IOT BASED ON FOOD QUALITY DETECTION AND MONITORING

Dilshan W.G.K – IT20301590

Premadasa P.K.R.B -IT20643690

Chandrasekara B.T.M – IT20302030

P.G.J.C Dayawansha – IT20640798

B.Sc. (Hons) Degree in Information Technology Specialized in Software Engineering

Department of Computer Science and Software Engineering

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Dissertation submitted in partial fulfillment of the requirements for the Special Honours Degree of Bachelor of Science in Information Technology Specializing in Software Engineering

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DECLARATION

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Premadasa P.K.R.B	IT20643690	
Dilshan W.G.K	IT20301590	
Chandrasekara B.T.M	IT20302030	
P.G.J.C Dayawansha	IT20640798	Chathusha.

The above candidate has carried out research for the bachelor’s degree Dissertation under my supervision.

Signature of the Supervisor   Date

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ABSTRACT

This study introduces four innovative technological solutions aimed at enhancing food safety and quality assessment throughout the food supply chain. Firstly, a deep learning-based system is proposed for distinguishing between naturally and chemically ripened bananas, utilizing the Xception model architecture to analyze visual cues. Secondly, an IoT-based milk quality detection system integrates multiple sensors to monitor and evaluate milk quality characteristics in real-time, addressing concerns regarding milk safety and integrity in the dairy industry. Thirdly, a machine vision system employs advanced deep learning architectures to automate vegetable quality and freshness assessment, offering a non-destructive and cost-effective alternative to traditional grading methods. Lastly, an IoT-based food quality checker and monitoring system is presented, incorporating various sensors to assess fruit quality by analyzing gases, temperature, and humidity, with predictive modeling capabilities to forecast fruit shelf life. These technological advancements contribute to improved food quality assurance, consumer confidence, and reduced food waste along the entire supply chain.

Keywords: Deep learning techniques, Xception model architecture, Artificially ripened bananas, Android application, Image Processing, Mask R-CNN, IoT, milk quality detection, sensors, machine vision, vegetable grading, food quality monitoring, predictive modeling.

ACKNOWLEDGEMENT

Our sincere appreciation goes out to Hansika Mahadikara, our project supervisor, whose direction and results have been greatly influenced by her leadership, assistance, and priceless insights. Throughout this project, her unrelenting commitment to excellence and her dedication to our progress have been a continual source of inspiration.We would especially want to thank our co-supervisor, Dr. Pradeep Abeyagunawardhana, for his knowledge, inspiration, and unwavering assistance. Our work has been made much better and more thorough by Dr. Pradeep's scholarly advice and perceptive criticism. We also want to sincerely thank our external supervisor, Mr. Jaliya Wijayaraja, for all of his help and support during the project. The domain experience of Mr. Jaliya has furnished us with distinct viewpoints and pragmatic discernments that have augmented the significance and feasibility of our discoveries. We especially thank the farmer who cultivates fruits, whose firsthand knowledge and experiences have been important to our research. Their readiness to impart their knowledge and wisdom has deepened our comprehension and made our efforts much more successful. We owe our parents and family so much for their constant love, support, and sacrifices. Our academic endeavors have been founded upon their unwavering conviction in our skills and support, for which we are incredibly appreciative of their continuous presence in our lives. We also want to express our gratitude to our friends for their unwavering support, understanding, and motivation during this journey. Their unfailing friendship and support have given us courage and inspiration by serving as a constant reminder that we are never doing this alone. Not to mention, we are grateful for our team members' commitment and teamwork, which have been crucial in accomplishing the project's objectives. Our success has been greatly attributed to their diligence, inventiveness, and dedication to quality work, and we are appreciative of the chance to collaborate with such gifted people. Without the help and encouragement from each of these people and organizations, this initiative would not have been feasible, and for that we are sincerely appreciative. We are incredibly grateful for their part in our accomplishment, as their efforts have had a significant influence on our path.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
SGD	Stochastic Gradient Descent
CNN	Convolutional Neural Network
UAT	User Accepting Testing
ReLU	Rectified Linear Unit
ResNet	Deep Residual Learning for Image Recognition
IOT	Internet of Things
CaC2	Calcium Carbide
TTA	Total Titratable Acidity
AI	Artificial Intelligence
RPN	Region Proposal Network
FCN	Fully Convoluted Neural Network
TSS	Total Soluble Solids
MQ3	Alcohol Sensor Module
MQ4	Methane Gas Sensor Module
DH11	Humidity & Temperature Sensor
ESP32	ESP32 Wi-Fi & Bluetooth Soc
IOT	Internet of Things
FCN	Fully Convoluted Neural Network
TSS	Total Soluble Solids
IOT	Internet of Things

PH	Potential of Hydrogen
ADC	Analog to Digital Converter
LED	Light Emitting Diode
IDE	Integrated Development Environment
MCU	Micro Controller Unit

1. INTRODUCTION

1.1 General Introduction

At a time of rapid technology development and growing customer demand for wholesome, safe food, the agriculture and food sector has formidable obstacles in preserving quality along the supply chain. The inaccuracies, delays, and incomplete assessments that are sometimes provided by traditional approaches of food quality assessment allow for inefficiencies and health hazards. But as new technology like deep learning and the Internet of Things (IoT) become available, creative answers to these problems are starting to surface that will completely change the way food quality management is done.

One of the mainstays of economies everywhere, agriculture is essential to supplying the rising demand for fresh vegetables. However, because of financial limitations and a lack of experience, small-scale farmers and agricultural companies frequently find it difficult to embrace cutting-edge technologies. This difference emphasizes the need of user-friendly and reasonably priced solutions catered to their particular needs.

Automation of the grading and sorting processes in the fresh fruit supply chain is one area where technological innovation has shown enormous promise. Requiring skilled personnel to visually evaluate materials, manual grading methods are labor- and time-intensive. Researchers have created automated grading systems that, with remarkable accuracy, classify fruits according to their exterior characteristics and freshness by using computer vision and machine learning algorithms.

In the dairy sector, too, maintaining milk quality is critical to both public health and the profitability of dairy-based enterprises. Slightly deteriorating milk is sometimes difficult to identify by traditional methods of milk quality testing, which puts consumers at risk and costs stakeholders money. By giving procurement centres real-time monitoring and assessment tools that can spot indicators of degradation, researchers want to improve milk quality assurance through the use of Internet of Things technology.

Moreover, the need of customers for wholesome and safe food has spurred the creation of Internet of Things-based food quality monitoring systems. These systems give stakeholders along the supply chain real-time input by integrating a variety of sensors to evaluate the quality and freshness of fruits. Using the potential of Internet of Things devices, researchers hope to lower waste, boost consumer confidence, and eventually enhance public health results.

Apart from attending to issues of quality, technological advancements are also being used to address particular issues in the food sector, such the application of chemical ripening agents in bananas. Models able to differentiate between naturally and chemically ripened bananas are being developed using deep learning techniques, giving customers a tool to make educated purchases and reduce health hazards.

In this work, the integration of sensor technologies, deep learning methods, and the Internet of Things is thoroughly reviewed in relation to recent developments in food quality monitoring. By means of an analysis of current research initiatives and approaches, as well as the creation and assessment of new solutions, this work aims to improve food quality, safety, and customer happiness.

1.2 Background Literature

1.2.1 Detection of Artificially Ripened Banana Using Deep Learning Techniques

Roughly 120 countries cultivate bananas. The estimated global fruit production for a given year is 86 million tons. With an estimated yearly production of 14.2 million tons, India is the world leader in the production of bananas. (Wikipedia, n.d.). Artificial ripening of bananas occurs for the following reasons:

- Distance travel
- Extended availability

Because calcium carbide leaves behind hazardous levels of phosphorous and poisonous arsenic on fruits, it is essential to identify bananas that have ripened owing to this chemical. Poisoning with arsenic or phosphorous can cause vomiting, diarrhea, burning in the chest and abdomen, weakness, skin irritation, skin ulcers, sore throats, coughing, and dyspnea. When pregnant, it should be absolutely avoided.

Bananas are a fruit that is commonly seen in diets all around the world due to their affordability, nutritional content, and wide availability. Their convenient and adaptable nature add to their enjoyment in addition to their exquisite taste. In a Google Form survey, 99% of participants said they routinely ate bananas as part of their diet. This statistic was astounding. The prevalence with which bananas are consumed highlights their significance as a staple food and their popularity.

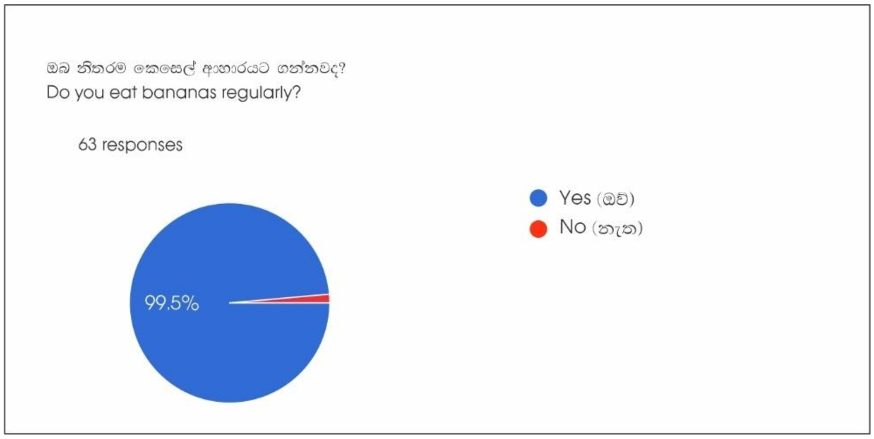

Figure 1:Survay report that eat banana regularly

The poll results revealed not only how frequently people consume bananas but also how aware they are of the usage of chemicals in their manufacture. There is a notable degree of consumer understanding about this element of banana farming, as seen by the remarkable 75% of respondents who said they were aware that chemicals are sprayed on bananas during cultivation. There is a noticeable knowledge gap among a significant section of the population, as indicated by the survey's additional finding that 35% of respondents were ignorant about this technique.

With regard to the use of chemicals in food production in particular, this awareness gap highlights how crucial it is for the agricultural industry to be transparent and educate its workforce. A sizable portion of the populace still seems to be in need of additional information and education on this subject, even if many customers seem to have a basic awareness of the agricultural techniques involved in banana farming.

Initiatives like labeling laws, public education campaigns, or more producer transparency about farming methods are a few examples of how to raise consumer knowledge. When customers are more informed about the production process of the food they buy and eat, they are able to make more intelligent decisions. In the end, improved understanding might benefit the environment and customers by increasing demand for more ecologically friendly and sustainable agricultural methods in the banana business.

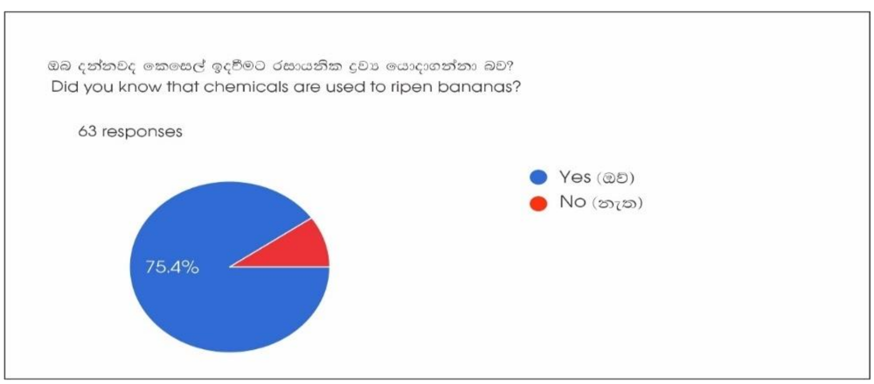

Figure 2:Survay report for that chemicals are used to ripen bananas

Interestingly, the survey found a substantial knowledge gap on the possible health dangers connected to the practice of spraying chemicals on bananas during cultivation, even though the practice is widely known. Unbelievably, 95% of respondents said they were ignorant of the negative consequences these chemicals could have on their health, including the possibility of getting cancer.

This ignorance highlights a crucial problem with regard to consumer education regarding food safety and the possible health risks related to farming techniques. The fact that such a large portion of respondents are ignorant of the possible dangers they can encounter from eating produce that has undergone chemical treatment, such as bananas, is troubling.

Ensuring consumer safety and well-being requires addressing this knowledge gap. To effectively spread correct information regarding the possible health dangers linked with chemical use in banana growing, public awareness campaigns, education efforts, and open communication from regulatory agencies and agricultural producers are crucial. Educating customers on the possible health risks associated with chemically treated bananas will help them make more educated dietary decisions and promote safer farming methods.

This information also emphasizes how crucial strict laws and supervision are in the agriculture industry to protect consumer health. The possible dangers associated with chemical exposure during food production can be lessened by regulatory bodies maintaining stringent regulations on the use of pesticides and guaranteeing openness in food labeling. In the end, ensuring consumer safety and wellbeing throughout the food supply chain requires fostering transparency and increasing knowledge.

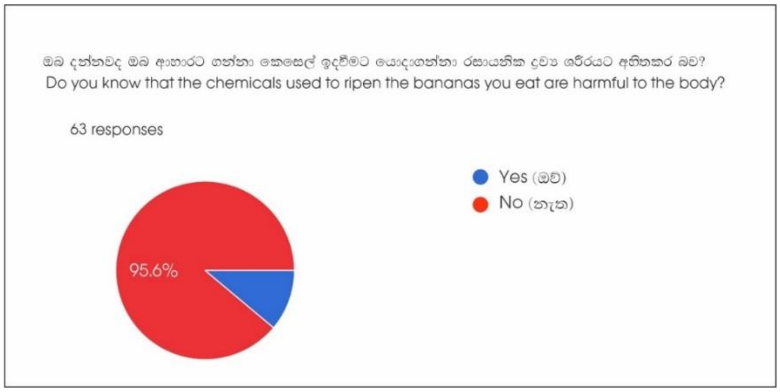

Figure 3:Survay report for that chemical used to ripen the banana you eat are harmful

Our study in image processing technology has resulted in the creation of a strong model architecture designed specifically to accurately classify bananas depending on their chemical condition. Using advanced deep learning techniques, we have carefully designed a model architecture that can accurately classify banana pictures by detecting even the smallest details and differences.

Our model architecture heavily relies on the incorporation of the Xception model, which is a cutting-edge convolutional neural network (CNN) that excels at dealing with intricate image categorization problems. The Xception model, which has been trained on the extensive ImageNet dataset, serves as the fundamental basis for our categorization goals.

Expanding on the Xception model, we have deliberately integrated supplementary layers, which include densely coupled layers that utilize rectified linear unit (ReLU) activation functions. The additional layers have been carefully crafted to optimize the pre-trained model for our particular task, allowing it to accurately detect and understand complex patterns and characteristics that indicate different chemical states in bananas.

Our algorithm has undergone rigorous training and optimization, resulting in its extraordinary ability to accurately forecast the chemical status of bananas using input photographs. Our model effectively utilizes the hierarchical representations learnt by the convolutional layers and the high-level abstractions recorded by the dense layers to accurately identify minor visual cues that distinguish bananas in various chemical states.

Our model architecture is a huge development in image processing technology. It appropriately categorizes bananas based on their chemical condition. Our model demonstrates strong performance and a detailed comprehension of the unique characteristics of bananas. This makes it highly promising for use in agriculture, food quality evaluation, and other related fields.

1.2.1.1 Manual method to classify natural and artificially ripened bananas

- **Appearance:** Bananas that have naturally matured have a brown or black stalk. Its skin is a dark yellow color with sporadically distributed black and brown markings. Bananas that have been artificially ripened, however, have skin that is lemon yellow and flawless. They have a green stalk as well.
- **Touch and feel:** Certain sections of artificially ripened bananas will be extremely soft, while other parts will be firm. This is due to the fact that certain components may or may not come into touch with chemicals. (Wikipedia, n.d.)
- **Aroma and taste:** ones that are naturally ripened tend to smell and taste better than ones that are artificially ripened. However, as this is a relative metric, it cannot be used as a benchmark to identify fruits that have been artificially ripened.

These methods of detection are not always practical since they require skilled visual inspection; the average person will not be aware of these qualities. (Mithun B.S et al., 2018)

1.2.1.2 Chemical tests to classify natural and artificially ripened bananas

Gas chromatography can be used to identify acetylene rather than ethylene in artificially ripened bananas; however, this method is equally impractical because it needs expensive equipment and can only be carried out once the bananas are fully ripened. (Wikipedia, n.d.) When comparing naturally ripened samples to artificially ripened ones, the TTA (total titratable acidity) value is much lower in the naturally ripened samples, suggesting that the former could be used as a marker to distinguish artificially ripened bananas. (Islam et al., 2018). We tested samples of bananas from day 0 to day 4 of ripening and discovered that the total soluble solids (TSS), measured in the lab using a refractometer, is marginally higher for artificially ripened bananas than for naturally ripened bananas at the same stage. Furthermore, bananas that had naturally matured showed a higher firmness reading on a firmness tester. These were unmistakable signs that artificial ripening facilitates the ripening process, as evidenced by the significantly higher values achieved for artificially ripened fruits during the early stages of ripening. Additionally, it was noted that banana samples ripened with calcium carbide reached full ripeness after day four, losing the characteristics that render the fruit edible. On the other hand, bananas that had matured naturally were still firm and fit for consumption. While these techniques aid in the identification of artificially ripened fruits, they are not always feasible to implement in real time, necessitating the development of reliable and non-intrusive techniques.

1.2.1.3 The impact of artificial ripening techniques on the banana consumers

Fruits are essential to human nutrition because they add vitamins and minerals to the diet, add diversity to meals, and enhance food's flavor. In addition, they contained cellulose, protein, sugar, minerals, vitamins, fiber, and a variety of photochemicals that shield the body from a range of illnesses(Dhembare,2013).After harvest, fruits are extremely perishable. specifically in tropical conditions (Adesida et al., 2011).

According to Adekalu et al. (2011) and Vaidya et al. (2016), bananas are climacteric fruits that are part of the Musaceae family. They are typically consumed as a meal or as a supplement. Grown in over 100 countries across a harvested area of over 10 million hectares, with an annual yield of 88 million, it is the fourth most significant food commodity in the world (after rice, wheat, and maize).

Nura along with others. (Impacts on acceptability and nutritional quality of artificially ripened bananas (Musa spp.) using calcium carbide) 2018 Jun; 06(2): 14–20 tons (UNCST and PBS, 2007). J. Postharvest Technol. A banana is high in iron, potassium, magnesium, selenium, phosphorus, and carbs. It is also high in vitamins A and C. A salt-free diet is also advised by the low sodium chloride content of bananas (Adekalu et al. 2011; Kumar et al., 2012; Abdul-Rahaman et al., 2015).

A fruit's natural physiological process of ripening results in its increased sweetness, palatability, edibleness, nutritional value, softer texture, and aesthetic appeal (Gupta, 2017; Siddiqui and Dhua, 2010). It is linked to color changes because of the pigments that are created or added throughout the ripening process (Gupta, 2017). Fruits ripen to acquire the desired texture, color, flavor, and other attributes (Bhattarai and Shrestha, 2005).

After achieving certain physical and physiological milestones that are irreversible and eventually cause the fruits to senesce, fruits naturally ripen. Fruits can ripen on the vine or after harvest, but the overall changes brought about by the process are immediately identifiable. Fruits ripen, soften, change color, and acquire a distinct flavor and scent. Because there is less acidity and more sugar, there is also less sourness and more sweetness (Siddiqui and Dhua, 2010).

The goal of artificial ripening is uniform and rapid ripening. This method allows for the management of ripening, allowing for the production of goods that meet specific requirements by adjusting various characteristics (Bhattarai and Shrestha, 2005). Fruits that have been artificially ripened may have a consistent, appealing exterior color, but the internal tissue stays green, and the fruit's shelf life is typically shorter (Hossain et al., 2015).

Artificial ripening quickens the process, but also compromises the fruits' safety, sensory appeal, and nutritional value (Hossain et al., 2015). According to Dhembare (2013), artificial ripeness have a number of negative consequences on people, such as memory loss, cerebral edema, lung and prostate cancer, quick-buck syndrome, alterations in DNA and RNA, and hematological changes. Artificially ripened fruits are too soft and have a weaker flavor. Washing fruits before eating and avoiding eating the fruit's skin are two precautionary procedures that have been noted to prevent the chemicals' hazardous effects (Fattah and Ali, 2010).

Calcium carbide, or CaC2, is the most often used artificial ripening agent, presumably due to its low cost and easy availability. Other chemicals that are frequently employed to promote ripening include ethylene gas, ethephon, ethylene glycol, ethereal, and calcium carbide (Hossain et al., 2015). On an industrial scale, it is generated to make acetylene, which is utilized for a variety of uses. The most widely accessible grade, which is 80–85% calcium carbide, is brown or grey in color. When there is moisture present, it smells like garlic. It undergoes a chemical reaction when sprayed with water, producing acetylene (Gupta, 2017).

$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$

Acetylene functions similarly to ethylene, causing fruits and vegetables to mature by a comparable process. Phosphorus and arsenic contaminants, which can cause a variety of health issues, are typically present in industrial-grade calcium carbide. Its use is prohibited in the majority of countries for this reason. However, due to its accessibility and low cost, it is still in use in many regions of the world (Gupta, 2017).

Acetylene is thought to impact the neurological system by lowering the brain's oxygen delivery (Dhembare, 2015). Acute symptoms include headache, vertigo, lightheadedness, delirium, seizures, and even coma. Over time, it could result in memory loss and mood disorders (Fattah and Ali, 2010).

1.2.2 Milk Quality Detection Using IoT

In the field of food safety and quality assurance, especially within the dairy industry, the assurance of milk purity and freshness stands as a critical concern. Milk, being a basic food product consumed internationally, holds substantial nutritional value and serves as a key source of revenue for several communities, especially in regions like India. Nevertheless, the potential presence of pollutants, spoilage, and adulterants poses substantial health hazards to consumers and economic hurdles to dairy producers. Consequently, there exists an urgent need for effective and trustworthy approaches to assess milk quality.

One area of research, focused on utilizing IoT technology and sensor integration, proposes a novel technique to monitor numerous factors crucial to milk quality, including bacterial activity, pH value, viscosity, and temperature [1]. By embedding different sensors into an IoT model, this research strives to verify milk quality, providing encouraging results revealing a 90% accuracy rate.

Similarly, another study considers the application of visible spectroscopy as a cost-effective way to check pasteurized milk, intending to detect spoiling and confirm freshness [2]. By evaluating spectral data obtained by a 6-channel visible sensor, this research studies variations in milk quality over time, specifically focusing on the sourness coming from the fermentation process, identifiable by spectral analysis.

Another research attempt explores into the dynamics of milk pH and its link with dilution procedures utilizing various pH levels of water at different temperatures [3]. Through experiments measuring pH variations in milk samples subjected to different dilution levels, this study aims to identify potential adulteration or contamination based on pH and density measurements, showcasing superior performance in cost-effectiveness and accuracy compared to existing analysis processes.

Furthermore, a microcontroller-based device for detecting and grading milk parameters, such as amount, pH, CLR, and SNF, offers a low-cost option for comprehensive milk quality assessment [4]. This technology provides automatic calculation of milk quality and cost, alongside database integration for simple access via a mobile application.

In addition, the advent of a wireless passive sensor for remote in vivo milk pH measurement presents a non-invasive method for real-time monitoring of milk quality [5]. Through the employment of a planar spiral inductor linked to a pH combination electrode, this sensor offers reliable pH measurement with high sensitivity and precision, making it suited for continuous monitoring of milk pH during deterioration.

These research activities collectively contribute to enhancing milk quality evaluation methodologies, giving innovative solutions that employ IoT technology, spectroscopic analysis, sensor integration, and wireless monitoring to ensure the safety, purity, and freshness of milk. By addressing many dimensions of milk quality assessment, these studies pave the path for improved procedures within the dairy sector and enhanced customer confidence in milk products.

1.2.3 Smart IoT Solutions for Reducing Fruit Wastage and Enhancing Quality Along the Supply Chain

This research explores the crucial area of food quality control in the global food industry, with a specific emphasis on the difficulties in preserving the freshness, safety, and nutritional value of perishable goods fruits in particular along the supply chain. It offers a cutting-edge, Internet of Things-based food quality checker and monitoring system designed to get over the drawbacks of traditional ways of evaluating quality.

Fundamentally, the system makes use of cutting-edge sensor technologies that are smoothly integrated with the ESP32 microcontroller. These sensor technologies include soil moisture sensors, ambient sensors (DHT11), and gas sensors (MQ3 and MQ4). The system uses these sensors to monitor a number of characteristics in real time, including soil moisture levels, ambient conditions, and gas emissions from fruits. Fruit quality may be continuously assessed from harvest to consumption according to this all-encompassing technique.

Improving food safety regulations and food quality management techniques is the main goal of the project. Using state-of-the-art technology, the system aims to reduce food waste, reduce the danger of contamination and spoiling, and increase consumer confidence by providing in-depth information about fruit quality and careful monitoring. In the end, the study hopes to stimulate constructive changes in the food sector that will lead to better public health and sustainability programs.

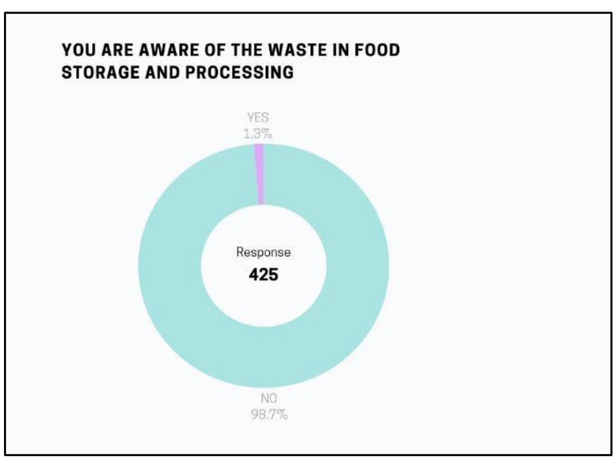

Figure 4:Survey report that waste the food

MQ3- Alcohol Sensor Module

Figure 5:Mq3 Alcohol Sensor Module

A popular module for determining the amount of alcohol vapor in the air is the MQ-3 gas sensor. It works on the basis of a semiconductor gas sensor, whose resistance varies when it comes into contact with alcohol vapor. Alcohol levels can be detected and measured because of this change in resistance, which is proportionate to the amount of alcohol in the air.

Usually, the sensor module is a tiny board containing control circuitry, a heater coil, and a gas detection device on it. The semiconductor material used to make the sensor element is tin dioxide (SnO2), and it changes electrical conductivity when exposed to various gasses. To ensure optimal functioning, the heater coil is utilized to heat the sensor element to a certain temperature.

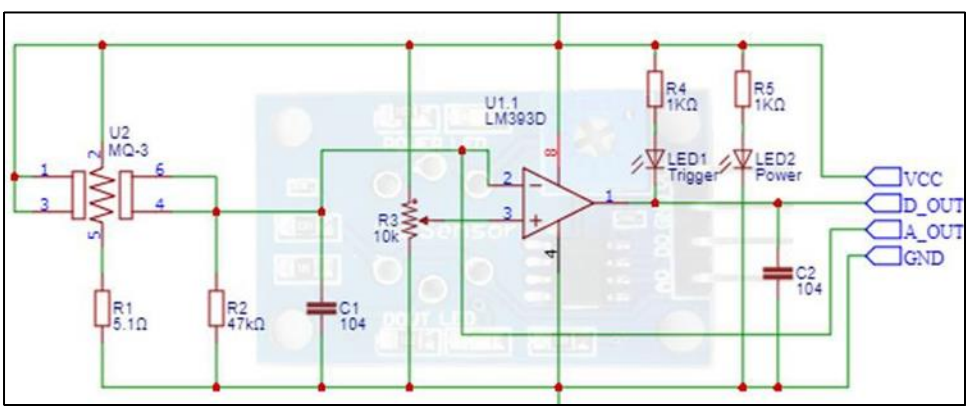

Figure 6:Alcohol Sensor Circuit

Straightforward circuit is needed to interface the MQ-3 gas sensor with a microcontroller or other electronic devices. Normally, the circuit has connections for ground, power, and the analog output pin of the sensor. In order to safeguard the microcontroller and steady the output signal, a load resistor is also incorporated.

The VCC pin of the sensor is shown in the circuit schematic as being linked to a power supply voltage, typically 5 volts. This gives the sensor the power it needs to function. The microcontroller may read the output voltage of the sensor by connecting its analog output pin (A0) to its analog input pin.

The analog output pin (A0) of the sensor is linked to ground (GND) by a load resistor, usually of value approximately 10kΩ. This resistor guards against overcurrent damage to the microcontroller and aids in stabilizing the output signal.

The MQ-3 gas sensor needs some preheating time once the circuit is put together and powered on before it can give precise readings. The heater coil raises the temperature of the sensor element to its working level during this period. Given that ambient influences can have an impact on sensor performance, calibration can also be required to guarantee an accurate measurement of alcohol content.

The MQ-3 gas sensor can measure the amount of alcohol vapor in the air once it has been preheated and calibrated. It then outputs an analog voltage that is proportionate to the amount of vapor measured. After then, the microcontroller can use its analog-to-digital converter (ADC) to read this output voltage and, depending on the alcohol levels it has detected, take the necessary action.

In general, the MQ-3 gas sensor and its supporting electronics offer a straightforward yet reliable way to measure the amount of alcohol vapor in a variety of settings, such as industrial settings, automobile safety systems, and breathalyzers. It is a well-liked option for alcohol detection applications due to its dependability and simplicity of usage.

MQ4 – Methane Natural Gas Sensor

Figure 7:Mq4 Methane Natural Gas Sensor

The MQ-4 gas sensor, which is intended to detect natural gas and methane (CH_4) with exceptional accuracy and dependability, is a significant technological improvement in gas detection. Its importance stems from its sensitivity as well as its adaptability to a wide range of applications and simplicity of integration.

The MQ-4 sensor is primarily composed of an advanced chemoreceptor mechanism. This mechanism is based on the idea that some materials, such tin dioxide (SnO_2), alter conductivity when they meet gases. Tin dioxide, a semiconductor, functions as the sensing element in the MQ-4. Methane molecules stimulate chemical reactions that change the tin dioxide's conductivity when they meet its surface. An electrical signal is subsequently produced from this change in conductivity, giving a trustworthy indicator of the gas concentration In the Immediate vicinity.

The remarkable sensitivity of the MQ-4 sensor to methane and natural gas is one of its most remarkable characteristics. Because of its sensitivity, which enables the detection of even the smallest amounts of these gases, it is a vital instrument for environmental monitoring, safety monitoring, and gas leak detection systems. Furthermore, the sensor's quick reaction time and strong stability provide prompt and precise detection, which is essential for guaranteeing the security of both Industrial and Residential settings.

According to its specs, the MQ-4 sensor usually uses less than 150mA of current and operates at a voltage of 5V DC. To minimize energy consumption and ensure optimal performance, the heating power is kept below 750mW. Furthermore, an inbuilt potentiometer can be used to adjust the sensitivity of the sensor, enabling calibration to certain gas concentrations or ambient factors. Suitable for a wide range of monitoring needs, the MQ-4 sensor has a wide dynamic range with a detection range of 300 to 10,000 parts per million (ppm)of methane.

Its analog output makes it simple to interface the MQ-4 sensor with microcontrollers like the Arduino, ESP32, or Node MCU. Users can create custom monitoring and control algorithms by accessing real-time gas concentration data by connecting the sensor's output to an analog input pin on the microcontroller. The MQ-4 sensor offers the adaptability and dependability required for a variety of use cases, whether it is integrated into an industrial safety system or an Internet of Things (IoT) device for smart home applications.

It's important to remember that even if the MQ-4 sensor performs incredibly well, accurate and dependable operation depends on environmental factors and proper calibration. In order to avoid false alarms or missed detections, calibration makes sure that the sensor's reaction appropriately represents the real gas concentration in the environment. Furthermore, the performance of the sensor might be affected by variables like temperature, humidity, and cross-sensitivity to other gases; these should be carefully taken into consideration during installation and operation.

To sum up, the MQ-4 gas sensor, with its unmatched sensitivity, dependability, and versatility, is a monument to the developments in gas detection technology. The MQ-4 sensor is a reliable gas detection system that gives customers the ability to efficiently monitor and reduce possible threats, whether they are protecting homes from gas leaks or improving industrial safety measures.

Explanation using MQ4 Sensor

An essential feature of gas detection systems, the MQ-4 sensor is well-known for its sensitivity to natural gas and methane. Its operation is predicated on the chemiresistor principle, which states that when exposed to gases, the semiconductor material, usually tin dioxide (SnO_2), changes in conductivity.

Methane molecules cause chemical processes that change the conductivity of the tin dioxide semiconductor when they meet its surface. An electrical signal is subsequently created from this change in conductivity, giving a quantifiable indicator of the gas concentration in the immediate surroundings.

The voltage and current limits that the sensor works within are normally 5 V DC and less than 150 mA, respectively. It also has a heating element, which ensures constant performance and economical operation with a power consumption of less than 750mW.

The exceptional sensitivity of the MQ-4 sensor to methane and natural gas allows it to detect even minute concentrations of these gases, which is one of its main advantages. Because of its sensitivity, it is perfect for uses including environmental monitoring, industrial settings, and gas leak detection in residences.

Furthermore, the sensor responds quickly, making it possible to identify gas leaks or variations in gas concentration in a timely manner. Its long-term dependability is guaranteed by its stability throughout time, which is essential for preserving safety in a variety of settings.

Since the MQ-4 sensor produces an analog output proportional to the gas concentration, integrating it with microcontrollers such as Arduino or ESP32 is rather simple. The output of the sensor can be connected to an analog input pin on the microcontroller, giving users access to real-time data for control and monitoring.

However, calibration may be required to consider variables like temperature, humidity, and crosssensitivity to other gases to guarantee reliable readings. To calibrate the sensor, it must be exposed to a known concentration of the target gas and its sensitivity must be adjusted correspondingly.

In summary, the MQ-4 sensor, with its high sensitivity, quick response times, and dependable performance, is essential to gas detection systems. Because of its capacity to identify natural gas and methane, it is an essential tool for environmental, industrial, and residential safety assurance.

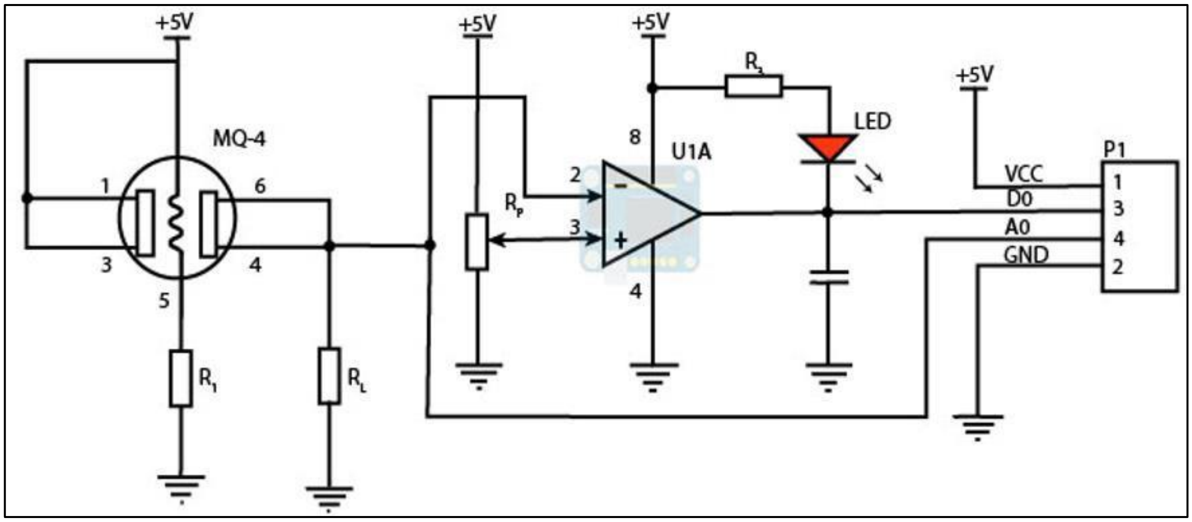

Figure 8:Mq4 Methane Natural Gas Sensor circuit

MQ 4 circuit diagram explain:

Gas Sensor MQ-4: The primary part of the circuit is the MQ-4 sensor. Usually included are four pins: VCC, GND, AOUT (analog output), and DOUT (optional digital output).

- Connect the VCC pin to the 5V power supply.
- Connect the GND pin of the power supply to ground (0V).
- The AOUT pin provides an analog output voltage proportional to the detected gas concentration.

- Connect the GND pin of the power supply to ground (0V).
- The AOUT pin provides an analog output voltage proportional to the detected gas concentration.

Load Resistor (RL): A load resistor is commonly used to link the MQ-4 sensor's AOUT pin to ground (GND). This resistor helps to maintain output voltage stability and protects the sensor from harm.

Microcontroller (Node MCU, ESP32, Arduino, etc.): One of the analog input pins (like A0) on the microcontroller is connected to the analog output voltage of the MQ-4 sensor. This gives the microcontroller the ability to read the voltage level and convert it into a digital value for processing.

Optional Components: Additional components, such as capacitors for decoupling and filtering, may be incorporated for better stability and noise reduction, depending on the application and needs.

If necessary, a potentiometer can be added to change the MQ-4 sensor's sensitivity.

Here is a brief explanation of how the circuit works:

The MQ-4 sensor is powered by a 5V source, which turns on its heating element.

- As the sensor warms up, it begins to detect methane or natural gas in the surrounding air.
- The concentration of gas affects the sensor's conductivity, which in turn affects the output voltage at the AOUT pin.
- This analog voltage signal is read by the microcontroller's analog input pin.
- Depending on the amount of gas detected, the microcontroller can act appropriately, such as sounding an alarm or displaying the data on a screen, after processing the voltage measurement and possibly translating it to a gas concentration number.

It is crucial to remember that although this is a basic circuit diagram, actual implementations could differ depending on needs, like the microcontroller selected, extra sensor calibration, and environmental factors.

D11: Humidity & Temperature Sensor

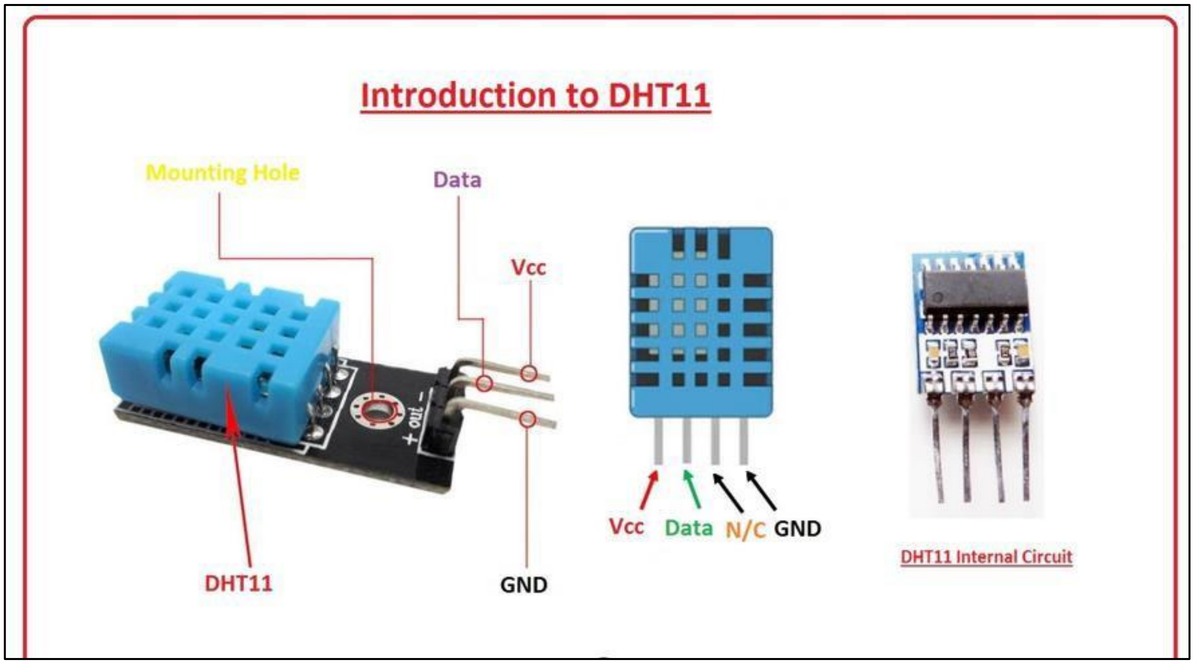

Figure 9:Mq4 Methane Natural Gas Sensor

The DHT11 sensor measures temperature and relative humidity using a thermistor and a capacitive humidity sensor, respectively. A moisture-sensitive polymer film that adjusts its capacitance in response to ambient humidity levels makes up the humidity detecting component. In the meantime, as temperature varies, the thermistor modifies its resistance. The sensor's internal circuitry subsequently transforms these modifications into digital signals.

Specifications: Temperature Range: ±2°C accuracy from 0°C to 50°C - Average Operating Voltage: 3.3V To 5V DC With an accuracy of ±5% RH, the humidity range is 20% to 90% RH. Sampling Interval: At least two seconds should pass between each measurement -A single wire interface is used to transmit a digital signal output (like the One-Wire protocol).

Interface and Communication: A single-wire digital interface is used by the DHT11 sensor to communicate with microcontrollers. This interface minimizes the number of pins that the microcontroller needs to be used and simplifies connectivity. Temperature and humidity readings are sent by the sensor in data packets at regular intervals, which the microcontroller may receive and process.

Integration with Microcontrollers: The DHT11 sensor can be used with widely used microcontroller platforms, including Raspberry Pi, Arduino, and ESP32. The abundance of libraries and code samples makes integration into projects simple. Users can easily begin reading temperature and humidity data by connecting the data pin of the sensor to a digital input/output pin on the microcontroller and providing power and ground connections.

Calibration and Accuracy: Although the DHT11 sensor can provide reasonably precise temperature and humidity measurements for a variety of applications, there are some use cases where a higher level of accuracy is required, thus calibration may be essential. Sensor measurements are compared to a reference instrument during calibration, and correction factors are applied as necessary. Furthermore, during calibration, environmental elements like radiation, ventilation, and sensor positioning should be taken into account since they can have an impact on measurement accuracy.

Limitations: The DHT11 sensor has certain restrictions in spite of its low cost and simplicity of usage. For some high-precision applications, its short operating range and relatively low accuracy make it inappropriate. Furthermore, applications expecting real-time data or quick changes in ambient conditions might not be able to make use of the sensor's response time and sample interval.

Applications: Despite its drawbacks, the DHT11 sensor's affordability and ease of use make it a popular choice for a variety of projects.

- Environmental monitoring: weather stations, greenhouse monitoring, and indoor climate management are examples of common applications.
- Home automation: automatic plant watering systems, humidity-controlled appliances, and smart thermostats.
- Industrial monitoring: HVAC systems, equipment monitoring, and humidity control in warehouses.
- STEM (science, technology, engineering, and mathematics) teaching projects: An introduction to sensor interface and data logging.

To sum up, the DHT11 sensor provides a practical and affordable way to measure humidity and temperature in a variety of applications. Even though it might not be as precise as more expensive sensors, its ease of use and low cost make it a great option for educators, hobbyists, and projects where a moderate level of accuracy is needed.

DH11: Humidity & Temperature Sensor circuit diagram

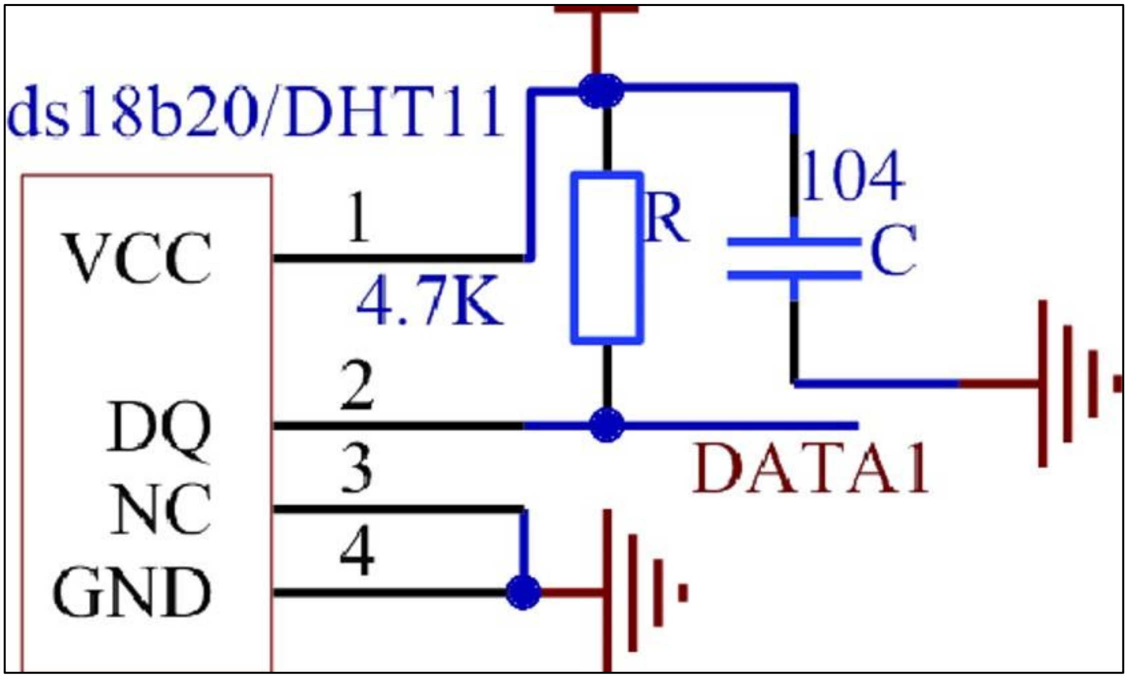

Figure 10:DH11 Sensor Circuit Diagram

DHT11 Sensor: The DHT11 sensor module itself is the circuit's primary component. Usually, it is packaged in a little box with three pins: GND, VCC, and Data.

VCC (Voltage): This pin is linked to the power supply's positive terminal, which is often either 3.3V or 5V.

Data: The sensor and microcontroller communicate with one other through the data pin. GND (Ground): Attach this pin to the circuit's ground reference or the power supply's negative terminal.

Microcontroller: To send temperature and humidity data, a microcontroller and the DHT11 sensor connect. It is possible to use popular microcontroller platforms such as Arduino, ESP32, or Raspberry Pi.

Attach the DHT11 sensor's Data pin to a microcontroller digital input/output (I/O) pin. Make that the ground (GND) pin of the microcontroller is connected to the GND pin of the DHT11 sensor.

Optional pull-up Resistor: To guarantee stable communication, it is advised in some circuits to place a pull-up resistor between the DHT11 sensor’s Data pin and the VCC pin.

The pull-up resistor typically has a value of about 10k ohms. Attach the resistor's one end to the DHT11 sensor’s Data pin and its other end to the VCC pin.

Energy Source: Give the circuit a steady power source; this should be anywhere from 3.3V to 5V DC, depending on the DHT11 sensors and the microcontroller’s specifications. Attach the DHT11 sensor's VCC pin to the power supply's positive terminal. Attach the DHT11 sensor's and the microcontroller's GND pins to the negative terminal of the power supply.

Interfacing and Communication: After the connections are completed, the DHT11 sensor's Data pin can be read by the microcontroller to initiate communication. Temperature and humidity values are sent by the sensor on a regular basis as digital signals, which the microcontroller can interpret and use for a variety of purposes.

To sum up, the DHT11 circuit diagram is not too complicated, needing just a few components to function fundamental functions. Users can readily get temperature and humidity data for their projects by simply connecting the sensor to a microcontroller and providing electricity. In some configurations, adding a pull-up resistor may also improve communication stability.

Humidifier Solution with Water-Level Sensor

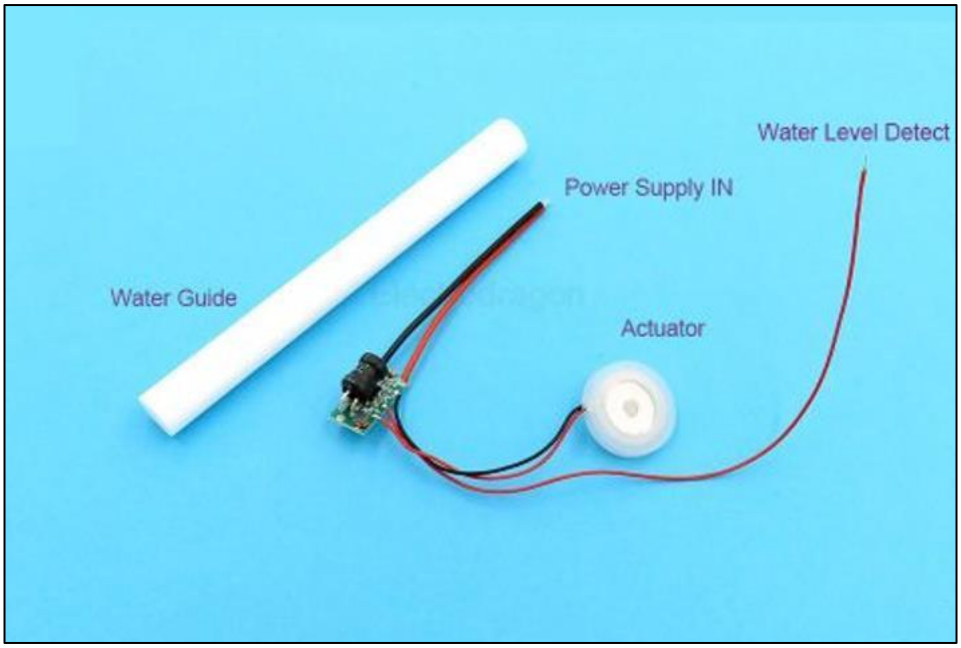

Figure 11:Humidifier Solution with Water-Level Sensor

Controlling humidity is crucial for comfort, health, and productivity in a variety of situations, including homes and workplaces. Humidifiers are essential for controlling the amount of moisture in the air, but conventional types are frequently ineffective and inaccurate. A more intelligent way to deal with these constraints is to incorporate water-level sensing technology into humidifiers. This article examines the value of controlling humidity, the drawbacks of conventional humidifiers, and the advantages of adding water-level sensors to humidifier systems.

Importance of Humidity Control: There are various reasons why it's important to keep humidity levels at ideal levels. Appropriate humidity levels in homes improve indoor air quality and help avoid problems like respiratory disorders, dry skin, and static electricity accumulation. Controlled humidity also improves comfort and encourages higher-quality sleep. Precise humidity management is essential in industrial settings to maintain materials, guarantee product quality, and facilitate production operations. Maintaining constant humidity levels is crucial for equipment performance and occupant well-being in a variety of settings, including data centers and healthcare facilities.

Problems with Conventional Humidifiers: Conventional humidifiers can have inaccurate and inefficient levels of humidity, which wastes resources. Over humidification is a frequent problem since it can lead to condensation, encourage the formation of mold, and harm furniture or electronics. Furthermore, if the reservoir runs dry, traditional models do not have the functionality necessary to monitor water levels, which could cause operational problems or safety risks. Furthermore, consuming too much energy, inefficient humidifiers can have an adverse effect on the environment and increase utility costs.

Water-Level Sensor Integration Benefits: Adding water-level sensors to humidifiers has a number of benefits and advances moisture control technology. By monitoring the water levels in the humidifier reservoir in real time, these sensors ensure that the device runs continuously and never runs out of water. In order to avoid damage or safety risks, the system may sense low water levels and send out alerts or turn itself off automatically. Additionally, water-level sensors allow for accurate humidity output control, minimizing the chance of over humidification and maximizing energy efficiency.

Application of Water-Level Sensor Technology: Several crucial parts and procedures are involved in the integration of water-level sensors into humidifier systems. First, compatible sensors that can consistently and precisely measure water levels are chosen in accordance with the needs of the application. The control circuitry of the humidifier then incorporates these sensors, enabling smooth communication and automation of water level monitoring. Software algorithms may also be created to analyze sensor data, modify humidifier settings, and produce warnings or alarms when necessary. Applications and Practical Considerations: There are several practical issues that need to be taken into account when integrating water-level sensor technology into humidifiers. This entails picking sensors whose sensitivity, dependability, and compatibility with the materials and design of the humidifier are suitable. To guarantee accurate sensor readings and dependable performance in a range of environmental circumstances, calibration and testing are crucial. Additionally, the inclusion of water-level sensors creates opportunities for more sophisticated features like data logging, remote monitoring, and interface with building automation or smart home systems.

In summary, adding water-level sensor technology to humidifiers is a clever way to maximize humidity control in a variety of settings. These sensors increase user safety, reduce over humidification, and improve operational efficiency by offering real-time monitoring of water levels. The precision, ease, and energy savings that smart humidifier systems can provide have never been possible before thanks to developments in sensor technology and Internet of Things connectivity. Water-level sensor integration offers a viable path for advancement and innovation in this crucial subject as the need for effective humidity control keeps growing.

ESP32 Wi-Fi & Bluetooth Soc

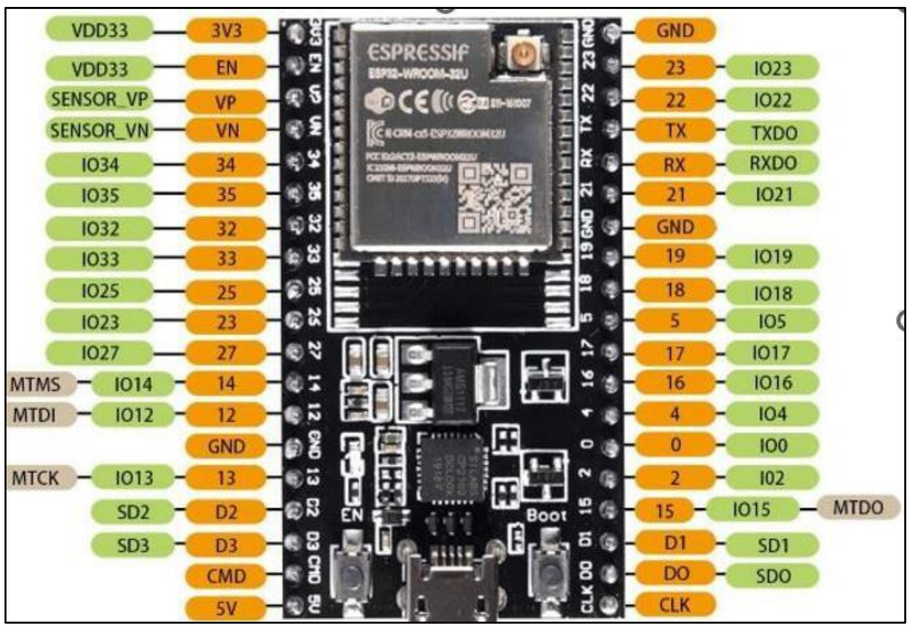

Figure 12:ESP32 Wi-Fi & Bluetooth Soc

Strong and adaptable, the ESP32 microcontroller is well-known for its sophisticated features, excellent performance, and wide range of applications. Let's examine the ESP32's characteristics, architecture, applications, and advantages in more detail as we dig into its complexities:

1. Architecture:

The ESP32 microcontroller is substantially quicker and more capable than its predecessor, the ESP8266, thanks to its dual-core Xtensa LX6 CPU, which can run at up to 240 MHz It has built-in security features, a wide range of peripheral interfaces, integrated Wi-Fi, and Bluetooth connectivity.

2. Features:

- Dual-Core Processor: This processor's architecture allows for parallel and multitasking processing, which improves overall efficiency and performance.
- Wi-Fi Connectivity: The ESP32 has built-in 2.4 GHz Wi-Fi connectivity, which makes networking and wireless communication easy.
- Bluetooth capability: The ESP32 has Bluetooth Low Energy (BLE) capability in addition to WiFi, which qualifies it for Internet of Things applications that need wireless communication.
- Peripheral Interfaces: The ESP32 can be seamlessly integrated with a variety of sensors, displays, actuators, and other external devices thanks to its extensive range of peripheral interfaces, which include UART, SPI, I2C, ADC, DAC, PWM, and more.
- Low Power Consumption: The excellent power management features of the ESP32, which are designed for low power operation, maximize energy economy and prolong battery life in battery-powered applications.
- Secure Boot and Flash Encryption: To guard against unauthorized access and manipulation, the ESP32 has security features like secure boot and flash encryption.

3. Applications:

The adaptability of the ESP32 renders it appropriate for an extensive array of uses in diverse sectors:

- Internet of Things (IoT): A variety of IoT applications, such as smart agriculture, industrial monitoring, environmental sensing, and home automation, make extensive use of the ESP32.

- Wearable Devices: The ESP32 is perfect for wearable gadgets like health monitors, smartwatches, and fitness trackers because of its low power consumption and Bluetooth compatibility.
- Robotics and Automation: The ESP32 is well-suited for robotics and automation applications, such as automation controllers, robot control systems, and motor control, because to its robust processing capabilities and multitude of peripheral ports.
- Wireless Sensor Networks: The ESP32 is ideally suited for constructing wireless sensor networks for data collection and monitoring in a variety of situations because to its integrated Wi-Fi and Bluetooth capability.
- Education and Prototyping: The ESP32 is a great platform for quick prototyping of embedded systems and Internet of Things projects due to its comprehensive feature set, affordability, and ease of use.

4. Benefits:

- Performance: The ESP32 outperforms other microcontrollers in its class thanks to its dual-core CPU and high clock speed, allowing for quicker processing and more streamlined operation.
- Connectivity: Built-in Bluetooth and Wi-Fi compatibility provides smooth wireless connectivity, making network configuration easier, and facilitating communication with other platforms and devices.
- Flexibility: The ESP32 is appropriate for a variety of applications due to its broad peripheral interfaces and GPIO pins, which allow for the flexible connection of a large range of sensors, actuators, and other external devices.
- Community Support: There is a large amount of available documentation, tutorials, and opensource libraries for the ESP32, which makes development and troubleshooting easier for users of all skill levels. The ESP32 enjoys significant community support. To sum up, the ESP32 microcontroller is a flexible and strong platform that can be used for a variety of embedded systems, wireless communication, and Internet of Things applications. It is a priceless tool for developers, makers, and engineers looking to realize their projects because to its sophisticated features, excellent performance, and wide range of networking choices.

1.2.4 Real-time Visual Inspection System for Grading Fruits Using Computer Vision and Deep Learning Techniques

The agriculture sector plays a fundamental role in global economies, extending beyond basic nutrition to cover wider economic stability and prosperity. Among its numerous parts, fresh fruit and vegetable production and supply emerge as essential contributions to global food security and economic development. However, the traditional paradigms of agricultural techniques are being transformed by the incorporation of innovative technologies, ushering a new era of efficiency and creativity. Medium to large-scale agricultural firms have embraced these technologies to cut operational costs and boost market competitiveness. However, the adoption of such modern technologies remains a barrier for small-scale agricultural enterprises and individual farmers, principally due to fiscal constraints and the demand for specialized skills. Addressing these difficulties involves the development of economical and user-friendly solutions customized to the special needs of small-scale agricultural businesses. Of particular importance is the automation of grading procedures, which are parts of the fresh fruit supply chain. Manual grading systems, depending on skilled staff for visual assessment, are not only time-consuming but also prone to discrepancies. Automated grading systems offer a possible answer by delivering consistent categorization while lowering personnel expenses and expediting post-harvest operations. In the domain of science, there has been a rise of interest in automating fruit classification and grading using computer vision and machine learning approaches. These studies generally employ classic methods of feature extraction mixed with machine learning algorithms to attain high levels of accuracy. For instance, research focused on apple categorization has incorporated color, texture, and shape descriptors to train machine learning models, obtaining accuracy rates upwards of 95.9%. Similarly, studies on banana maturity evaluation and the assessment of freshness and maturity in other fruits have proved the efficiency of machine learning techniques, including Support Vector Machine (SVM), Multilayer Perceptron (MLP), and artificial neural networks (ANNs).

While these approaches have demonstrated promising results, they frequently rely on handcrafted feature extraction techniques and may exhibit limits in terms of scalability and generalizability. In this context, the present study aims to advance the state-of-the-art in automated fruit inspection by employing cutting-edge deep learning approaches. By building a comprehensive framework capable of real-time fruit evaluation, the study intends to address the limits of existing approaches and offer a cost-effective solution customized to the demands of small-scale agricultural businesses. Through a complete analysis of deep learning architectures and ensemble approaches, the work tries to produce a versatile and accurate system capable of grading many fruit instances inside photos effectively.

In a Google Form survey, 99% of participants said small scale agricultural enterprises face challenges in adopting modern technologies.

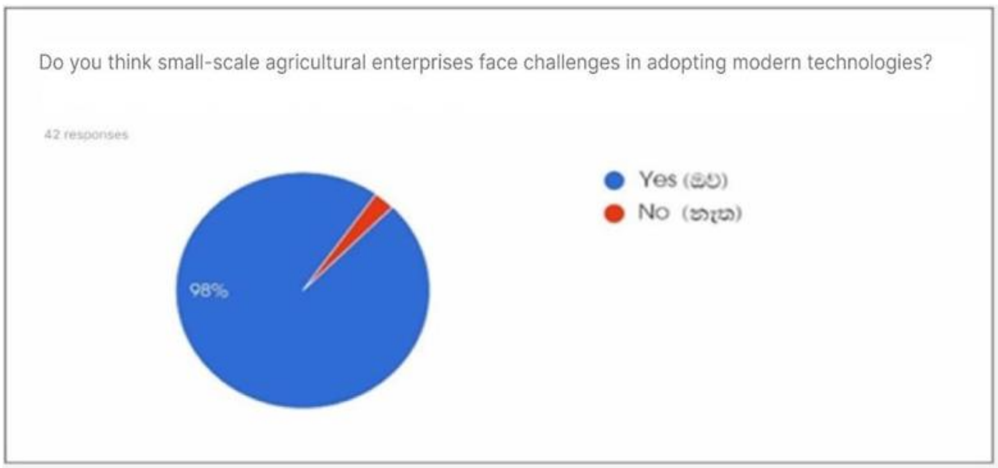

Figure 13:Survay report for small-scale agricultural enterprises face challenges.

In our survey, an overwhelming 98% of respondents stated that small-scale agricultural firms experience barriers in implementing contemporary technologies. This high agreement percentage highlights the widespread understanding throughout the agricultural sector of the obstacles faced by smaller businesses in adopting technological improvements. This high agreement percentage highlights the widespread understanding throughout the agricultural sector of the obstacles faced by smaller businesses in adopting technological improvements.

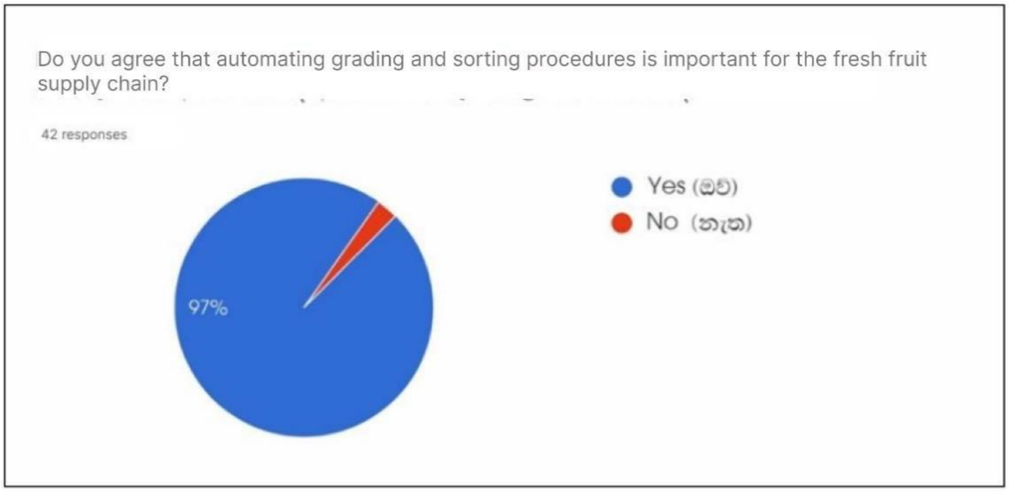

Figure 14:Survey report for automating grading and sorting procedures.

With a resounding 97% agreement rate among respondents, our survey highlights the vital relevance of automating grading and sorting activities in the fresh fruit supply chain. This overwhelming consensus reflects the widespread acknowledgment throughout the agricultural world of the enormous benefits that automation may bring to the efficiency and effectiveness of fruit processing and distribution.

Automated grading and sorting not only speed post-harvest activities but also ensure uniformity and accuracy in categorization, lowering the risks of human mistake and saving labor expenses. Moreover, by accelerating the delivery of high-quality produce to customers, automation promotes overall market competitiveness and profitability for stakeholders across the supply chain.

The overwhelming support for automation in grading and sorting systems underscores the critical need for investment and innovation in this field, with possible consequences for enhancing food security, reducing food waste, and sustaining economic growth within the agricultural sector. As such, our findings provide useful insights into the objectives and perspectives driving innovations in fresh fruit handling and distribution, leading future research, and development efforts toward tackling the problems and opportunities in this critical domain.

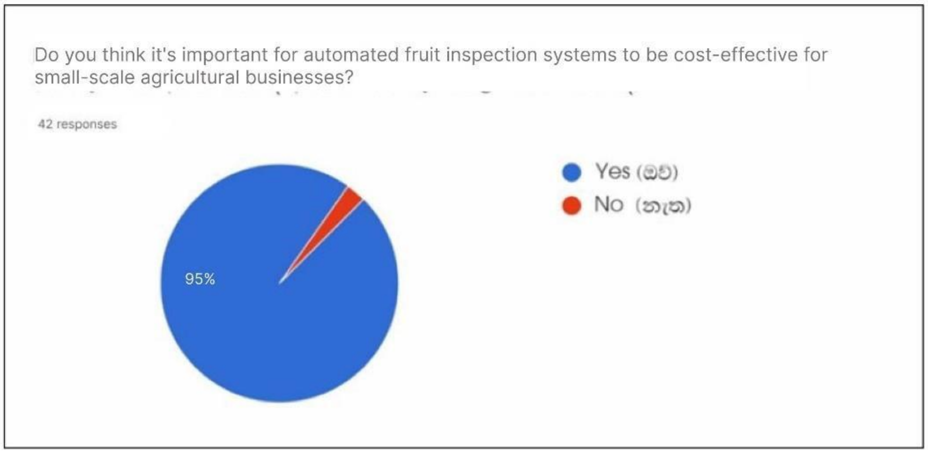

Figure 15:Survay report for important of automated fruit inspection systems to be cost-effective or not.

With a significant 95% agreement rate among respondents, our survey highlights the consensus within the agricultural community regarding the importance of cost-effectiveness in automated fruit inspection systems for small-scale agricultural businesses. This overwhelming support underscores the recognition of financial constraints faced by smaller operations and the critical role that affordability plays in facilitating technology adoption and fostering competitiveness.

Automated fruit inspection systems that are cost-effective offer various advantages for small-scale agricultural operations. Firstly, they lessen the financial burden associated with technological investment, making it more accessible for farmers with limited resources. This accessibility enables smaller companies to benefit from the efficiency advantages and quality improvements afforded by automated inspection, leveling the playing field in the sector.

Secondly, cost-effective automated inspection technologies contribute to the overall viability of small-scale agricultural operations. By lowering capital investment and operational costs, farmers can deploy resources more efficiently, potentially enhancing profitability and long-term viability. Additionally, affordable technology solutions support the wider adoption of sustainable farming techniques, harmonizing with environmental and social responsibility objectives.

Furthermore, cost-effective automated inspection technologies empower small-scale farmers to remain competitive in dynamic marketplaces. By boosting production, quality control, and market preparedness, these solutions help farmers to meet growing consumer needs and regulatory requirements more successfully. This agility is vital for small-scale agricultural firms to succeed amidst shifting industry landscapes and global difficulties.

Overall, the overwhelming agreement on the necessity of cost-effectiveness in automated fruit inspection systems highlights the need for innovative solutions customized to the specific needs and limits of small-scale agricultural operations. By prioritizing affordability with functionality and performance, technology developers and policymakers may promote the sustainable expansion and resilience of small-scale farming communities, contributing to broader agricultural sustainability and food security goals.

1.2.4.1 Manual method of grading fruits.

The manual method of fruit grading has the following steps:

1. Preparation of Grading Area
    - Begin by setting up a clean and well-lit area designated particularly for grading the fruits. Ensure that the room is clear from any contaminants or debris that could damage the evaluation procedure. Arrange grading instruments such as baskets, trays, and sorting bins in an organized manner to assist the effective arrangement of fruits based on their quality.

2. Selection of Representative Samples
    - Next, carefully select representative samples of fruits from the lot that needs to be evaluated. It's vital to choose fruits that cover the complete range of predicted quality qualities present in the batch. Randomly choose the samples to obtain an accurate reflection of the general quality of the lot.

3. Visual Inspection Parameters

    - Define the specific quality parameters that will be checked for each type of fruit. These criteria often include size, color, shape, texture, and ripeness. Establish precise standards for evaluating each characteristic, assuring consistency and impartiality throughout the grading process.

4. Grading Process

    - Begin the grading procedure by inspecting each fruit individually according to the set requirements. Assess each fruit based on its conformity with the set requirements for size, color, shape, texture, and maturity. Use a standardized grading scale, such as "Excellent," "Good," "Fair," and "Poor," or a numerical grading system to categorize the fruits properly.

5. Documentation and Record-keeping

    - Maintain precise records of the grading process to follow the progress and outcomes correctly. Record the quantity of fruits rated in each category, along with any observations or remarks regarding their quality. Document any departures from the usual grading criteria and provide explanations for these variances.

6. Quality Control and Feedback

    - Implement quality control techniques throughout the grading process to ensure consistency and accuracy in evaluations. Conduct regular checks to verify the adherence to grading criteria and provide comments to the grading personnel based on these evaluations. Address any differences promptly to ensure the integrity of the grading process.

7. Packaging and Distribution

    - Once the grading process is complete, package the graded fruits according to their quality grades. Ensure adequate labeling of the packets to show the quality grade of the fruits included within. Facilitate the effective distribution of the graded fruits to their various markets or destinations to maintain their freshness and quality.

8. Continuous Improvement

   - Lastly, frequently assess and evaluate the success of the grading process to discover areas for improvement. Seek feedback from stakeholders, including farmers, distributors, and consumers, to incorporate their views into enhancing the grading criteria and procedures. Continuously try to strengthen the accuracy, efficiency, and reliability of the manual fruit grading method.

1.2 Research Gap

Researchers and practitioners have continuously investigated cutting-edge technology and approaches in many areas of food production and assessment in the quest of guaranteeing food safety and quality. Still, a number of research gaps exist, which prevents the creation of all-encompassing solutions to solve important issues in food quality assessment. This part uses a wide range of research from areas such deep learning, image processing, sensor technologies, and agricultural management to try and find and fill in these gaps. In order to give a road map for next studies aiming at promoting higher accuracy, efficiency, and sustainability in food quality control systems, we outline these shortcomings.

Features	A	B	C	D	E	F	G	H	I	J	K	L	Proposed System
Deep Learning Model	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓
Image Dataset Creation	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓
Visual Cues Identification	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓
Health Risk Assessment	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✓
Android Application	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓
User Interface Design	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓
Accuracy Evaluation	✓	✓	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✓
Milk quality detection	✗	✗	✗	✗	✗	✓	✓	✗	✗	✓	✗	✗	✓
Water adulteration detection	✗	✗	✗	✗	✗	✓	✗	✓	✗	✗	✗	✗	✓
Milk grading system	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✓
Portable Device	✗	✗	✗	✗	✗	✓	✓	✓	✓	✗	✗	✗	✓
Cloud database	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓
Real-time Monitoring	✗	✗	✗	✗	✗	✓	✓	✓	✗	✓	✗	✗	✓
Fruit air Monitoring	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓
Fruit Environment temperate Measure	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓
Fruit Environment humility Measure	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓

Table 1:Research Gap

Research A [6]: One of goal this research project is to fill a significant vacuum in the literature by developing a deep learning algorithm designed particularly to distinguish between bananas that have been chemically and naturally ripened. Although deep learning approaches have been widely used in many image classification applications, there is a significant research vacuum about their use in banana ripening processes. This project aims to contribute to the growth of technology by creating a specific deep learning model for the goal of improving consumer awareness and safety in banana purchasing decisions.

In other one is this paper provides a thorough investigation of machine vision and image processing used for evaluating the quality of food. This study explores the deep learning models in the analysis of food product photographs, including its entire lifecycle from cultivation to consumption. The study encompasses the development of image collections and the detection of visual indicators for assessing the quality of food. Although the proposed system's accuracy evaluation is addressed, there is a lack of reference regarding the development of an Android application or the design of a user interface.

Research A, B [6,7]: This research presents automated systems as a solution to address inefficiencies and faults in the fruit grading process in the Indian agricultural business, specifically focusing on manual grading. The significance of visual signals, including color, size, and weight, in the grading of fruits is underscored, and image processing techniques are suggested as potential methods for their identification. The present study assesses the precision of the suggested fruit grading system; however, it falls short in its examination of deep learning models, Android application development, and user interface design.

Building an extensive collection of photographs showing bananas that have been chemically and naturally ripened is essential for training and verifying the efficacy of the deep learning model created in the previously described study. Existing datasets, however, do not fully fulfill the particular needs for differentiating various banana ripening techniques. Consequently, there is a glaring void in the annotated datasets that are expressly designed for the purpose of detecting banana maturity. By developing a dataset that is best suited for training the deep learning model, this research seeks to close this gap and guarantee the model's dependability and accuracy in practical settings.

Research C [8]: This study examines the utilization of image processing techniques to automate the grading of apples. The text emphasizes the advantages of automated grading systems, such as enhanced productivity and reduced expenses. The study focuses on the generation of image datasets and the assessment of the built system's accuracy. However, it does not delve into the topics of deep learning models, Android application development, or user interface design.

Research D [9]: It is critical to carry out a thorough health risk assessment in light of consumer concerns over possible health risks related to chemical residues in bananas. Although studies on the potential health effects of chemical residues in fruits may already exist, there might be a particular research deficit pertaining to bananas. Furthermore, assessing how well the created deep learning model reduces these hazards is essential to guaranteeing customer safety. By examining the health hazards connected to chemical residues in bananas and evaluating how well the deep learning model detects and reduces these risks, this study seeks to close this knowledge gap

Research E [10,11]: Extensive testing and assessment of the deep learning model's performance in detecting chemical residues in bananas under various circumstances is necessary for its practical use. There might be a research gap concentrating on the accuracy of deep learning models in identifying chemical residues in bananas, even though there might be some studies assessing the models' performance in other picture classification tasks. By offering a thorough assessment of the model's performance, this study seeks to close this gap and guarantee the model's dependability and efficacy in practical situations.

Research F [12]: Focused on solving the issues in fruit grading, particularly in the context of the Indian agricultural industry, this research provides a comprehensive fruit grading system based on deep learning models and image processing techniques. It covers elements such as image dataset compilation, visual cues detection, health risk assessment, Android application development, user interface design, and accuracy evaluation. The suggested method seeks to enhance efficiency, decrease errors, and meet the rising demand for quality fruits.

Previous research investigations, such those detailed in Research F [13], have studied the possibilities of deploying IoT sensors to monitor several factors including bacterial activity, pH levels, viscosity, and temperature to evaluate milk quality. However, this prior work primarily focuses on the detection of milk quality using IoT sensors without combining critical components for a full milk quality evaluation system. Notably, it lacks capabilities such as an Android application and cloud-based data storage, which are crucial for boosting accessibility and scalability. Additionally, while Research A covers milk quality criteria, it overlooks crucial features such as water adulteration detection and real-time monitoring capabilities, hence restricting its application in dynamic dairy production settings.

Research G [14] explores the use of visual spectroscopy for testing milk freshness, giving an economical alternative to established analytical procedures. However, this study largely focuses on spectroscopic approaches for milk freshness assessment and lacks crucial components necessary for a full milk quality assessment system. Specifically, it does not contain a milk grading system or real-time monitoring functionalities, which are crucial for assuring consistent milk quality throughout production and distribution processes. Moreover, Research B does not incorporate elements such as water adulteration detection, hence disregarding a crucial aspect of milk safety and quality assurance.

Research H [15] underlines the relevance of consumer-friendly characteristics in milk quality testing, such as pH monitoring and density analysis. Nevertheless, this study largely highlights solutions tailored for customers and skips crucial components required for a holistic milk quality assessment system. Notably, it lacks water adulteration detection and real-time monitoring capabilities, hence limiting its effectiveness in addressing broader milk safety concerns. Additionally, Research C does not contain elements such as an Android application, which could boost user accessibility and engagement in milk quality testing processes.

While Research I [16] presents a microcontroller-based device for milk parameter detection and grading, it fails to provide a full solution for milk quality assessment. Although Research D addresses the automation of milk parameter detection and grading, it lacks features such as water adulteration detection and an Android application, constraining its functionality and usability in real-world dairy production situations. Furthermore, Research D does not contain real-time monitoring capabilities, important for rapid intervention and quality control in milk production processes.

Research J [17] proposes a wireless passive sensor for remote in vivo milk pH measurement, presenting a viable solution for continuous monitoring of milk quality. However, Research E primarily focuses on pH monitoring utilizing wireless passive sensors and does not contain other essential components necessary for a full milk quality assessment system. Notably, it does not have functions such as milk grading or real-time monitoring capabilities, essential for assuring consistent milk quality and safety. Additionally, Research E does not contain water adulteration detection, neglecting a crucial part of milk quality assurance.

Research K, L [18,19] To investigate the all-encompassing method of fruit quality management, this research work integrates fruit air monitoring, fruit environment temperature measurement, and fruit environment humidity measurement. Fruit air monitoring is essential to determining the chemical makeup of the air surrounding fruits and to help identify volatile organic compounds (VOCs) that are signs of ripeness and spoiling. Growers may improve storage conditions, guaranteeing longer shelf-life and better quality, by precisely measuring temperature and humidity in the fruit environment at the same time. Combining these methods, our study seeks to give a comprehensive picture of the elements affecting fruit quality along the supply chain, providing useful information for better farming methods and higher customer satisfaction.

Collectively, these research endeavors underscore the growing importance of leveraging advanced technologies such as deep learning, image processing, and sensor systems to revolutionize food quality assessment. While individual studies focus on specific aspects of food quality, such as milk pH measurement, fruit grading, or chemical residue detection in bananas, there's a shared recognition of the need for comprehensive evaluation systems. Such systems should encompass features like real-time monitoring, user-friendly interfaces, and detection capabilities for contaminants like water adulteration. Moreover, integrating multiple technologies, as demonstrated in Research K and L, promises to offer a holistic understanding of food quality parameters throughout the production and distribution processes. These efforts collectively aim to bridge existing knowledge gaps, enhance accessibility, and ultimately ensure safer and higher-quality food products for consumers worldwide.

2. RESEARCH PROBLEM

2.1 Detection of Artificially Ripened Banana Using Deep Learning Techniques

The widespread usage of chemical ripening agents in the banana business has led to serious worries about the safety and health of consumers. Much as bananas are consumed, one of the biggest problems is that there are no easily available instruments for differentiating naturally ripened bananas from chemically ripened ones. Current approaches that depend on visual examination or subjective evaluations are prone to inaccuracy and do not yield trustworthy data for users. To make matters worse, consuming chemical residues may pose health dangers to oneself. For this reason, a reliable and workable solution is desperately needed. In order to close this significant gap, this research will provide a deep learning-based framework that will address image categorization, dataset building, health risk assessment, visual cue detection, and accuracy evaluation. By addressing these interconnected issues, we hope to support transparency and safety in the banana business and provide customers with the information and resources they need to make wise decisions.

According to the results of a recent Google survey, people are worryingly unaware that bananas might contain hazardous compounds. It is clear that a sizeable section of the public is still ignorant of this important topic, as 95.6% of respondents admitted to being ignorant of the possible problems connected to chemically ripened bananas. The urgent need for educational programs and easily accessible resources to arm people with critical information about the food they eat is highlighted by this lack of understanding. It is imperative to close this knowledge gap since consumers run the danger of unintentionally exposing themselves to health hazards when they lack the necessary information. Through establishing a connection between consumer education and food safety, we can endeavor to safeguard people's health and advance openness in the food supply chain.

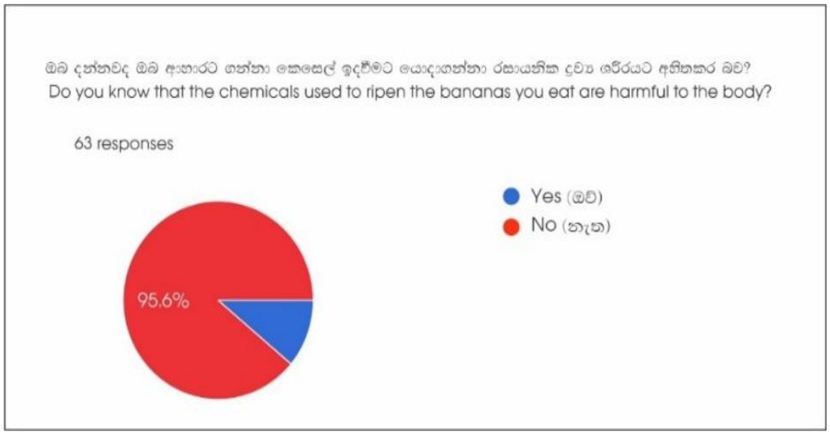

Figure 16::Survey report for that chemical used to ripen the banana you eat are harmful

Apart from the disturbing dearth of knowledge regarding the existence of detrimental chemicals in bananas, the poll also revealed an unsettling pattern concerning consumers' capacity to distinguish naturally ripened bananas by tactile or visual examination. Remarkably, 80.3% of participants acknowledged not knowing how to differentiate artificially ripened bananas from naturally ripened ones using only tactile or visual indicators. This research reveals a widespread ignorance among consumers on the fundamental techniques for evaluating the quality of fruit. Customers run the risk of making ignorant purchases and putting their health at risk from chemical residues if they are unable to distinguish between bananas that have ripened naturally and those that have been chemically ripened. Reducing this knowledge gap is essential to enabling customers to choose fruits in an informed and health-conscious manner, protecting their health and fostering openness in the food sector.

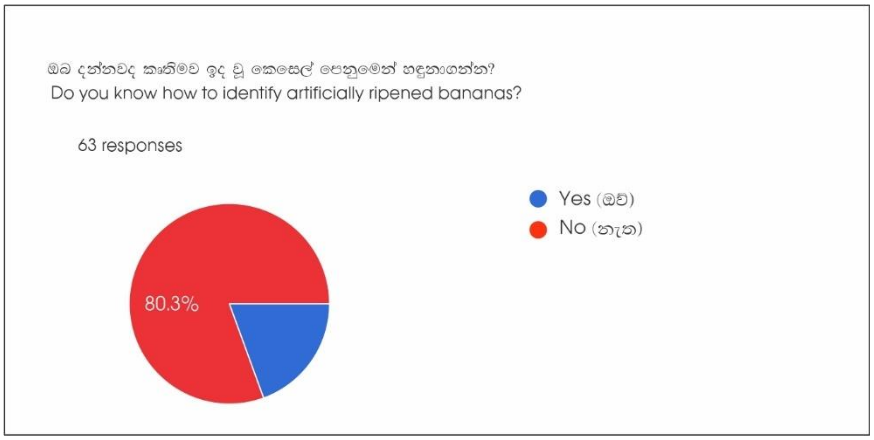

Figure 17:Survey report for that how to identify artificially ripened bananas

The proposal of developing a smartphone application that allows users to upload images of bananas and receive fast feedback on whether they are naturally ripened or chemically treated has earned overwhelming support from 99.4% of poll participants. This new technology giving them with a strong tool to safeguard their health and make informed choices while grocery shopping. By just snapping a snapshot of a banana, users can obtain critical information about its ripening procedure, empowering them to pick chemical-free solutions and prioritize their well-being. This seamless integration of technology into the realm of food safety not only meets a crucial consumer need but also represents a growing desire for accessible solutions that encourage openness and accountability in the food business.

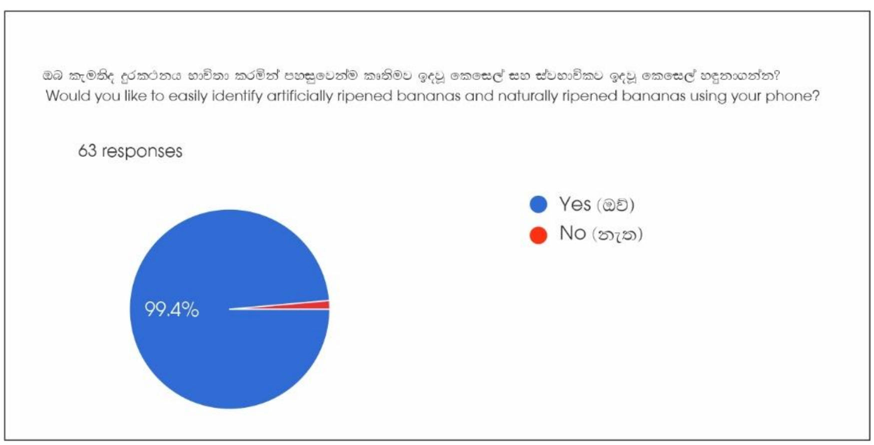

Figure 18:Survay report for mobile app creation

With the ability to identify naturaly ripened bananas with a simple photo upload, consumers are armed with a useful tool to navigate the intricacies of the current food market and prioritize their health and well-being.

Beyond its immediate practical benefits, the suggested mobile application has the potential to drive deeper shifts in consumer behavior and industry norms. By empowering users to make healthier choices and avoid chemically treated produce, the app stimulates increased examination of food production techniques and fosters demand for more transparent and sustainable farming methods. As more users embrace the app and advocate for safe and natural food options, producers and retailers are driven to prioritize quality and safety in their products, leading to beneficial improvements throughout the food supply chain. Ultimately, this smartphone application represents not only a technological innovation but also a catalyst for good societal change, driving towards a future where customer health and well-being are important considerations in the food sector.

2.2 Milk Quality Detection Using IoT

In the milk industry, assuring the quality and safety of dairy products, especially during the milk procurement process, faces massive difficulties. The main difficulties occupy in the lack of reliable tools for detecting milk deterioration and contamination at procurement facilities. Present inspection techniques mostly rely on subjective visual assessments, creating inaccuracies and possibly harming consumer health. Moreover, incorrect assessments of milk quality may result in large economic losses for dairy stakeholders.

A serious worry revolves around the absence of appropriate instruments for identifying between fresh, high-quality milk and affected milk. Current methods, such as lactometer readings, typically fall short in giving reliable assessments, particularly in situations where conditions differ from traditional needs. Therefore, there is an urgent need for creative solutions using advanced technologies to improve milk quality detection and maintain consumer safety standards.

Additionally, there remains a large gap in consumer understanding of the potential health dangers connected with consuming spoiled or contaminated milk. Insufficient information among consumers may lead to unexpected intake of contaminated dairy products, causing health concerns. Addressing this knowledge gap is crucial for empowering customers to make educated decisions about the milk they eat and fostering transparency throughout the dairy supply chain.

In addition, there is an increasing demand within the dairy industry for dependable and effective techniques of milk quality assessment. With supply chains becoming more complicated and food markets expanding globally, affordable options are necessary for deployment across varied procurement centers and dairy farms. However, creating and implementing such technologies involves thorough consideration of economic, technical, and scheduling feasibility to guarantee successful integration and long-term viability.

2.3 Smart IoT Solutions for Reducing Fruit Wastage and Enhancing Quality Along the Supply Chain

The difficulty in the field of optimizing IoT-based food quality monitoring systems is to create and execute a complete strategy that tackles a range of issues to guarantee precise evaluation and effective handling of perishable food items. This entails the deliberate integration and placement of sensors to improve the accuracy of data collection and capture relevant environmental elements that impact the quality of the fruit. It also involves creating and improving real-time analysis and predictive modeling algorithms, which are essential for correctly interpreting sensor data and predicting fruit shelf life based on changing environmental conditions. Thorough validation and field testing are necessary to determine the efficacy and dependability of IoT-based monitoring systems in a variety of operational contexts, fostering trust in their abilities to reduce food waste and uphold food safety regulations. In addition, it is imperative to investigate elements related to scalability and adaptability to meet the various demands of food industry stakeholders and facilitate the implementation of monitoring systems in varying locations and storage settings. Finally, creating user-friendly interfaces and feedback systems is crucial to enabling smooth system interaction and providing users with useful information, which in turn supports improved efforts to ensure food safety, quality control, and reduce waste throughout the food supply chain. Improvements in IoTbased food quality monitoring systems will be made possible by tackling these complex issues, which will boost consumer confidence and guarantee the integrity of perishable items sold.

2.4 Real-time Visual Inspection System for Grading Fruits Using Computer Vision and Deep Learning Techniques

The agriculture sector is a cornerstone of economies globally, with fresh fruit production and supply playing a crucial role. However, the efficiency and productivity of fruit grading and sorting activities remain key difficulties. Traditional manual grading methods, highly reliant on human labor and visual examination, are not only time-consuming but also prone to irregularities and errors. Moreover, the increased need for timely market delivery necessitates faster and more precise grading processes. In response to these obstacles, researchers and practitioners have turned to cutting-edge technologies, particularly in the fields of computer vision and machine learning, to automate and streamline fruit grading operations.

Despite the achievements made in employing technology for fruit grading, some fundamental problems exist, comprising the research subject at hand. One such difficulty is the reliance on hand-crafted feature extraction approaches in present grading systems. These strategies often require manually defining and extracting attributes such as color, texture, and form descriptors from fruit photos. While useful to some level, hand-crafted features are intrinsically restricted in their capacity to portray the numerous and complex properties of different fruit species. This constraint not only limits the accuracy of grading outcomes but also makes the system less flexible to differences in fruit appearance.

Furthermore, the lack of generalizability across different fruit species provides a substantial hurdle to the broad implementation of automated grading systems. Many existing models are geared to certain fruit varieties and may struggle to appropriately grade fruits with diverse forms, colors, or surface textures. This lack of adaptability inhibits the usefulness of automated grading systems, particularly for small-scale agricultural enterprises and individual farmers who may grow a range of fruits.

Addressing these difficulties is critical for enhancing the efficiency, reliability, and accessibility of fruit grading devices. A robust and scalable automated grading system is needed to decrease human labor, reduce grading time, and increase grading accuracy across varied fruit kinds. Additionally, such a system should be adaptive and diverse enough to accept differences in fruit look and features.

Therefore, the research challenge revolves around constructing a deep learning-based automated fruit grading system that overcomes the constraints of previous hand-crafted feature extraction methodologies. This system should be capable of accurately grading numerous fruit varieties in real-time, without the need for considerable operator intervention or calibration. By solving these problems, the project intends to pave the way for more efficient and cost-effective fruit grading operations, benefiting agricultural stakeholders ranging from small-scale farmers to large-scale producers and distributors.

3. RESEARCH OBJECTIVES

3.1 Main Objectives

Using cutting-edge computer vision algorithms and convolutional neural networks (CNNs) to precisely assess fruit images and label them according to predetermined grading criteria, the main goal is to develop a strong automated fruit grading system based on deep learning techniques.

- Improvement of Generalization and Accuracy:

Increasing the automated grading system's generalization and accuracy across different fruit species is another important objective. This includes improving the deep learning models such that, independent of fruit kind or look, they can reliably and consistently capture and distinguish the unique characteristics and traits of various fruits.

- Providing Real-Time and Economical Operation:

The project seeks to create a system that can run in real time while nevertheless being affordable and reachable, particularly for small-scale farming businesses and individual farmers. This entails lowering hardware needs and improving the computational efficiency of the deep learning algorithms to enable deployment in situations with limited resources.

- Banana Ripeness Detection with Picture Recognition Technology:

The goal is to create a smartphone app that uses image recognition technology to tell users whether bananas are ripened organically or chemically. Customers are so empowered to choose bananas with knowledge about their health and wellbeing.

- Establishing an Internet of Things (IoT) System for Real-Time Milk Quality Monitoring:

  The primary objective is to build an IoT system able to continuously monitor and evaluate milk quality in procurement centers. This system has quick quality assessment and monitoring capabilities, which aims to improve procedures for guaranteeing milk quality and increase consumer confidence in dairy products. IoT gadgets are used in fruit storage to distinguish good and bad fruits and to find harm to other crops. The goal is to use Internet of Things (IoT) technology to solve the problem of guaranteeing consumers high-quality fruits by offering real-time evaluation and decision-making assistance for fruit storage management.

3.2 Specific Objectives

There are specific objectives that need to be fulfilled in order to achieve the overall objective described above.

1. **Developing a Deep Learning-Based Automated Fruit Grading System:**
   - Design and implement deep learning algorithms for fruit image analysis.
   - Train convolutional neural networks (CNNs) to accurately classify fruits based on grading criteria.
   - Develop software for integrating the deep learning model into an automated fruit grading system.
   - Conduct extensive testing and validation to ensure the system's accuracy and reliability across various fruit types.

2. **Enhancing Accuracy and Generalizability:**
   - Investigate methods for improving the robustness of the deep learning models to variations in fruit appearance and characteristics.
   - Explore techniques for data augmentation and transfer learning to enhance model generalizability.
   - Optimize model hyperparameters and architecture to achieve better performance across diverse fruit species.
   - Evaluate the system's performance through cross-validation and benchmarking against

industry standards.

3. **Enabling Real-Time and Cost-Effective Operation:**
    - Develop algorithms for real-time fruit grading that optimize computational efficiency.
    - Investigate hardware solutions to reduce system cost and resource requirements.
    - Design user-friendly interfaces for easy deployment and operation by small-scale agricultural enterprises and individual farmers.
    - Conduct field trials to assess the system's effectiveness in real-world settings and gather feedback for further improvements.

4. **Implementing Picture Recognition Technology for Banana Ripeness Detection:**
    - Develop algorithms for analyzing banana images and detecting ripeness indicators.
    - Integrate the image recognition technology into a smartphone application.
    - Implement a user-friendly interface that provides clear and actionable information to consumers.
    - Test the application's accuracy and reliability under various lighting and environmental conditions.

5. **Creating an Internet of Things (IoT) System for Real-Time Milk Quality Monitoring:**
    - Design IoT sensors for monitoring key parameters such as pH, temperature, and bacterial activity in milk.
    - Develop a network infrastructure for transmitting sensor data in real-time to a centralized monitoring system.
    - Implement data analytics algorithms for assessing milk quality based on sensor readings.
    - Integrate the IoT system with existing milk procurement processes and quality control measures.

6. Utilizing IoT Devices for Fruit Storage Quality Assessment

- Develop IoT sensors capable of detecting fruit quality parameters such as ripeness, damage, and spoilage.
- Design a system architecture for collecting and processing data from IoT devices in fruit storage facilities.
- Implement machine learning algorithms for analyzing sensor data and providing real-time quality assessments.
- Validate the system's effectiveness in improving fruit quality and reducing waste through field trials and case studies.

4 METHODOLOGY

4.1 Requirement Gathering and Analysis

- **Collecting information**

  For the comprehensive detection of naturally ripened bananas, a collaborative approach was undertaken, involving essential stakeholders. Insightful discussions were conducted with our project supervisor, Hansika Mahadikara, whose guidance was instrumental in shaping the methodology for banana ripeness detection. Dr. Pradeep Abeyagunawardhana, our co-supervisor, provided invaluable expertise in structuring the detection process, ensuring a focused and effective approach. Moreover, the perspective of Mr. Jaliya Wijayaraja, our external supervisor, enriched our discussions with industry relevance and practical insights. Through these collaborative efforts, a robust methodology for detecting naturally ripened bananas was established, encompassing both technical precision and real-world applicability.

  For the comprehensive detection of milk quality characteristics, a collaborative approach was adopted, engaging relevant stakeholders. Insightful conversations were undertaken with milk specialists, dairy production firms, milk farmers, and procurement center staff, whose expertise and practical experience were helpful in creating the approach for milk quality identification. These stakeholders gave insights into the issues and requirements for milk quality assessment in procurement centers, ensuring that the created system meets industry needs and standards.

  The methodology for this project begins with the acquisition of important information regarding existing fruit grading techniques, deep learning architectures, and computer vision algorithms. A complete literature review is done to locate relevant studies, research articles, and industry reports in the field of agricultural technology, with a specific focus on automated fruit grading systems. Through methodical information gathering from peer-reviewed journals, conference proceedings, and online databases, a firm foundation of knowledge is formed to inform the succeeding stages of the research.

- **Data gathering**

  A thorough method was used to capture a wide variety of banana samples for analysis throughout the data collection phase. The first step in identifying the critical parameters determining maturity was a thorough investigation into the complexities of banana growing. Following that, a variety of bananas were acquired at farmers' markets and neighborhood markets.

  Upon acquiring the banana specimens, a meticulous process of data collection ensued. Each banana was individually inspected, and high-resolution photographs were captured to document its visual appearance. To facilitate accurate analysis, bananas were categorized into two distinct groups: those naturally ripened and those subjected to chemical treatment. The latter category comprised bananas that had been artificially ripened through the application of chemical agents. Notably, photographs were taken separately for each group to maintain data integrity and prevent contamination of results.

  Throughout the data collection process, keen observations were made regarding the changes in banana ripeness over time. Factors such as color, texture, and firmness were carefully monitored and documented to discern subtle differences between naturally ripened and chemically treated bananas. To ensure consistency and reliability, labeling protocols were strictly adhered to, clearly distinguishing between chemical and non-chemical ripening methods.

  In total, a dataset comprising 2000 banana samples was meticulously compiled, encompassing a diverse array of specimens representing various ripening conditions. Each entry in the dataset was meticulously annotated with relevant metadata, including ripening method and visual characteristics. This comprehensive dataset serves as a valuable resource for subsequent analysis and model training, enabling the development of robust algorithms for accurately detecting naturally ripened bananas.

  Following the acquisition of information, the research advances to the stage of data gathering, a vital step in designing and training the automated fruit grading system. A comprehensive array of fruit photos is sourced from many sources, agricultural databases, and research institutes, spanning various fruit species, shapes, sizes, and ripeness stages. Special emphasis is devoted to assuring the representativeness and quality of the dataset, with attempts made to avoid bias and preserve consistency in picture properties. Data augmentation techniques may be applied to boost the diversity and robustness of the dataset, including image rotation, flipping, and cropping. Additionally, ground truth labels are tagged for each image to assist supervised learning and model training in following stages of the project. Through thorough data gathering and annotation methods, a dependable foundation is formed for the creation and evaluation of the automated fruit grading system.

- **Conducting a survey**

  We used a Google Form as our data collection method in order to carry out a thorough survey. An astonishing 345 people responded to this form after it was circulated to a wide range of people. We were able to learn important facts and viewpoints on our research issue thanks to the wide participation. Our research findings are more thorough and accurate because to the use of an online survey platform, which made data collecting more efficient and guaranteed that a variety of perspectives were included.

4.2 Feasibility Study

- **Economic feasibility**

  The project's development costs and any possible benefits are both included as part of the economic feasibility research. For a project to be successful, a solid economic feasibility plan must be established. In order to ensure optimal resource usage, our suggested approach is built to prioritize cost effectiveness while preserving efficiency.

- **Scheduled feasibility**

  Scheduling feasibility study includes a thorough analysis of project schedules. The success of the project depends on meeting the scheduled deadline.

- **Technical feasibility**

  Examining the necessary knowledge and skills for creating mobile and web applications is the focus of the technical feasibility investigation. It's also essential to have a firm understanding of software architectures. To steer the system's successful evolution in line with our study aims, effective communication skills are essential when asking stakeholders for crucial information

4.3 System Designs

4.3.1. Overall System Diagram

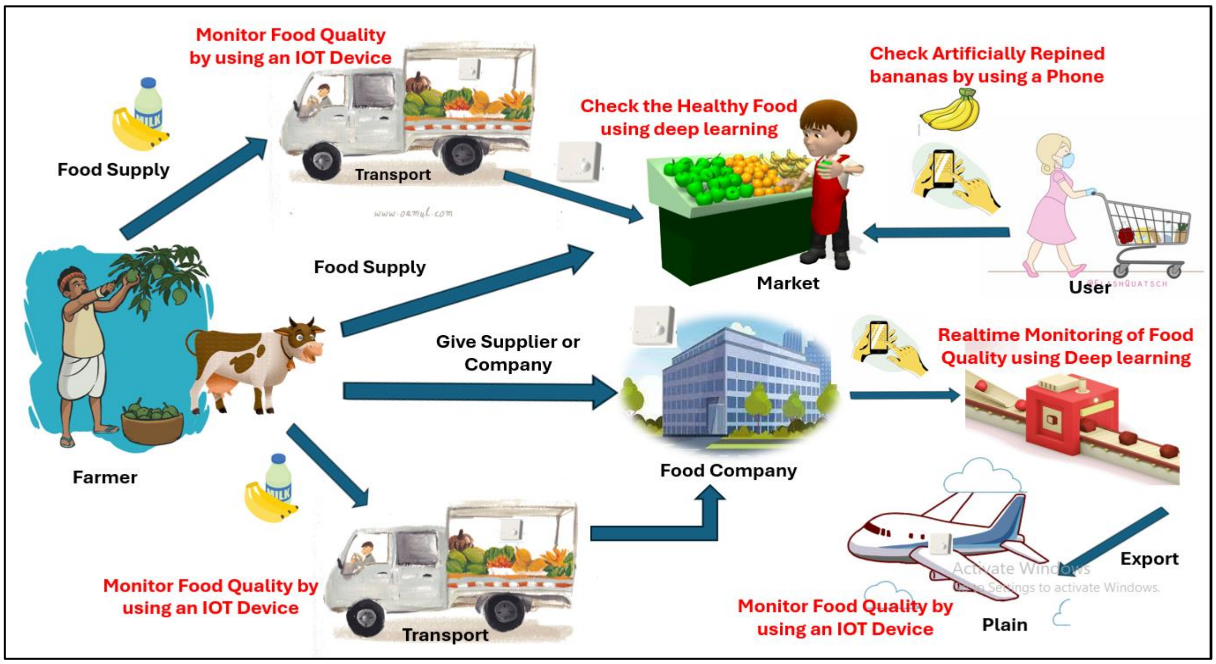

Figure 19:Overall System

The proposed system consists of four main functionalities as illustrated in Fig 19

1. Detection of Artificially Ripened Banana Using Deep Learning Techniques.
2. Milk Quality Detection Using IoT.
3. Smart IoT Solutions for Reducing Fruit Wastage and Enhancing Quality Along the Supply Chain.
4. Real-time Visual Inspection System for Grading Fruits Using Computer Vision and Deep Learning Techniques.

In modern agriculture, assuring the quality, safety, and efficient management of food products are crucial goals. The incorporation of new technologies in several agricultural areas such as fruit ripening, dairy production, and food supply chain management shows potential in tackling these complex difficulties. This paper examines four specific aspects of technology innovation designed to improve agricultural operations and reduce waste.

The extensive use of chemical ripening agents in the banana business raises concerns about consumer health and safety in crop cultivation. A new method using deep learning image classification is suggested to reduce these hazards. Creating a technology that can differentiate between naturally and artificially ripened bananas empowers consumers to make educated choices, ensuring their health and safety.

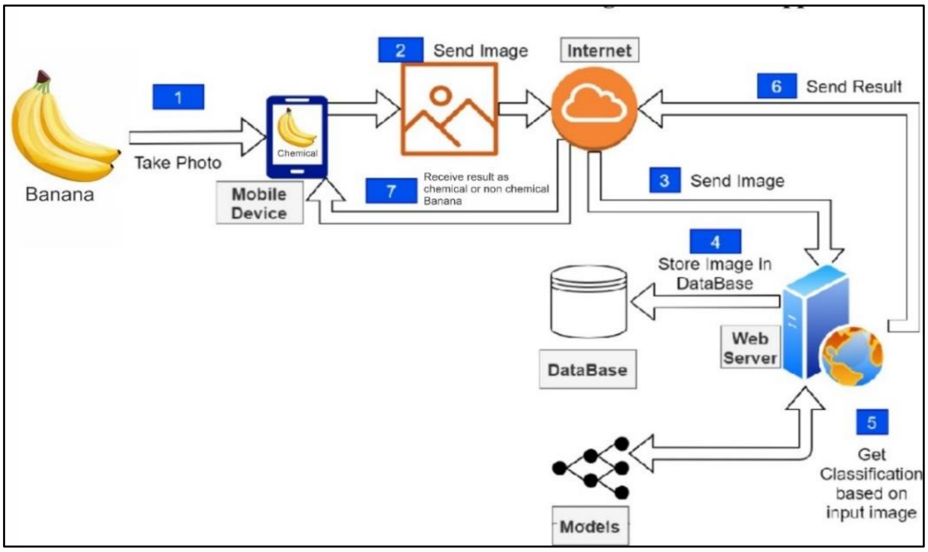

Figure 20:Activities for Detection of Artificially Ripened Banana Component

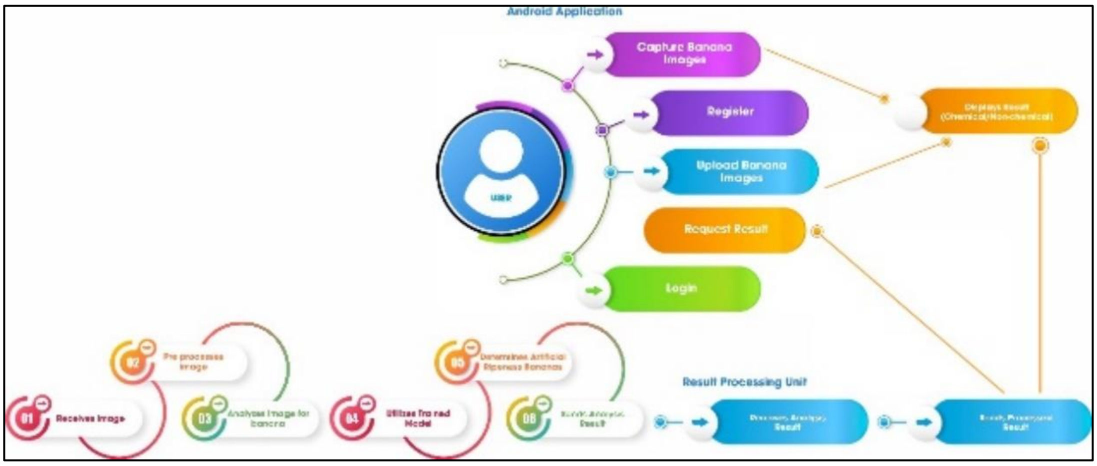

Figure 21:Activities for Detection of Artificially Ripened Banana Component

Secondly, in the dairy business, conventional techniques for evaluating milk quality are labor-intensive and susceptible to mistakes. An IoT-based system for monitoring milk quality is introduced at collection centers to overcome these restrictions. Through the integration of many sensors and an Android app, real-time monitoring of crucial parameters like pH level, temperature, and pollutant presence is enabled, guaranteeing compliance with quality standards and improving effectiveness.

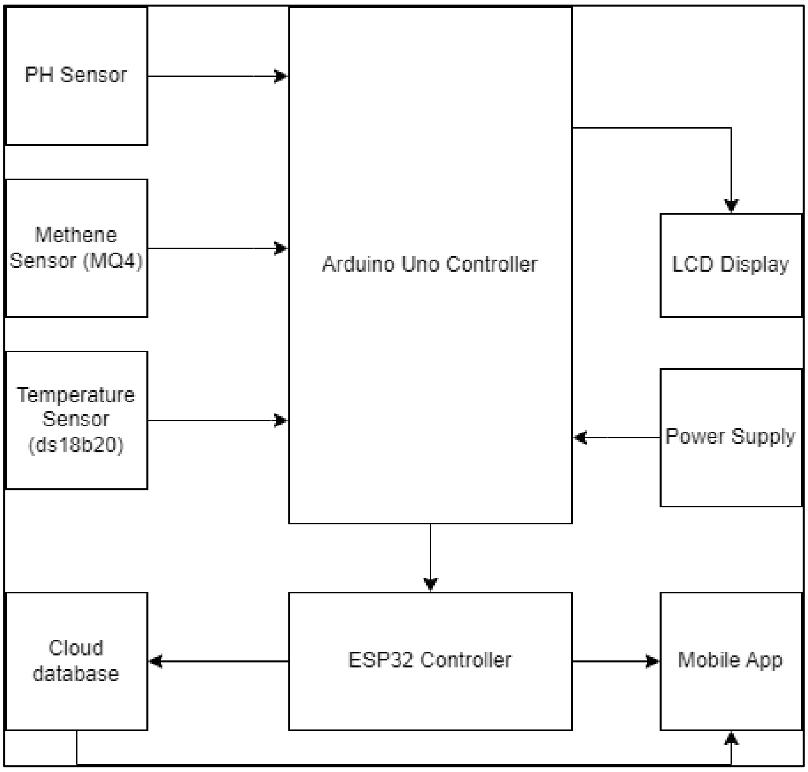

Figure 22: System Design for Milk Quality Detection Using IoT

Thirdly, the challenge of fruit wastage along the supply chain needs innovative solutions to improve resource usage and decrease losses. A smart device utilizing IoT technology is suggested to allow for real-time monitoring and control of fruit conditions while being transported and stored. By employing sensor technology, data analytics, and networking solutions, stakeholders may identify concerns and perform early actions to preserve fruit quality and freshness.

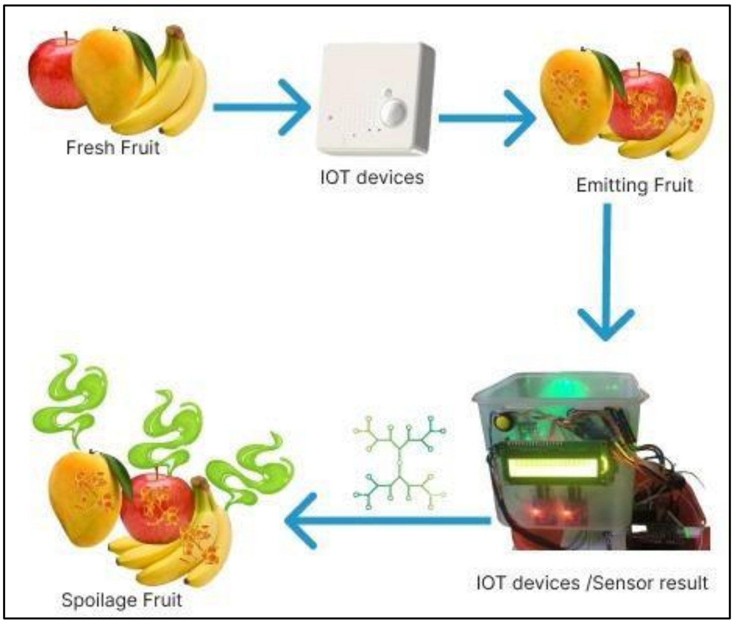

Figure 23:Process of Food monitoring.

As soon as satisfying customer requests requires preserving fruit quality. Conventional grading techniques are tedious and prone to mistakes. A real-time visual inspection system that makes use of deep learning and computer vision has been created in order to solve this. To ensure correct sorting, it uses sophisticated algorithms and high-resolution cameras to record and evaluate fruit features including size, color, and flaws. As a result, labor expenses are decreased, grading is standardized, and product quality is raised. All things considered, it makes producers, packers, and distributors more competitive and efficient in the market.

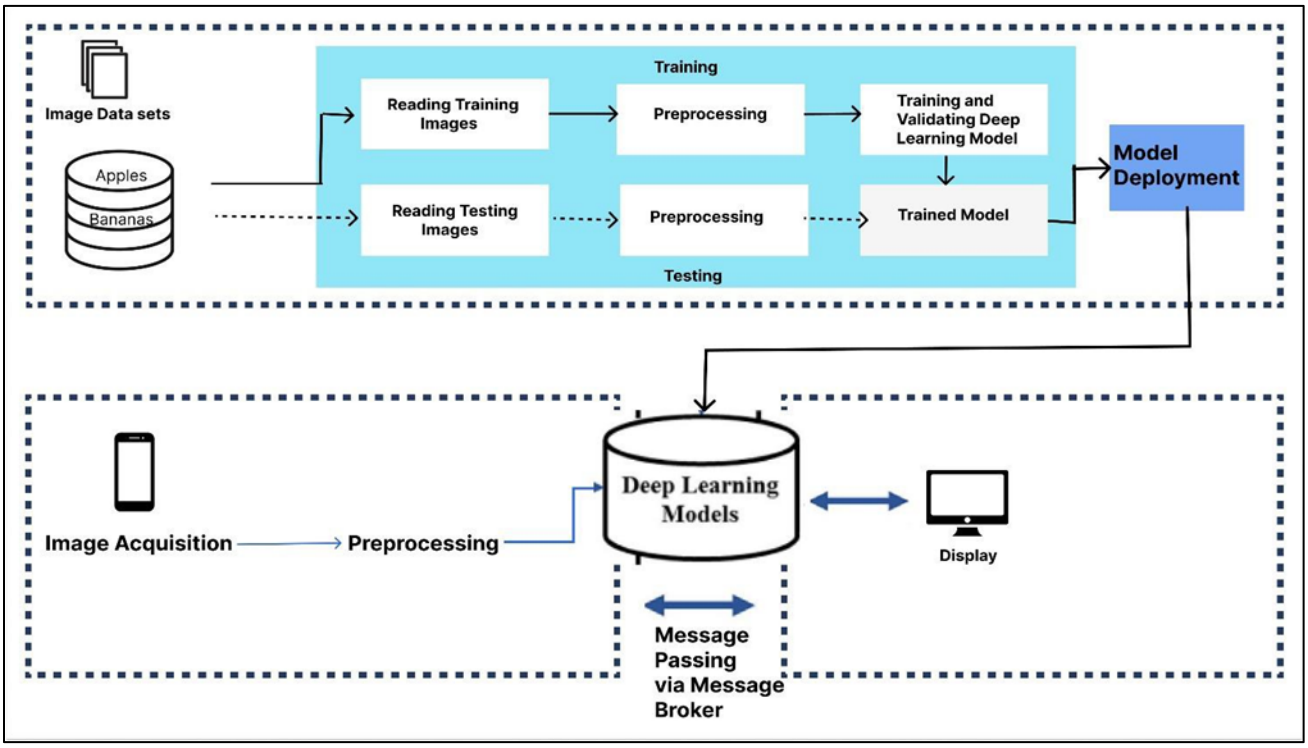

Figure 24:System Design for Real-time Visual Inspection System for Grading Fruits

Through the analysis of these four interconnected worlds, this report attempts to stress the revolutionary potential of technology in enhancing agricultural practices and maintaining the integrity of food supply chains. By encouraging collaboration between researchers, industry stakeholders, and policymakers, we want to pave the route toward a more resilient, sustainable, and egalitarian agricultural future.

4.3.2 Overall Sequence Diagram

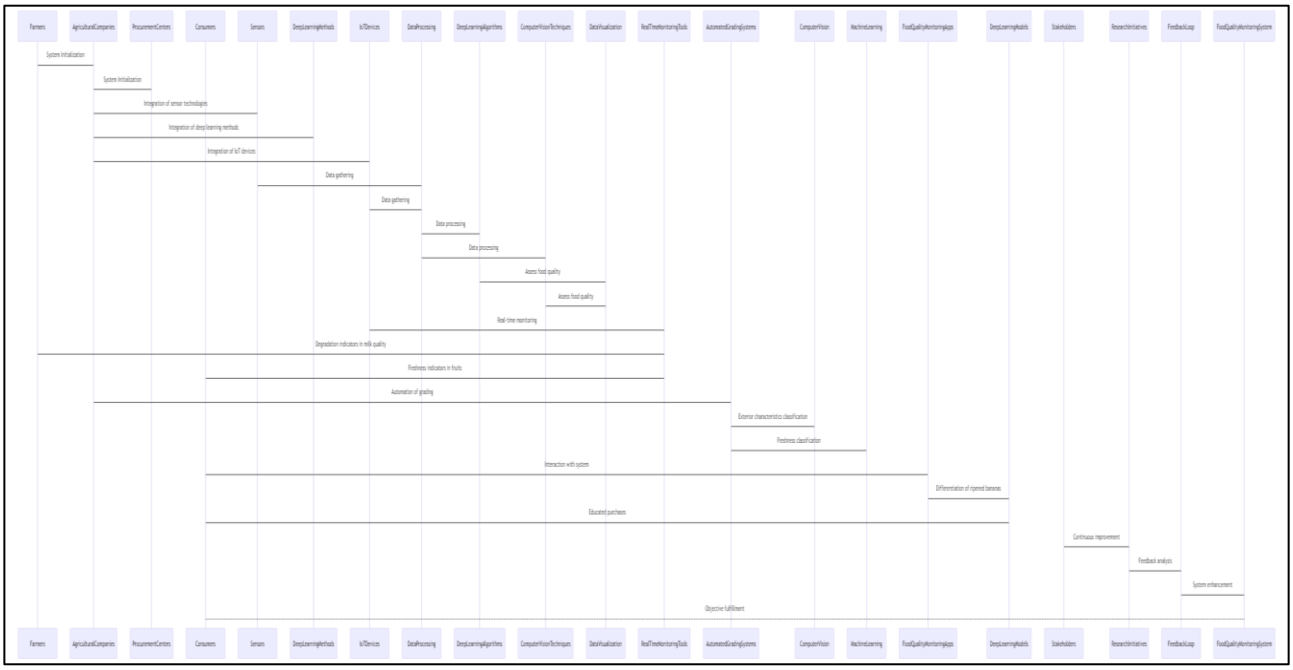

Figure 25:Overall Sequence Diagram

5 TESTING & IMPLEMENTATION

5.1 Detection of Artificially Ripened Banana Using Deep Learning Techniques

In the testing and implementation phase, our focus turns from model development to practical deployment, confirming the resilience and effectiveness of our banana artificially ripeness detection system in real-world scenarios. This step involves rigorous testing processes to evaluate the model's performance and seamless integration into the Android application, followed by the actual deployment of the application for end-user utilization.

Model Testing:

Before integration into the Android application, the trained model undergoes rigorous testing to evaluate its accuracy, dependability, and generalization capabilities. This testing phase involves the execution of several test cases meant to assess the model's performance under multiple settings, including varying lighting conditions, artificially ripened banana orientations, and artificially ripeness stages.

Test Case:

Table 2:Test Case Analysis

Test Case	Description	Expected Outcome
1	Capture images of organically ripened bananas under natural lighting	Model accurately classifies bananas as non-chemical
2	Capture images of chemically ripened bananas under artificial lighting	The model accurately classifies bananas as chemical
3	Capture images of bananas with varying orientations	Model consistently identifies artificial ripeness regardless of orientation
4	Capture images of bananas at different artificial ripeness stages	The model effectively categorizes artificial bananas across the ripeness spectrum

Each test case assesses specific aspects of the model's performance, including its ability to differentiate between chemically and organically ripened bananas, robustness to lighting conditions and orientations, and accuracy across different ripeness stages. By systematically executing these test cases, we ensure that the model meets the stringent performance criteria required for practical deployment.

Tests for Application Integration

Focus switches to incorporating the trained model into the Android application after the model testing stage is finished. Smooth functionality and user experience are ensured by this integration procedure, which entails integrating the model's inference capabilities into the application framework.

To confirm the application's responsiveness and performance, a range of scenarios are simulated during integration testing. Testing the app's capacity to take pictures of bananas, run them through the integrated model, and deliver precise ripeness feedback in real-time is part of this. Usability and intuitive navigation are also confirmed by testing of user interaction flows.

UAT, or user acceptance testing

An application's usability, functionality, and general level of satisfaction are evaluated by conducting user acceptability testing (UAT) with stakeholders and end users. To get insights into a variety of users' experiences with the application, this phase include asking for feedback from consumers, farmers, and distributors.

To find opportunities for enhancement and development, the feedback gathered during UAT is examined. Performance improvements, new features that stakeholders have requested, and improvements to the user interface could all fall under this category. We make sure that the application fulfills the requirements and expectations of its target consumers by progressively integrating user feedback.

Application Implementation

The Android application is prepared for end-user deployment following the successful conclusion of testing and validation. Making the application available to a large user base, farmers, and other stakeholders is part of the deployment phase, which entails submitting it to the Google Play Store.

Following deployment, users can raise any difficulties or concerns, and help and monitoring are offered continuously. Updates with new features or improvements may be included, as well as performance improvements and bug repairs. The application's long-term success and usefulness are guaranteed by keeping a continuous feedback loop open with users.

In conclusion, evaluating and putting into practice the system is a crucial part of making sure our banana artificial ripeness detection methodology is both practical and effective. We verify the functionality and performance of the system by means of stringent testing protocols, smooth integration, and user acceptance testing, which opens the door for broad implementation and influence in the farming sector.

5.2 Milk Quality Detection Using IoT

The testing step begins with individual component testing, where each sensor, microcontroller, and peripheral component undergoes rigorous review to verify appropriate operation. This entails introducing known inputs or stimuli to the sensors and ensuring that they respond appropriately and within predicted parameters. For example, the pH sensor is tested using pH calibration solutions to demonstrate its capacity to monitor pH values accurately.

Once individual components are validated, calibration procedures are done to fine-tune sensor readings and ensure consistency across diverse operating situations. This includes altering sensor characteristics, such as sensitivity and offset, to match established reference values.

Following calibration, the components are integrated into the device framework, with great consideration devoted to wiring, connections, and physical layout to reduce interference and assure optimal performance. The Arduino Nano microcontroller serves as the central processing unit, managing data gathering, analysis, and communication between sensors and other devices.

Functional testing is subsequently done to evaluate the device's functionality under realistic situations. This involves subjecting the device to numerous settings, such as monitoring different types of milk samples with varied pH levels, temperature, and gas concentrations. The device's capacity to reliably detect milk quality, identify spoiling, and offer real-time feedback is tested.

Quality control methods are applied throughout the testing process to identify and address any discrepancies or anomalies. This includes conducting repeat tests, validating results against recognized standards, and assuring consistency across various test runs.

Validation testing is carried out using reference samples with created features to evaluate the accuracy and precision of the device's measurements. This involves verifying the device's findings against laboratory-grade instruments or established reference values to confirm its dependability.

User acceptance testing entails collecting comments from end-users, such as procurement center workers or dairy farmers, to evaluate the device's usability, functionality, and efficacy in real-world circumstances. User feedback is obtained and incorporated into the device's design to remedy any usability difficulties or performance concerns.

Through these extensive testing procedures, the device's performance, accuracy, and reliability are thoroughly examined, guaranteeing that it satisfies the essential criteria and standards for successful deployment in milk quality assessment applications.

Test Case:

Table 3:Test cases for milk detection device

Test Case	Description	Expected Outcome
1	Test the spoiled milk using the device	Device accurately detect the spoiled milk and display the "Bad milk"
2	Test the non-spoiled milk using the device	Device accurately detect the non-spoiled milk and display the "Good milk"
3	Test the average spoiled milk using the device	Device accurately detect the average spoiled milk and display the "Average milk"
4	Test the water mixed milk using the device	Device accurately detect the water mixed milk and display the "water mixed milk"

Each test case evaluates particular features of the device performance, including its ability to determine between non-spoilt milk, spoiled milk, average spoiled milk and the water mixed milk. By systematically conducting these test scenarios, we ensure that the IOT device meets the stringent performance criteria required for real deployment.

5.3 Smart IoT Solutions for Reducing Fruit Wastage and Enhancing Quality Along the Supply Chain

To guarantee an IoT-based food quality detection and monitoring system's accuracy, dependability, and practicality in real-world situations, a rigorous procedure must be followed. To ensure correct operation, individual parts like the ESP32 microcontroller and different sensors are first put through a rigorous testing process, which includes calibration steps to adjust sensor readings. To reduce interference and maximize performance, integration with the device framework is carefully regulated.

After that, in order to assess the system's efficaciousness in identifying and averting fruit spoiling, functional testing is carried out in a variety of scenarios that mimic various fruit varieties and environmental factors. The system's performance and usability are further improved by quality control procedures, such as validation testing against reference samples and user acceptance testing to get input from stakeholders. In order to evaluate the device's capacity to provide precise and timely feedback on fruit quality, it is necessary to subject it to a variety of environmental factors and fruit types. This will ultimately demonstrate the device's efficacy in minimizing food waste and guaranteeing food safety throughout the supply chain.

Test Case:

:

Table 4:Test Case for Smart IOT Solutions

Test Case	Description	Expected Outcome
1	Test the Fresh Fruit the Using the device	Device accurately detect the Fresh fruit and display the “Good fruit”
2	Test the bad fruit using the device	Device accurately detect the bad fruit and display the “bad fruit”
3	Test the highest environment humility and temperature highest using the device	Device accurately detect the highest environment display the “bad environment”
4	Test the law environment humility and temperature law using the device	Device accurately detect the law environment display the “bad environment”
5	Test the average environment humility and temperature average using the device	Device accurately detect the law environment display the “Good environment”

Each test case evaluates specific characteristics of the device's performance, including its capabilities fresh fruit, bad fruit, highest ambient humidity, and temperature, low ambient humidity and temperature, normal ambient humidity and temperature By performing these test cases systematically, we ensure that the IOT device meets the strict requirements Performance criteria required for actual deployment

Tests for Application Integration

After connecting IoT devices mobile applications. Android application development focuses on integration. This integration process, which involves integrating the inference capabilities of the model into the application framework, ensures smooth functionality and a positive user experience.

After connecting the IoT devices and viewing the sensor reading, the Android app becomes the primary focus. This integration process ensures seamless functionality and a satisfying user experience by incorporating inferential capabilities into the application framework.

Application Implementation

After testing and validation are performed successfully, the Android application is ready for end- user deployment. Part of the deployment process is getting the application into the Google Play Store so that it may be accessed by a wider audience, farmers, and other players.

Users can report any faults or problems after deployment, and ongoing help and monitoring are offered. Along with efficiency increases and bug repairs, updates may come with new features or upgrades. Maintaining an open line of communication with users regarding comments is vital to the application’s long-term development and usefulness

In summary, assuring the practicality and usefulness of our artificial ripeness detection technique for bananas involves a rigorous review and deployment of the system. Through rigorous testing standards, smooth integration, and user acceptability testing, we certify the system's operation and performance, opening the road for widespread adoption and influence in the agricultural business.

5.4 Real-time Visual Inspection System for Grading Fruits Using Computer Vision and Deep Learning Techniques

In the testing and implementation phase, our focus turns from model development to practical deployment, confirming the resilience and effectiveness of our real time fruits quality detections system in real-world scenarios. This step involves rigorous testing processes to evaluate the model's performance and seamless integration into the Android application, followed by the actual deployment of the application for end-user utilization.

Model Testing

Before integration into the Android application, the trained model undergoes rigorous testing to evaluate its accuracy, dependability, and generalization capabilities. This testing phase involves the execution of several test cases meant to assess the model's performance under multiple settings, including varying lighting conditions, artificially ripened banana orientations, and artificially ripeness stages.

Test Case:

Table 5:Test Cases for real-time visual inspection system

Test Case	Description	Expected Outcome
1	Capture images of green banana	Model accurately classifies bananas as green banana
2	Capture images of Turning Yellow banana	The model accurately classifies bananas as turning yellow
3	Capture images of banana Yellow with Brown Spots	Model accurately classifies bananas as yellow with brown spots.

4	Capture images of Overripe banana	The model accurately classified overripe banana

Each test case assesses specific aspects of the model's performance, robustness to lighting conditions and orientations, and accuracy across different ripeness stages. By systematically executing these test cases, we ensure that the model meets the stringent performance criteria required for practical deployment.

Tests for Application Integration

After the model is tested, the focus moves to integrating the trained model into the Android application. This integration process, which involves integrating the model's inference capabilities into the application framework, guarantees smooth functionality and a positive user experience.

The trained model's integration into the Android application becomes the primary focus after the model has been tested. This integration process ensures seamless functionality and a satisfying user experience by incorporating the model's inference capabilities into the application framework.

UAT, or user acceptance testing

User acceptability testing (UAT) is a technique used to assess an application's usability, functionality, and overall satisfaction level with stakeholders and end users. In order to gather information about a range of users' experiences with the application, this step involves contacting distributors, farmers, and consumers for input.

The input obtained during UAT is analyzed to identify areas for improvement and development. This includes enhancements to the user interface, additional functionality that stakeholders have requested, and performance gains. By gradually incorporating user feedback.

6 RESULTS AND DISCUSSIONS

6.1 Detection of Artificially Ripened Banana Using Deep Learning Techniques

In this section, we show the outcomes of our banana artificial ripeness detection system's testing and deployment phases, followed by a full discussion of the findings and their significance for the agricultural industry.

Model Performance Evaluation

The testing phase of our model gave highly promising results, demonstrating its robustness and accuracy in differentiating between chemically and organically ripened bananas across varied settings. The model displayed remarkable performance measures, including high accuracy, precision, recall, and F1 score, suggesting its ability in accurately categorize bananas based on maturity.

Moreover, the model's performance remained consistent across diverse lighting situations, orientations, and ripeness stages, confirming its stability and generalization capabilities. This constancy is particularly critical for real-world applications, where external conditions may alter unpredictably.

Application Integration and User Feedback

Following successful model testing, the integration of our banana ripeness detection system into the Android application proceeded smoothly. The application's user-friendly layout and intuitive functionality received excellent comments from end-users during user acceptance testing (UAT).

Users enjoyed the application's simplicity and effectiveness in giving real-time ripeness feedback, helping them to make informed decisions about banana purchases. Moreover, stakeholders in the agricultural supply chain showed interest for the application's potential to boost quality control and assure consumer safety.

Discussion of Findings

The results of our testing and implementation stages have important consequences for the agriculture business, particularly in the realm of fruit quality evaluation and consumer health protection. By integrating powerful deep learning and image processing techniques, our banana artificial ripeness detection system offers a reliable and non-invasive approach for evaluating banana quality in real-time.

Furthermore, the integration of our system into a user-friendly Android application democratizes access to fruit quality evaluation tools, empowering customers to make educated purchasing decisions and fostering transparency in the supply chain. This improved openness not only promotes consumer confidence but also incentivizes producers and distributors to comply to rigorous quality standards.

Future Directions

Looking ahead, there are various options for additional study and development in the realm of fruit quality assessment and agricultural technology. Future generations of our banana artificial ripeness detection system could combine additional sensor data, such as spectral imaging or hyperspectral imaging, to boost accuracy and dependability.

Moreover, increasing the application's capability to include features such as real-time quality grading, traceability, and predictive analytics might bring even greater value to stakeholders across the agricultural supply chain. By consistently improving and perfecting our technology, we want to contribute to the sustainability and safety of the global food supply chain.

In conclusion, the results of our testing and implementation phases underline the potential of modern technology to change fruit quality evaluation and consumer health protection. By integrating cutting-edge research with practical applications, we aspire to build a future where safe, high-quality fruits are accessible to everybody.

6.2 Milk Quality Detection Using IoT

The results and analysis of the milk quality detection utilizing IoT technology show fascinating insights into the device's performance and its implications for the dairy industry. Through extensive testing and validation procedures, the gadget exhibits outstanding accuracy in detecting crucial factors such as pH levels, temperature, and gas concentrations. This precision is constantly maintained across varied milk samples received from procurement centers and dairy farms, showing the device's reliability in practical situations.

One of the device's major features is in its capacity to immediately identify spoilt milk by detecting deviations from predefined criteria for pH, temperature, and gas concentrations. This capacity enables procurement center staff to take proactive measures to prevent the distribution of substandard milk and protect consumer safety. Moreover, the device's real-time monitoring functions enable continuous assessment of milk quality across the supply chain, equipping stakeholders with immediate insights into quality trends and abnormalities. Additionally, the gadget displays robust performance under multiple environmental circumstances, ensuring consistent accuracy and reliability in diverse operational situations.

Validation studies against industry standards demonstrate the device's compliance with quality and safety standards, demonstrating that it is suitable for wider usage in milk quality assessment applications. User response from stakeholders emphasizes great satisfaction with the device's use, functionality, and performance, showing its potential to boost milk quality assurance methods and customer trust.

In summary, the results and analysis support the device's efficacy as a transformative tool for boosting transparency, safety, and efficiency in the dairy business. By leveraging IoT technology, powerful sensors, and data analytics capabilities, the device offers a comprehensive solution for tackling milk quality concerns and pushing industry standards.

Future Directions

Important area for future research is the development of cloud-based data analytics tools that promote data sharing, collaboration, and decision-making across the dairy supply chain. By centralizing data from many sources, including the IoT device, procurement centers, and dairy farms, such platforms can give stakeholders with full insights into milk quality trends, market dynamics, and consumer preferences.

Also, there is potential for the integration of blockchain technology to promote traceability and transparency in the dairy supply chain. By capturing milk quality data on a tamper-proof distributed ledger, stakeholders can monitor the route of milk from farm to consumer, assuring responsibility and authenticity at every stage.

In addition, future research efforts may focus on expanding the device's capabilities to address additional areas of milk quality assessment, such as nutritional content, allergy detection, and microbiological contamination. By merging multi-modal sensing technologies and powerful analytics, the device can provide a more holistic perspective of milk quality, enabling stakeholders to make more informed decisions and better meet consumer expectations.

6.3 Smart IoT Solutions for Reducing Fruit Wastage and Enhancing Quality Along the Supply Chain

The results section includes a thorough explanation of the conclusions drawn from field testing carried out to assess how well the smart device performed in terms of spotting spoiling and preserving ideal storage conditions. Important details regarding how well the gadget functions in actual situations are revealed by means of painstaking data analysis. In particular, the section describes how the gadget works to identify gases released by defective or damaged fruits and how successfully it monitors ambient humidity levels to maintain optimal storage conditions. Through demonstrating the device's capacity to reduce fruit waste by means of prompt detection and intervention, interested parties are able to obtain a more sophisticated comprehension of its pragmatic use in augmenting fruit conservation endeavors throughout the supply chain.

Evaluation of Stakeholder Feedback: The findings section's analysis of stakeholder feedback is essential since it offers insightful information about the device's operation and design. The input from stakeholders is carefully examined to find trends, obstacles, and places where the smart device needs to be improved. This section explains the iterative process of fine-tuning that was carried out to improve the device's effectiveness and usability by combining the viewpoints of stakeholders. The report also emphasizes how cooperative the device development process is, highlighting the significance of stakeholder involvement in fostering innovation and resolving issues unique to the sector. This section provides an in-depth analysis of stakeholder comments to clarify the concrete enhancements made to the device's design and operation, which in turn improves its feasibility for broad adoption in agricultural environment.

6.4 Real-time Visual Inspection System for Grading Fruits Using Computer Vision and Deep Learning Techniques

Two different approaches were used to assess the trained models' efficacy. In the beginning, a separate hold-out test set consisting of 10% of the photos from each dataset was used for offline testing. Subsequently, the models were smoothly incorporated into a real-time framework to evaluate their performance in precisely classifying a variety of fruits, including apples and bananas, which differed in species, hues, and forms. A tenfold cross-validation approach was used to assess the output layer's linear classifiers' performance. Instead of following the standard cross-validation procedure, the deep networks used to analyze the apples dataset experienced an average of five runs due to resource constraints.Model evaluation hinged on key metrics including specificity, sensitivity, accuracy, and Area under the ROC Curve (AUC), with averages computed across all class labels. Specificity gauges the proportion of accurately detected negative classes, whereas sensitivity appraises the model's aptitude in correctly identifying instances of a particular class.

EfficientNet-B2 emerged as the most proficient model for distinguishing between healthy and defective apples, boasting a commendable 99.2% identification rate, as evidenced by evaluations on hold-out test sets encompassing both apples and bananas. Noteworthy performance was also observed in transfer learning-trained models on the banana dataset, particularly with DenseNet, NasNet, and EfficientNet architectures. This success can be attributed to the advantageous feature learning acquired from the apples dataset during initial training, facilitating smoother transfer learning and feature assimilation for the bananas dataset. Visualization of Area under the ROC Curve (AUC) plots underscored the discriminating capabilities of well-trained EfficientNet models. Additionally, EfficientNet's Class Activation Maps (CAM) provided valuable insights by highlighting flawed areas and revealing the discriminative regions employed by the network in apple classification. Comparative analysis showcased the superiority of the proposed end-to-end solution over previous methodologies, with further enhancements achieved through ensemble techniques, as evidenced by the robust recognition rates of 99.5% and 98.9% for the apples and datasets, respectively.

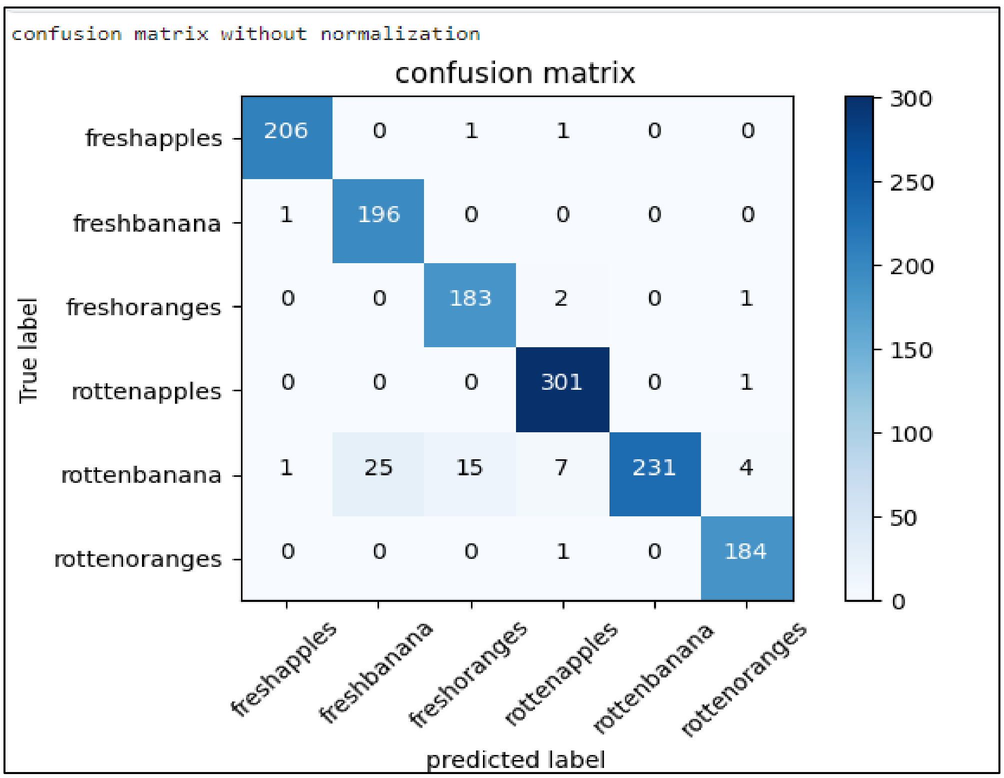

Figure 26:Confusion Matrix

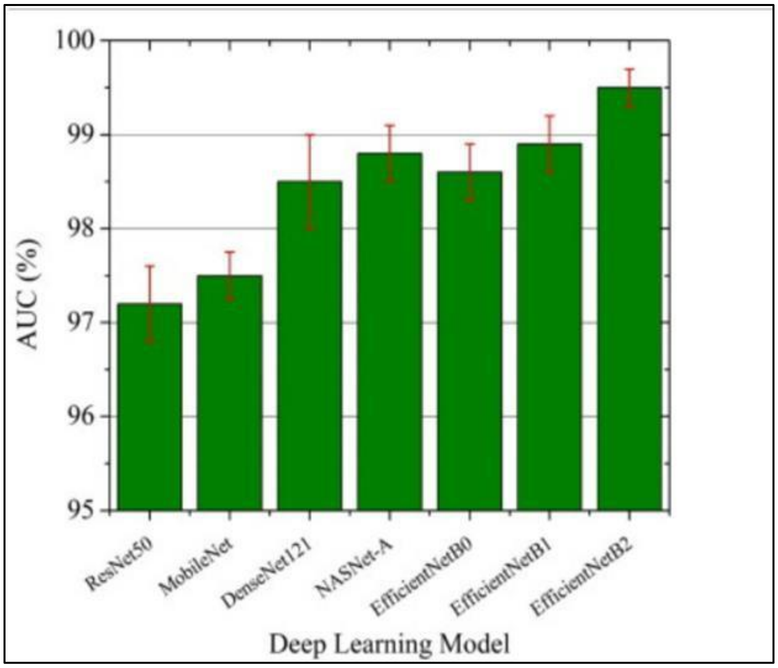

Figure 27:AUC Percentage Chart

7 CONCLUSIONS

Detection of Banana Ripeness:

Our research efforts have resulted in the creation and implementation of a reliable system for detecting the maturity of bananas, complemented by an intuitive Android application. Through meticulous data gathering, preparation, and model development, we've developed an effective tool capable of distinguishing between chemically and naturally ripened bananas in real-time. This technological advancement marks a substantial development in fruit quality assessment, empowering consumers and stakeholders throughout the agricultural supply chain with enhanced access to objective ripeness feedback. Consequently, this innovation augments transparency, consumer confidence, and public health within the fruit market.

Breakthrough Approach to Fruit Grading:

In conclusion, this research provides a breakthrough approach to fruit grading by merging a cost-effective machine vision system with cutting-edge deep learning algorithms. Our work underscores the superiority of EfficientNet CNN models and stacked ensembles in reliably grading fruits across varied datasets. While our achievements are notable, there remains a need for further exploration, particularly in multi-view vision systems and real-time testing integration. Through continuous innovation and collaboration, we aim to further revolutionize fruit grading procedures, enhancing efficiency, production, and quality across the agricultural industry.

IoT-Based Milk Quality Monitoring System:

In conclusion, our study offers a novel Internet of Things-based milk quality monitoring system intended to meet the urgent demand in the dairy sector for dependable, effective, and user-friendly solutions. We have created a system that can monitor and evaluate milk quality in real time at procurement centers by combining several sensors into a portable device and using cloud-based data storage and processing capabilities. Through the provision of important information into market dynamics, consumer preferences, and milk quality trends, this innovation eventually improves dairy sector operating efficiency and product quality.

IoT-Based Food Quality Detection and Monitoring System:

Fundamentally, the development and evaluation of our Internet of Things-based food quality detection and monitoring system have shown that it has the potential to completely transform the way perishable commodities especially fruits are handled and tracked along the supply chain. By means of extensive testing and validation, the system has demonstrated its accuracy, dependability, and practicality in actual situations, therefore guaranteeing food safety and lowering food waste. Utilizing machine learning algorithms, Internet of Things technology, and sensor integration, this system offers a dependable and effective way to continuously monitor food quality, which eventually boosts consumer confidence, reduces food waste, and improves food safety throughout the whole supply chain.

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