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SMART DETECTION SYSTEM FOR PESTICIDE CONTAMINATION IN FRUITS AND VEGETABLES USINGIOT AND MACHINE LEARNING

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ABSTRACT
To grow more food for more people, people developed innovative techniques. These days, fruits and vegetables are essential for providing us with the nutrition and energy we require. But occasionally, chemicals are applied to aid in their growth. Our project's goal is to use an Arduino Mega 2560 microprocessor, which is integrated with an LCD display, spectral triad sensor, pH sensor, gas sensor, and buzzer, to identify pesticides in fruits and vegetables. The system uses real-time sensor data collection and Random Forest analysis powered by machine learning (ML) and the internet of things (IoT). The spectral triad sensor captures comprehensive spectral data while the gas and pH sensors monitor the presence of pesticides and acidity. Using the Random Forest method, the machine learning model examines the sensor data to identify potential pesticide contamination. The results are displayed on LCD in addition toa buzzer alert. This inventive invention enhances the efficacy and precision of pesticide identification in food, hence promoting food safety.

Keywords:
Machine Learning, IoT, Spectral Triad Sensor, Fruits and Vegetables.

I. Introduction
An essential part of guaranteeing food safety and public health is detecting pesticides in fruits and vegetables. In order to protect crops from pests and diseases, pesticides are an essential part of contemporary agricultural techniques. But if residues on food above safety limits, customers may be at risk. Thus, it is crucial to have precise and trustworthy techniques for identifying pesticide residues in order to keep an eye on and control their existence throughout the food chain. These techniques cover a broad spectrum of analytical procedures, such as molecular biology approaches, mass spectrometry, immunoassays, and chromatography. Scientists and government organizations may evaluate the amounts of pesticide residues in fruits and vegetables using these techniques, guaranteeing that regulations are followed and protecting the public's health. Furthermore, by keeping an eye on their effects on ecosystems and directing the adoption of sustainable agricultural methods, the detection of pesticide residues also helps to protect the environment. In the agriculture sector, detecting pesticides in fruits and vegetables is essential to preserving food safety, consumer trust, and environmental sustainability. A novel approach for the real-time monitoring and prediction of pesticide residue levels in agricultural products is revealed by utilizing the power of machine learning algorithms for analysis and Internet of Things sensors for data collecting. In order to guarantee food safety and regulatory compliance, this introduction gives an overview of how the combination of IoT and machine learning is revolutionizing the identification of pesticides in fruits and vegetables. It offers improved accuracy, efficiency, and proactive management techniques.

II. Literature
José Antonio Gabaldón [1] This study, which focuses on technique development, addresses the

creation and verification of immunoassay-based kits for quick pesticide detection in food samples. It looks at validation parameters, assay optimization, and useful factors to take into account when implementing kits in food safety monitoring systems.
Markus Lipp [2] An overview of PCR technology is given in this review, with an emphasis on its concepts and uses in agricultural biotechnology. It provides insights into the adaptability and usefulness of PCR in agricultural research by covering subjects like primer selection, amplification techniques, and PCR assay design.
Changlong Wang [3] A 2019 publication that described a quick way to detect pesticide residues in vegetable or water samples was based on a mini-colorimeter.
Pesticide residues in fruits and vegetables can be quickly identified with the help of a method described in a 2020 publication by Xia Sun [4]. This method is based on an amperometric acetylcholinesterase biosensor. Using the catalytic substrate of the acetylcholinesterase biosensor's electrochemical property, this device detected pesticide residues with precision. In order to design the data acquisition and processing circuit for the weak current signals of the biosensor, analyzing the prepared biosensor's cyclic voltammogram (CV) behaviour. Low-pass filtering, differential amplification, I/V conversion, A/D conversion, and other operations are included in this circuit.
The voltage signal that is ultimately produced is roughly 0.5V, which is commensurate to the tiny current that the enzyme biosensor is generating. Using the detecting technique, four different kinds of conventional pesticides were tested at various amounts.
Zhao jie [5] Collectively, these publications provide insights into the fundamentals, practical uses, and technological developments of multi-residue methods for pesticide analysis, with particular emphasis on the Quenchers sample preparation method and triple quadrupole mass spectrometry in gas chromatography. They offer useful data for your investigation into creating a quick and accurate technique for determining pesticide.
Shalini Gnanavel [6] proposed a system that would enable easy access to a wide variety of fresh fruits and vegetables due to India's diversified environment. China is in first place. second in the world for fruit production. India produced 90.2 million metric tons of fruits in 2018–19, based on the National Horticulture Database maintained by the National Horticulture Board. Among other fruits, India is the world's top producer of papayas (43.6%), mangoes (40.4%), and bananas (25.7%). Fruit quality has an impact on shelf life since fresh items are prioritized in supply chain management and post-harvest processing. Unfortunately, as bananas and mangoes are eaten in ever- increasing amounts, they are artificially ripened. People could be gravely injured by the pesticides used in the production of these crops.
Wang Lili [7] The difficulties of assessing raspberry ketone in food matrices are discussed in this work, along with sample preparation, matrix effects, and analytical methods. It provides insights into raspberry ketone analysis and addresses methods for developing methods and resolving these issues.
Ivana Cesarino [8] The application-focused portion of this study addresses the use of electrochemical biosensors for monitoring food safety, which includes fruit and vegetable residue detection. Insights into the application of biosensor technology in actual environments are provided by examining pragmatic issues such sample preparation, on-site detection, and regulatory compliance."
Chang-Chi Lee [9] In 2023, A study was suggested to use color identification technology to create a pesticide residue testing system for fruits and vegetables. This research could accelerate and lower the cost of testing. The suggested system converts the pesticide concentration using a network camera and Raspberry Pi 3B. It then applies the Acetylcholinesterase (AChe) pesticide testing method to perform color identification processing.
S. Zhang et al [10] This review addresses the use of wireless sensor networks (WSNs) for agricultural product pesticide residue monitoring, while it does not only focus on IoT. It covers a wide range of topics, including data processing methods, sensor technology, and data transfer protocols. The research emphasizes how WSNs, which may be included into IoT frameworks, can be used to monitor pesticide levels in fruits and vegetables in real time.

M. Sharma et al [11] An Internet of Things-based system for tracking and identifying pesticide residues in fruits and vegetables is presented in this research. For the purpose of gathering data in real time on environmental factors including temperature, humidity, and pesticide levels, the system incorporates Internet of Things sensors. Pesticide residues are found by analysing the data and using machine learning techniques. The study shows how well the system. works to guarantee the quality and safety of food.
R Chandramma [12] 2020 has put up a model that implies it is difficult for the contemporary agricultural industry to export a sizable quantity of fruit to other nations. Farmers in this sector need manual examination. Our method saves farmers time and allows them to provide fresh produce as soon as it is practical by identifying diseases in fruits and vegetables and assisting them in packing their items as rapidly as possible. We use the CNN algorithm to diagnose ailments and identify fruits and vegetables. A neural network is used to segment the image first, and subsequently specific attributes are retrieved. The image of the fruits and vegetables has finally been discovered and given a name.
M. Sharma et al [13] An Internet of Things-based system for tracking and identifying pesticide residues in fruits and vegetables is presented in this research. For the purpose of gathering data in real time on environmental factors including temperature, humidity, and pesticide levels, the system incorporates Internet of Things sensors. Pesticide residues are found by analysing the data and using machine learning techniques. The study shows how well the system works to guarantee the quality and safety of food.
Archana B S [14] a paper about the daily life of humans was proposed in 2021. Fruits and veggies are necessary. As a result, their need is immense. To increase production Fruits and vegetables require a variety of toxicants to extend their shelf life. When applied frequently, these insecticides endanger both the environment and human health. Lists and analyses of the various techniques for determining which fruits and vegetables contain pesticides are the main objectives of this research. In addition to increasing efficiency, these techniques ensure the quality of fruits and vegetables.
Kingsley O. Omeje [15] This study addresses the significance of guaranteeing analytical accuracy and reliability in AAS analysis of heavy metals in food crops, with a focus on quality assurance and method validation. It investigates methods for proficiency testing, calibration techniques, and validation parameters to guarantee adherence to legal requirements.
B. Li et al [16] The creation of a portable Internet of things gadget with sensors to find pesticide residue in fruits and vegetables is presented in this research. The gadget processes and analyses data in real time using machine learning techniques. The study shows the device's potential for on-site pesticide residue testing and assesses how well it detects different kinds of pesticides.
Te'er Gai [17] This paper addresses the difficulties and viewpoints associated with quickly identifying pesticide residues in fruits and vegetables. It looks at new technologies with a focus on their potential for sensitive and quick detection, including spectroscopy, biosensors, and assays based on nanomaterials.

III. In - Place System

Historically, labor-intensive and time-consuming methods have been used to identify pesticides in organic fruits and vegetables. Sample extraction is usually the first step in these traditional methods, which are then followed by mass spectrometry and chromatographic methods like liquid or gas chromatography. These methods, however, are expensive and require certain tools and instruction. Furthermore, the turnaround time for results is frequently somewhat long. Most of the time, we use embedded systems for real-time monitoring of a variety of devices in our daily lives, including microwaves, calculators, TV remote controls, home security systems, and traffic control systems in our neighborhoods.

IV. Intended System

The recommended method for identifying pesticides in fruits and vegetables combines triad

spectroscopy, pH sensing, and gas sensing technologies, as shown in Figure 1. Pesticides are identified via triad spectroscopy, which measures light intensity at different wavelengths. Gas sensors and pH sensors measure gas concentrations and pH values respectively and using The Internet of Things (IoT) component of the hardware system design is where the three sensors pH, triad spectroscopy and gas sensor are used to detect the presence of pesticides in fruits that are sold in stores. The microcontroller, in this case an Arduino UNO, receives the sensed values after that. After the controller receives this data, the Wi-Fi module sends it to MATLAB Think Speak. The controller changes the values through the module to a channel that is formed in Think Speak. The pesticides are identified by averaging the values received from the controller following the introduction of the channel. Pesticides falling between the pH values of 6 and 20 are deemed unsafe for human consumption. As can be seen from the hardware design, the Arduino microcontroller powers the whole system, including the Wi-Fi module and all of the sensors. The data is then stored in the MATLAB Think Speak cloud storage. The collected data is fed into a Python-based system, which applies machine learning algorithms to process it. In the case that the algorithms detect pesticides, a buzzer is triggered for immediate notification under this proposed method. On the other hand, if pesticides are not detected, a good result confirming the safety of the produce is displayed on an LCD screen. This comprehensive, automated approach is being utilized to enhance pesticide monitoring and safeguard organic agricultural products. The recommended method for identifying pesticides in fruits and vegetables combines triad spectroscopy, pH sensing, and gas sensing technologies, as shown in Figure 1. Pesticides are identified via triad spectroscopy, which measures light intensity at different wavelengths. Gas sensors and pH sensors measure gas concentrations and pH values respectively and using The Internet of Things (IoT) component of the hardware system design is where the three sensors pH, triad spectroscopy and gas sensor are used to detect the presence of pesticides in fruits that are sold in stores. The microcontroller, in this case an Arduino UNO, receives the sensed values after that. After the controller receives this data, the Wi-Fi module sends it to MATLAB Think Speak. The controller changes the values through the module to a channel that is formed in Think Speak. The pesticides are identified by averaging the values received from the controller following the introduction of the channel. Pesticides falling between the pH values of 6 and 20 are deemed unsafe for human consumption.
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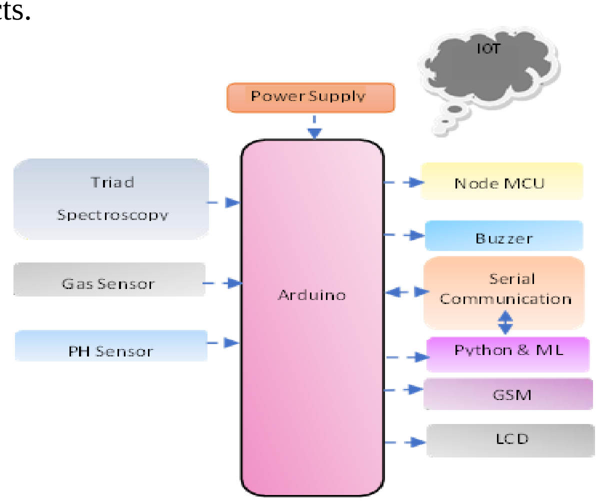

Figure 1: Block diagram of Proposed Model

V. methodology

In this Paper we have designed the Proposed Model which consists of Hardware and Software Technologies with it.

A) HARDWARE USED: -

Arduino Mega 2560

The Arduino Mega 2560 is based on the ATmega2560. is a microcontroller board. Its strong features, which include four hardware serial ports, sixteen analog inputs, and fifty-four digital input/output pins—four of which enable PWM make it an adaptable platform for a range of applications. It requires very little setup because it comes with a 16 MHz crystal oscillator, a USB connector, a power jack, an ICSP header, and a reset button. To get started with programming and experimenting, just plug it in using a USB connection to a computer, an AC-to-DC adapter, or a battery.

Triad Spectroscopy Sensor

By examining how materials interact with electromagnetic radiation, spectroscopy sensors are essential in many different fields. These sensors, which go by the name "triad," use three distinct methods, wavelengths, or sensing techniques to improve analysis and precision. Comprehensive investigation of the composition of substances is made possible by this triadic approach, which is advantageous for fields like food analysis, biology, chemistry, and environmental science.

Ph Sensor

A pH sensor is a device that measures the concentration of hydrogen ions in a solution and generates a signal that reflects the solution's acidity or alkalinity. It typically consists of a signal transmission component and a chemical sensor device. The output signal is represented digitally as a range of 0 to 14, where 7 represents neutrality. A greater number indicates alkalinity, while a lower amount indicates acidity. In industries, pH sensors are often used to assess materials such as solutions and water.

Gas sensor

There is a vast range of specifications for gas sensors based on physical dimensions, kind of gas to be sensed, sensitivity levels, and many other considerations. This insight looks at a methane gas sensor that can detect gases that methane may create, such ammonia. The detecting element assures the gas after it has been ionized into its constituent parts through interaction with the sensor. Through the output pins, the processing unit receives the potential difference created by this adsorption in the form of current.

Buzzer

Mechanical, electromechanical, and piezoelectric are the three categories of aural signaling devices. There are buzzers and beepers as examples of this. They are heavily utilized in alarm systems, timers, and user input confirmation (e.g., mouse clicks, keystrokes). Powered by a DC source, buzzers are electronic transducers that perform essential sound duties. Electronic toys, telephones, copiers, computers, alarm clocks, printers, copiers, and timers are among the devices that have them integrated.

Node MCU

Node MCU is a well-liked open-source platform with straightforward programming capabilities and Wi-Fi connectivity, built around the ESP8266 microcontroller. Because it combines the capabilities of a Wi-Fi module and microcontroller, it is perfect for Internet of Things (IoT) applications. Because Node MCU boards are small, inexpensive, and Arduino IDE compatible, developers may quickly prototype and implement Internet of Things applications using them. Due to its vast community support and abundant library and resource environment, Node MCU has emerged as the preferred option for Internet of Things enthusiasts and developers across the globe.

Lcd Display

Liquid Crystal Display (LCD) technology is utilized in LCD (16x2) displays, which are frequently seen in scratch pads and mini-PCs. Together with gas-plasma and light-emitting diode (LED) technology, LCDs allow for much thinner presentations than cathode ray tubes (CRT). LCDs are an energy-efficient option because they use a lot less electricity than gas and LED displays because they operate by blocking light rather than emitting it.

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B) SOFTWARE USED: -

Arduino IDE

The program of choice for writing, assembling and uploading code to Arduino devices is the Arduino IDE (Integrated Development Environment), which is made available by Arduino.cc. It's an open-source tool that works with a variety of Arduino modules and provides simple installation and code compilation. The Arduino IDE is a vital tool for Arduino fans and developers as it allows users to quickly build and deploy code for their projects.

Python IDLE

The IDLE (Integrated Development and Learning Environment) isa popular integrated development environment (IDE) for Python programming. IDLE is usually included by default in the Python installer for Windows, giving users access to a full programming environment. However, IDLE might not be included right out of the box in Linux Python distributions. Under these circumstances, users can install IDLE by utilizing the package managers compatible with their Linux distribution.

C) ALGORITHMS USED: -

Algorithm for Random Forest: Random Forest, a versatile ensemble learning algorithm, revolutionizes the landscape of supervised learning with its robustness and scalability. At its core, Random Forest leverages the power of ensemble learning by constructing multiple decision trees on different subsets of the dataset through a technique known as bootstrap aggregating (bagging). This process ensures diversity among the trees, mitigating the risk of overfitting and enhancing the model's generalization capabilities. Moreover, Random Forest introduces an additional layer of randomness by selecting a random subset of features at each node of the decision tree, further reducing correlation between trees and promoting robustness. The algorithm's predictive power lies in its democratic approach to decision-making, where each tree's prediction is given equal weight through a voting mechanism, culminating in an ensemble prediction that reflects the collective wisdom of the forest. Additionally, Random Forest offers flexibility through hyperparameter tuning, allowing practitioners to optimize performance based on specific dataset characteristics and modelling requirements. With its ability to handle high- dimensional data and complex relationships, Random Forest has found widespread applications across domains such as finance, healthcare, and bioinformatics, where accurate predictions are paramount.

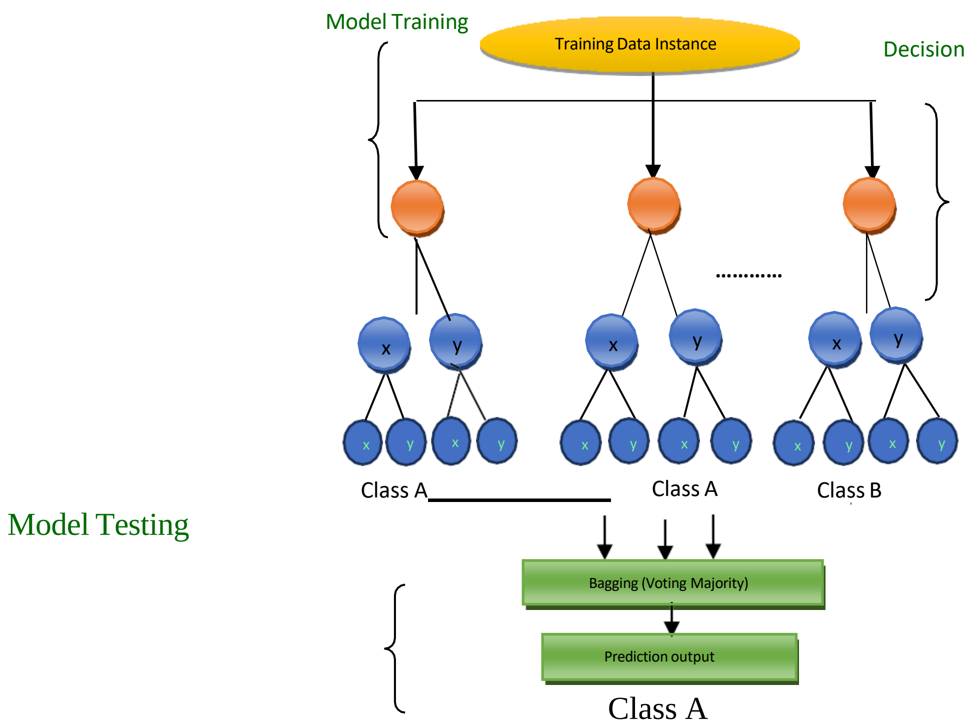

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Figure 2: Algorithm of Random Forest

IV. Implementation

The triad spectroscopic sensor is initially positioned in front of a fruit. The fruit is then scanned by the sensor. We monitor the pH with a pH sensor and look for any gas released by the fruit with a MQ135 sensor. The Random Forest approach is used in machine learning to create a dataset of fruit that is of a high caliber. It is feasible to compare the results obtained from the triad spectroscopy sensor with the previously created dataset. The ML will detect whether the fruit is good and display it on the LCD; if not, a buzzer will sound. First, we have to connect the port through the Arduino. Triad spectroscopy detects the chemical compositions of the fruit through the light intensity of wavelengths. Then the Ph and gas sensor says about the gas concentrations and the Ph values of the respected fruit. The dataset is created in the Python IDLE. The compositions are shown in the Python IDLE. Now checking the Random Forest algorithm to detect the fruit is of good quality or not. The Buzzer will be on if the quality of the fruit is containing the more amount of pesticides else the buzzer will be off.

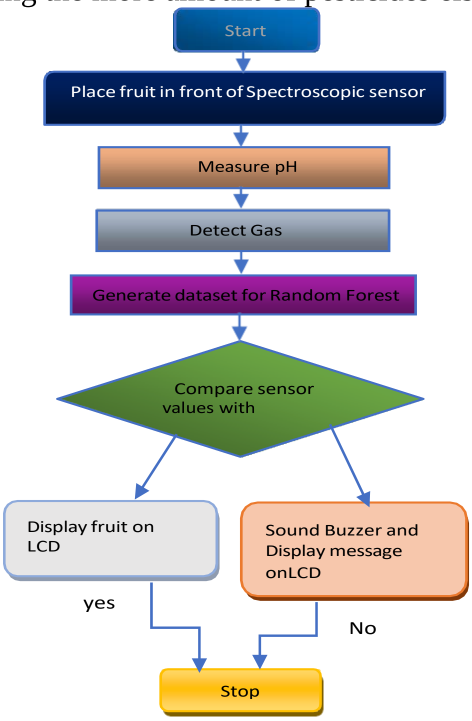

Figure 3: Flow Chart for Detection of Fruits

VII. Result and Output

In the experiment, a fruit was chosen, and the sensors were used to determine the amount of pesticides present in the chosen fruits and vegetables. The sensor output values were then shown in the Thing Speak application. Table 1 shows the comparing of all algorithms of the Logistic Regression, Decision Tree Classifier, Extra Trees Classifier, and KNN Classifier, the accuracy rates of the Logistic Regression, Decision Tree Classifier, Extra Trees Classifier, and KNN Classifier were 65%, 85.6%, 89%, and 90%, respectively. The chosen fruitis detected with a 92% accuracy rate for pesticides in fruits and vegetables using the Random Forest Method.

TABLE 1: Comparison Algorithms

Model Name	Accuracy	Precision
Logistic Regression	65%	0.777778
Decision Tree Classifier	85.6%	0.875000

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Random Forest Classifier	92%	0.916667
Extra Trees Classifier	89%	0.958333
K Neighbors Classifier	90%	0.913043

TABLE 2: Comparison Algorithms

Fruits	Sensors	Maximum Residue Level	Affected Output Value
	**PH Sensor** **Gas Sensor**	4-5.5 200-530	7.42 175
	**PH Sensor** **Gas Sensor**	4-5.5 200-530	5.95 179
	**PH Sensor** **Gas Sensor**	4-5.5 200-530	6.94 176
	**PH Sensor** **Gas Sensor**	4-5.5 200-530	14.06 164
	**PH Sensor** **Gas Sensor**	4-5.5 200-530	7.65 164
	**PH Sensor** **Gas Sensor**	4-5.5 200-530	6.94 166
	**PH Sensor** **Gas Sensor**	4-5.5 200-530	9.15 163
	**PH Sensor** **Gas Sensor**	4-5.5 200-530	5.95 182

The various factors taken into account for measuring pesticides in fruits and Vegetables are displayed in Table 2. In this instance, it has been determined by two sensors that the fruit is contaminated with pesticides. Produce's maturity and freshness, as well as the success of preservation techniques, can be assessed by keeping an eye on pH and gas levels.

```
Received data: 1.68,5.71,13.09,6.91,7.45,13.60,8.10,5.73,11.56,2.93,6.07,2.60,7.19
,7.96,7.79,0.00,2.82,0.00
prediction [1]
Random Forest predicts good.
Received data: 1.68,5.71,18.71,6.04,9.69,18.36,12.15,7.45,15.03,2.93,9.11,3.47,7.9
9,9.55,9.52,0.00,2.82,0.00
prediction [1]
Random Forest predicts good.
Received data: 4.20,24.73,56.12,40.57,28.31,26.51,21.99,21.79,36.99,17.07,15.18,4.
77,7.99,8.75,9.52,0.00,3.52,0.00
prediction [1]
Random Forest predicts good.
Received data: 4.20,19.97,39.28,16.40,23.10,26.51,17.36,15.48,24.28,9.27,11.13,4.7
7,8.79,9.55,12.12,0.00,4.23,0.00
prediction [0]
Random Forest predicts bad.
Received data: AT
Received data: AT+CMGF=1
Received data: ALERT...!
Received data: [illegible]
Received data: 4.20,18.07,37.41,14.67,20.12,25.15,13.31,13.19,20.81,8.78,10.12,4.3
4,7.99,9.55,9.52,0.00,3.52,0.00
prediction [0]
Random Forest predicts bad.
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Figure 4: Random Forest Algorithm Predicted Output

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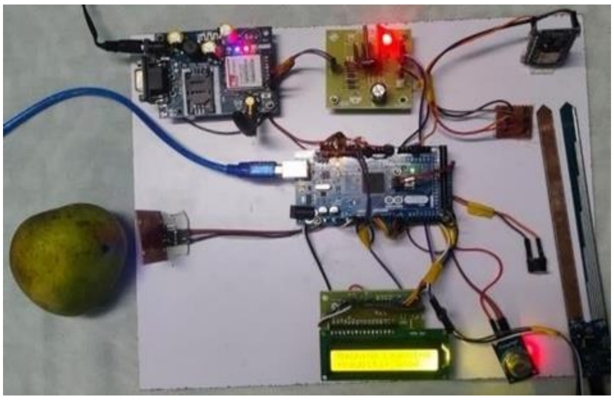

Figure 5: Machine Learning predicts good fruit in LCD

Figure.4 and Figure. 5 shows the produce and fruits that are impacted by pesticides. It is possible to compare the output from the trinity spectroscopy sensor with the dataset that was previously established. Using the Python IDLE and LCD display as a guide, the machine learning system will determine if the fruit is good or bad and provide the results on the LCD. The Random Forest Algorithm was utilized., which yield an accuracy rate of 92%, the impacted selected fruits and vegetables were able to determine whether the pesticides present were good or bad. Thus, it can be said that the chosen fruit is either Good or Bad.

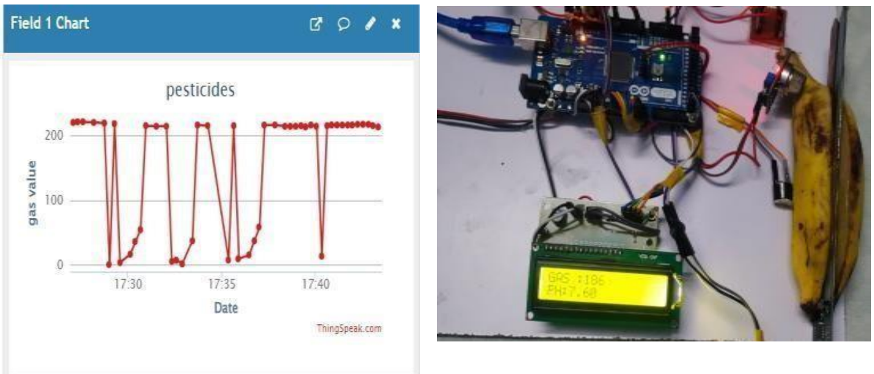

Figure 6: Gas Values

The creation of an appliance to measure the fruit's chemical composition. To determine the chemical, the individual is exposed to a sample that is placed in front of a sensor that detects gases. Figure 6. Shows the Pesticides Values presented in fruits and Vegetables by using Gas Sensor these values are stored in MATLAB Think Speak and shows the LCD Display.

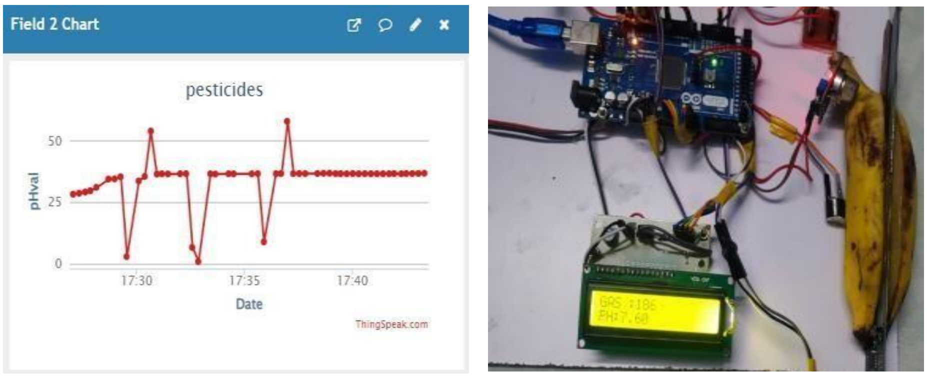

Figure 7: Ph Values

The identification of chemical levels at varying PH levels is displayed in Figure 7. The chemical level threshold. Here, the user receives an alarm message as soon as the chemical level rises above the threshold. Figure 6. Shows the Pesticides Values presented in fruits and Vegetables by using PH Sensor these values are stored in MATLAB Think Speak and LCD Display.

The identification of chemical levels at varying PH levels is displayed in Figure 7. The chemical level threshold. Here, the user receives an alarm message as soon as the chemical level rises above the threshold. Figure 7. Shows the Pesticides Values presented in fruits and Vegetables by using PH Sensor these values are stored in MATLAB Think Speak and shows the LCD Display.

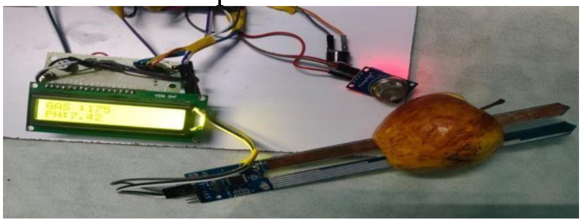

Figure 8: Machine Learning predicts PH and Gas Values in LCD

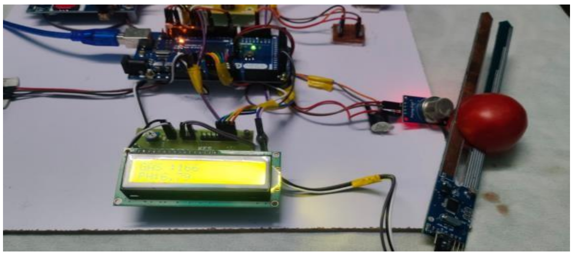

Figure 9: Machine Learning predicts PH and Gas Values in LCD

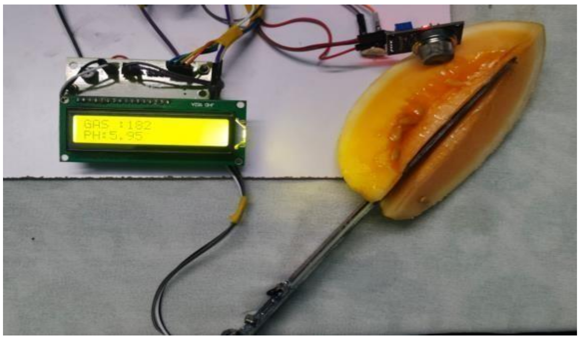

Figure 10: Machine Learning predicts PH and Gas Values in LCD

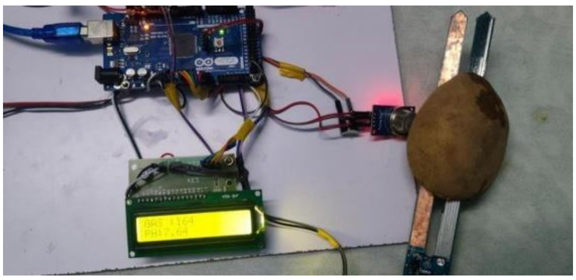

Figure 11: Machine Learning predicts PH and Gas Values in LCD

Above figures 8 -10 Fruit quality and freshness must be maintained at ideal pH and gas levels throughout the production and distribution process. Fruits usually grow best in a pH range of 3 to 5, with deviations indicating possible problems. High pH values (above 5) can hasten spoiling by encouraging bacteria development and eroding texture and flavor. On the other hand, conditions that are too acidic below 3 can produce unwanted qualities like mushiness or bitterness. In a similar vein, gas concentrations, such as carbon dioxide and ethylene, are essential for preservation and ripening. Overexposure to ethylene speeds up the ripening process, which causes early softness and flavour changes. Meanwhile, elevated carbon dioxide levels could indicate insufficient ventilation or microbial activity, which speeds up deterioration. On the other hand, low gas concentrations can hinder the effectiveness of preservation or postpone ripening.

VI. Conclusion

In conclusion, the integration of IOT and ML within Python offers a robust solution for the identification of pesticides in organic fruits and vegetables. Triadic spectroscopy, pH sensing, and gas sensing technologies combined with advanced data processing using machine learning algorithms enable this robust and efficient system. This approach permits real- time monitoring of environmental factors influencing pesticide residues and ensures accurate and timely detection. A buzzer that sounds when pesticides are detected and an LCD panel that indicates whether or not fruit is pesticide-free are two examples of how this technology is actually used in the field. The recommended method has a great deal of potential to improve food because of its superior technological capabilities to preserve food's originality and quality.

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