness of fruits and vegetables and notifying workers before they spoil, this system can help minimize food waste. In addition, by decreasing food spoilage, it can help ensure that consumers have access to fresh and healthy produce. It can help prevent consumers from eating spoiled fruits and vegetables, which might be risky for their well-being. This system is an innovative application of machine learning technology with the potential to revolutionize the supply chain, reduce waste, and focus on promoting health and sustainability.

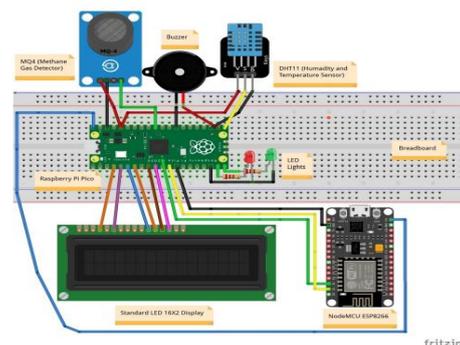


Fig. 4. Circuit Diagram of Proposed System (Fritzing)

By using Fritzing simulator, the circuit diagram of the proposed system has been created that detects lifespan of fruits inside or outside of warehouses. This project aims to detect the lifespan of fruits and get an idea of their expiry date. DHT11 sensor is attached to the ESP32 C3 to measure temperature and humidity readings, and MQ-4 gas sensor is connected to the ESP32 C3 to measure Methane gas emission.

V. HARDWARE DEVELOPMENT AND TESTING

The objective is to introduce a budget-friendly effective early food spoilage detection system to detect the lifespan of fruits and vegetables for ensuring the supply of fresh products to consumers. Table 1 displays all of the system’s components’ parameters and all components connecting to pin numbers of ESP32 C3 are enlisted in Table 2.

TABLE I  
TABLE OF SPECIFICATIONS

Serial No.	Component Used	Quantity
1	Raspberry Pi Pico (RP 2040)	1
2	MQ4 - Methane Gas Sensor	1
3	DHT11 - Temperature and Humidity Sensor	1
4	Breadboard	1
5	NodeMCU ESP8266	1
6	Power Supply (5V, 2A)	1
7	LCD 16*2 display	1
8	LED Lights	2
9	Buzzer	1
10	Connecting Wires	1

TABLE II  
PIN NUMBERS CONNECTED WITH RASPBERRY PI PICO

Name of Component	Component Pin Number	Raspberry Pi Pico Pin Number
LCD display (16*2)	RS	GP2
	E	GP3
	D4	GP4
	D5	GP5
	D6	GP6
NodeMCU ESP8266	Vin	VBUS
	GND	GND
	GPI05	GP8
LED Red	GPI04	GP9
		GP14
LED Green		GP15
DHT11 - Temperature and Humidity Sensor	VCC	3V3(OUT)
	DATA	GP16
	GND	GND
Buzzer/ Alarm	VCC	GP17
	GND	GND
MQ4 - Methane Gas Sensor	VCC	3V3(OUT)
	GND	GND
	AO	GP26

DHT-11 (Temperature and Humidity Sensor) and MQ-4 (Methane Gas Sensor) are connected to the ESP32 C3 Picoto collect data on Temperature, Humidity and Methane gas emission. DHT-11 and MQ-4 both sensors have 4 pins. These two sensors can

collect data on the fruit. The ESP32 C3 is a SoC microchip integrated with a TCP/IP protocol stack used for IoT based embedded applications development. The Vin is connected to the Raspberry Pi Pico at pin VBUS, GPIO5 and GPIO4 are connected to pin GP8 and GP9, and the GND pin is connected to the Raspberry Pi Pico at GND. The LCD 16\*2 display is used to display the condition of the fruit. The ESP32 C3 are used to connect the LED lights and buzzer. The system is run by a 5V and 2A power supply. The implemented model of the proposed system which detects the lifespan of fruit is represented in figure 5.

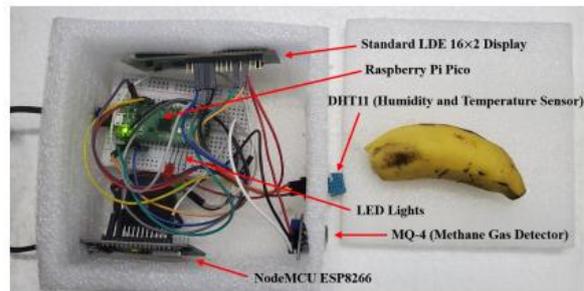


Fig. 5. Lifespan Detection of Banana using Proposed System

By utilizing a variety of sensors and connectivity methods, an IoT-based fruit quality inspection and lifespan detection system could possibly be developed in order to monitor and assess the quality and freshness of fruits. It can help ensure that consumers can access fresh and healthy produce by reducing food deterioration. It helps prevent people from consuming spoiled fruits, which could be hazardous to their health.

VI. PERFORMANCE ANALYSIS AND DISCUSSION

Machine Learning (ML) algorithms/mathematical calculations are used to predict decay % and lifetime of fruits on basis of methane gas emission, temperature, and humidity data, resulting in the hazard level and remaining lifetime. As a result, a sample of predicted decay % and predicted lifetime is obtained, and from this lifetime, the hazard level and remaining lifetime are derived.

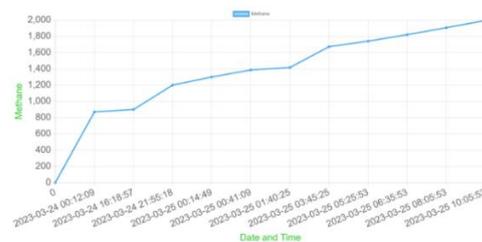


Fig. 6. MQ-4 Methane Gas Sensor based Collected Data Set Graph

Figure 6 shows the emission of Methane gas over time. As the fruit starts to decay, the emission of methane increases until it is fully decayed, and the emission becomes constant after the fruit has been fully decayed. The graph illustrates that when the fruit starts to rot, it has a threshold of Methane emission.

Table 3 represents the collected data on banana decay over time. A ripe banana can typically begin to show signs of decay within a few days when kept in a standard room temperature (20-25 degrees Celsius) with moderate humidity.

TABLE III  
COLLECTED DATA FROM EXPERIMENT (SQLITE DATABASE)

Timestamp	Temperature	Humidity	Methane Level
2023-03-24 00:12:09	24	78	870
2023-03-24 16:18:57	31	37	900
2023-03-24 21:55:18	24	70	1200
2023-03-25 00:14:49	22	75	1300
2023-03-25 00:41:09	23	74	1387
2023-03-25 01:40:25	22	71	1417
2023-03-25 03:45:25	21	71	1673
2023-03-25 05:25:53	21	71	1741
2023-03-25 06:35:53	20	72	1821
2023-03-25 08:05:53	22	73	1907
2023-03-25 10:05:53	24	75	1996

The experiment is only done with bananas. Hence, for future projection, early decay detection of various fruit items, for instance, apple, orange, strawberry and vegetables like tomato, potato, or other perishable vegetables, can also be implemented in cold storage or warehouses using the proposed system. Along with this, liquid food quality inspection and decay detection, such as in milk and fruit juices, can also be executed in the future to preserve their actual state. Based on possible future requirements, the proposed IoT-based food spoilage and expiration detection system can be employed in warehouses, supermarkets, and food item manufacturing industries. By using the MQ-4 Methane gas sensor and the DHT-11 temperature and humidity sensor, this experiment has been conducted. Other gas sensors that can be used in a fruit quality inspection system, in addition to the Methane gas ( $CH_4$ ) sensor, include Ethylene ( $C_2H_4$ ) sensor, Carbon Dioxide ( $CO_2$ ) sensor, Oxygen ( $O_2$ ) sensor, Ammonia ( $NH_3$ ) sensor, Volatile Organic Compound (VOC) sensor, Sulfur Dioxide ( $SO_2$ ) sensor etc. To identify the quality and lifespan of any fruit, it is crucial to choose gas sensors according to the individual requirements and features of the fruit under inspection. Fruits may differ in their gas emission profiles and reactions to various gases, so it is important to select sensors appropriately. The gas sensors must be calibrated and validated to ensure accurate measurements and reliable fruit quality inspections. The project has some limitations too because the Ethylene gas sensor and pH meter are

absent from this research due to unavailability. With future development, the proposed system can be extended to determine the lifetime and expiration of other perishable items. The experiment is only done with bananas. Hence, for future projection, early decay detection of various fruit items, for instance, apple, orange, strawberry and vegetables like tomato, potato, or other perishable vegetables, can also be implemented in cold storage or warehouses using the proposed system.

## VII. CONCLUSION

Food provides humans with nutrients and other essential elements that they need to grow and repair the tissues in their bodies. Additionally, a wide variety of macro and micronutrients with particular nutritious qualities are added to fruits and vegetables, which grow throughout the year in a variety of seasons. Food must therefore be preserved in cold storage or warehouses in order to be consumed, to meet future demands, and to avoid spoiling. This study focuses exclusively on food quality inspection utilizing IoT (Internet of Things) to measure temperature, humidity, and methane gas to calculate the expiration date. The process of detecting food freshness using traditional machine learning techniques is time-consuming and costly. Therefore, implementation of IoT-based food freshness detection, including expiration dates, facilitates the avoidance of unnecessary health issues caused by the consumption of contaminated food items. Furthermore, the system has a higher accuracy rate for food spoilage and expiration date detection and is more cost-effective than other traditional machine learning techniques.

## VIII. LITERATURE REVIEW

Many researchers have proposed their novel approaches for detecting food freshness using several machine learning algorithms or sensors. Li et al [3], represented and analyzed 300 'Xuxiang' kiwifruit in order to observe the lifespan including the rotting process in cold storage ( $2^\circ C$ ) using RGB recognition software. Kathirvelan et al [4], highlighted IR thermal emission based ethylene gas sensor detects ethylene accurately by absorption of IR across the fruit's wavelength. Chakraborty et al. [5], proposed a model to prevent the propagation of rotteness using CNN, on a Kaggle data set for achieving the highest accuracy rate of 99.46%. Megalngam et al. [6], used artificial intelligence along with image processing by CNN, k cluster algorithm, and HSV that can detect the spoilage percentage of food. Goel et al [7], develop an algorithm that combines three algorithms of MFA,

PSO, and GSA to detect rotten food and this hybrid algorithm contains an 83.33% accuracy rate.

Tian et al. [8] proposed a new technology called Hyperspectral Transmittance Image to detect early decaying process caused by *Penicillium Spp.* In another research paper, Hemamalini et al. [9] used image processing techniques with k-means clustering, Support Vector Machine (SVM) and Gaussian elimination method to remove noise from collected photos. Karthickeyan et al. [10] combined Object Detection Algorithm YOLO and Convolutional Neural Network (CNN) for identifying spoiled areas on food skin. Paul et al. [11] proposed a new approach that can be easily implemented in refrigerators.

Gogula et al. used MQ-4 gas sensor to monitor Methane gas in solid food and pH sensor to monitor liquid food whereas Sahu et al. used ESP32 C3, Gas Sensors (MQ-2, MQ-3 and MQ-9) along with humidity & temperature sensor and Machine Learning (ML) algorithms to detect alcohol, hydrogen, benzene, and LPG [21], [22]. Moreover, Abasi et al. developed a portable optical device to determine apple ripeness [23].

#### IX. RESULTING CONFIGURATION AND OUTCOME

After harvest, up to but excluding the retail stage of the supply chain, about 14% of the world's food is lost, and an additional 17% is wasted at the retail and consumer levels. 8–10% of global greenhouse gas emissions are attributable to food loss and waste, which also contributes to an unstable climate and extreme weather events like droughts and flooding. The 2030 Agenda for Sustainable Development mandates that global per capita food waste at the retail and consumer levels, as well as food losses throughout the production and supply chains, be cut in half [1]. This is especially true for SDG 12, Target 12.3. As seen in figure 1, fungi, bacteria, and other microbiological agents cause significant amounts of food spoiling in different stages of the food preservation process [2]. It is feasible to economically preserve more food items if spoilage is identified in the early post-harvest stage. Therefore, this paper's innovative strategy is to provide an IoT-based system for early decay detection and food quality inspection while reducing costs to prevent food loss, thereby guaranteeing food freshness and sufficient food preservation to fulfill future demands. With the use of cutting-edge technology including sensors, data storage, and machine learning (ML) algorithms, the suggested system offers a viable method for keeping

an eye on fruit deterioration and precisely projecting its expiration date. While an IoT-based system may provide helpful insights, it should also be utilized in conjunction with suitable handling, storage conditions, and excellent agricultural practices to maintain fruit quality along the supply chain. This study offers a thorough review of the current methods for identifying fruit deterioration and estimating shelf life. Figure 2 displays FPGA-based food rotting detection system presented by R. Paul et al. [12]

2 demonstrates FPGA-based food spoilage detection system proposed by R. Paul et al. [12].

#### X. APPLICATIONS

Although fruits are a vital source of nutrients, their freshness and shelf life—both of which are influenced by a variety of outside variables—have a significant impact on their quality. This paper offers a thorough analysis of fruit deterioration and the creation of a lifespan detection system that combines a MQ-4 methane gas detector sensor to estimate methane gas emissions from spoiled fruits, a ESP32 C3, and a DHT-11 sensor to measure the temperature and humidity of fruits in real time. Then, to precisely forecast the expiration date of fruits, machine learning (ML) techniques and data storage are employed. The suggested method employs a ESP32 C3 to measure a few key components that basically determine the fruit's state of spoiling. The measurements are then relayed to a local database. The fruit's expiration date is then predicted using the gathered data and a recommended equation that has a high degree of accuracy and dependability. This research presents a graphical depiction of real-time data with an estimated fruit lifespan by gathering the essential data regarding the temperature, humidity, and methane emission of fruit. The technology is practical, affordable, and helpful in the cold storage, warehousing, and food quality inspection industries. The suggested method can be expanded to identify the expiration date and lifespan of additional perishable goods with additional study and development, offering a complete solution for food safety and preservation.

#### XI. CHALLENGES AND FUTURE DIRECTIONS

Based on temperature, humidity, and methane gas emission data, machine learning (ML) algorithms and mathematical computations are utilized to anticipate the fruit's lifetime and decay percentage, which determines the level of hazard and remaining life. Consequently, a sample of the anticipated lifespan and

decay percentage is collected, and the hazard level and remaining lifetime are deduced from this lifetime.

Food must therefore be preserved in cold storage or warehouses in order to be consumed, to meet future demands, and to avoid spoiling. This study focuses exclusively on food quality inspection utilizing IoT (Internet of Things) to measure temperature, humidity, and methane gas to calculate the expiration date. The process of detecting food freshness using traditional machine learning techniques is time-consuming and costly. Consequently, the usage of IoT-based food freshness monitoring, which takes expiration dates into account, helps prevent avoidable health problems that arise from eating tainted food. In addition, the system is more affordable than other conventional machine learning methods and has a greater accuracy rate for detecting food rotting and expiration dates.

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