IoT-Powered Intelligent Framework for Detecting Food Adulteration: A Smart Approach

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Abstract. Food adulteration refers to the practice of deliberately adding substances to food to increase its volume, weight, or to improve its appearance, texture, or flavor; it is a significant issue that affects the health and safety of consumers. With the increasing demand for food, the risk of contamination and the intentional addition of harmful substances has increased. There are several existing methods for detecting food adulteration, including chemical analysis, microscopy, sensory analysis, etc. While these methods are helpful, they can be time-consuming, labor-intensive, and may not provide Real-time results. Using the Internet of Things (IoT), Machine Learning (ML) can significantly enhance the ability to identify food adulteration.Within this Framework, we are propose a solution to detect food adulteration using IoT and machine learning. The system comprises IoT sensors and devices to gather data on various parameters such as color, pH, gas content, etc. The collected data is fed into machine learning algorithms for preprocessing, analysis, and testing. Any anomalies or deviations from the standard patterns are flagged for further investigation. ML algorithms can continuously learn from the collected data, enabling them to enhance their accuracy and effectiveness over time. By implementing this system, we aim to create a Real-time, data- driven approach to detecting food adulteration, ensuring food safety and quality for consumers by creating a warning system.

1 Introduction

Information Systems and Telecommunications are particularly critical for enabling the connectivity, data management, and analysis required to detect and combat food adulteration effectively.The Smart Framework for Food Adulteration Detection, leveraging the potential of IoT (Internet of Things) and ML (Machine Learning), represents a forward-looking initiative meticulously crafted to address the pressing challenge of food adulteration. The pervasive and profound threat posed by food adulteration to public health unequivocally underscores the urgency of a proactive response. This Framework has been meticulously designed to harness the capabilities of IoT devices, sophisticated ML algorithms, and a user-

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centric Kodular application, coalescing to enable Real-time identification and prevention of food adulteration.

At its very core, this endeavor is underpinned by a resolute mission to engender a comprehensive ecosystem that seamlessly integrates IoT sensors, cutting-edge data analysis algorithms, and a mobile application geared toward user convenience. The overarching objective is to provide individuals with immediate and precise insights into the quality of the food they are consuming. The pivotal essence of this Framework resides in its innate capacity to discern contaminants, pollutants, impurities that not only jeopardize safety but also compromise the authenticity of food items. The pivotal ambition of this Framework revolves around establishing a robust and efficacious system, one that not only enhances food safety but also fosters industry transparency and strengthen public health. The operational mechanism of this system hinges upon the Real-time monitoring and assessment of food products. This is facilitated by IoT sensors adept at assimilating multifaceted data points, spanning from color profiles and gas compositions to pH levels. The indispensable role of ML algorithms cannot be overstated, as they untangle the intricate web of amassed data, elucidating patterns, and unveiling anomalies or telltale indicators of adulteration.

The beneficiaries of this innovation are poised to reap substantial advantages, as the Kodular application interfaces with them through an intuitive and user-friendly platform. Rapid feedback concerning the quality of consumables is swiftly rendered, thereby empowering individuals with information about the safety quotient of their chosen sustenance. The application further extends its utility by recommending alternative products and disseminating comprehensive insights about identified adulterants.

Unquestionably, this ingenious platform endeavors to redefine the conventional landscape of food adulteration detection and mitigation. By orchestrating a harmonious synergy of IoT, ML, and mobile app technologies, it not only empowers consumers to make enlightened decisions but also compels food producers to uphold unswerving standards of quality. Moreover, it equips regulatory bodies with the means to exercise vigilant oversight within the culinary realm. The culmination of these concerted efforts converges into an epochal juncture that unequivocally addresses a critical societal concern through the lens of cutting-edge innovation.

Fig. 1. Food Adulteration.

Figure 1 serves as an illustrative representation that offers a visual panorama encompassing a spectrum of diverse methods employed for the adulteration of a range of consumable items, including vegetables, milk, and other essential food materials. This comprehensive depiction acts as a graphic exposé, shedding light on the multifaceted strategies and techniques that

unscrupulous entities employ to compromise the integrity and quality of these indispensable sustenance sources.
The visual composition within Figure 1 encapsulates an array of deceptive maneuvers orchestrated with the intention of subverting the innate attributes of vegetables, milk, and various other food materials. The intricate web of adulteration methodologies presented herein constitutes a mosaic that conveys the depth and complexity of the challenge at hand. This grapHic elucidation serves as a potent tool in unveiling the hidden dimensions of adulteration, transcending textual descriptions by providing an instant and vivid comprehension of the pervasive threats that these commodities face. . By offering a tangible representation of the adversities vegetables, milk, and other food materials face, Figure 1 acts as a catalyst for fostering collective responsibility and collaboration across industries, academia, and regulatory bodies to proactively mitigate and thwart the menace of adulteration.

1.1 Various Methods of Food Adulteration

Food adulteration encompasses a range of deceptive practices aimed at compromising the quality, safety, and authenticity of food products. These methods exploit vulnerabilities in the food supply chain and pose significant risks to public health. Here are some common methods of food adulteration:

Addition of Water or Other Liquids:

Diluting food products with water, cheaper liquids, or substances such as milk to increase the volume and weight of the product while reducing its actual content.

Substitution or Replacement:

Replacing a genuine ingredient with a cheaper or inferior one. For example, using margarine instead of butter, or substituting groundnut oil with other cheaper oils.

Excessive Use of Food Additives:

Adding excessive amounts of food additives such as artificial colors, flavors, and preservatives to mask inferior quality or spoilage.

Use of Unauthorized Colors and Dyes:

Adding unauthorized synthetic colors to enhance visual appeal and cover up discoloration due to spoilage or age.

Adulteration with Non-Permitted Substances:

Introducing substances that are not legally allowed in food products, such as chemical contaminants, pesticides, or heavy metals.

Undeclared Ingredients:

Failing to list all ingredients accurately on product labels, thus misleading consumers about the actual composition of the product.

Fake or Counterfeit Products:

Creating counterfeit products that imitate popular brands, leading consumers to believe they are purchasing authentic goods.

Mislabeling:

Labeling products with false claims or misleading information regarding nutritional content, origin, or certification.

Adulteration of Edible Oils:

Mixing high-quality oils with lower-quality or less expensive oils, or using non-edible oils in food products.

Tampering with Packaging:

Replacing original packaging with counterfeit or substandard materials to create the illusion of premium quality.

Using Artificial Sweeteners:

Substituting natural sugars with artificial sweeteners to reduce production costs and enhance shelf life.

Presence of Foreign Matter:

Introducing foreign materials like sand, dirt, or sawdust to increase the weight of products like spices or grains.

Over ripening or Under ripening:

Selling fruits and vegetables that are over ripened or under ripened, affecting their taste, texture, and nutritional value.

Efforts to combat food adulteration require a multi-pronged approach involving stringent regulations, transparent supply chains, advanced testing methods, consumer education, and technological innovations such as IoT and ML, as mentioned in the original context. Addressing these methods is crucial to ensure the safety and integrity of the food supply and to safeguard public health.

2 Literature Survey

Food adulteration remains a global concern due to its potential health risks and erosion of product integrity. In response to growing apprehensions about food quality and wellness, diverse detection approaches have emerged. Some employ traditional techniques, while others incorporate hardware gadgets with sensors and microcontrollers. Additionally, methods integrating machine learning, artificial intelligence, and image processing are prevalent. Noteworthy prior solutions in this domain include:

Momtaz M et al.[1] thorough review exposes the severe health consequences of food adulteration. Some adulterants have carcinogenic and genotoxic properties, highlighting the gravity beyond nutritional compromise. The study reveals potential long-term health risks, including cancer and genetic damage. Their research urges prompt action, advocating for strict regulations, surveillance, and awareness campaigns to counteract the far-reaching impacts of adulterated food. This work serves as a crucial reminder of the pressing need to protect public health and restore food integrity. In their scholarly contribution V.R. Singh et al.[2] introduced a pioneering methodology grounded in ultrasonic principles. This innovative approach was designed to address the significant concern of adulteration within fluid-based food products. By harnessing the capabilities of ultrasonic technology, the researchers aimed to enhance the accuracy and reliability of detection methods for such deceptive practices.

In parallel endeavors, distinct scholars, namely authors [3,4], embarked on an exclusive exploration of milk adulteration. Their research pursuits were dedicated to dissecting the intricacies of this particular form of food adulteration. By employing sophisticated tools like ultrasonic sensors and laser beams, these researchers aimed to unravel the hidden layers of milk adulteration, striving to shed light on the specific adulterants that might compromise its integrity. In a separate trajectory [5] adopted an innovative strategy by integrating nanocomposite gas sensors. This inventive approach sought to offer a novel means of discerning instances of food adulteration. By leveraging the sensitivity and selectivity of nanocomposite gas sensors, this group of researchers aimed to create a reliable system capable of promptly and accurately identifying various forms of adulteration within food products.Meanwhile, the research conducted by W. Ning et al.[6] charted a distinct course. Employing a blend of specialized instrumentation and advanced statistical methodologies, this group embarked on the development of an intelligent model specifically geared toward the evaluation of food product quality. By amalgamating intricate measurements and sophisticated data analysis techniques, their work aimed to establish a comprehensive Framework for assessing the authenticity and overall excellence of food items.

Deepiga et al. [7] introduced an IoT-based seafood adulteration detection approach employing sensors to identify formalin and monitor formalin-affected fish. Ruth Moly et al.[8] done an elaborate survey on food adulteration. Kanwalpreet Kour et al. 98] proposed techniques for assessing saffron quality and suggested methods for the eliminating of counterfeit products in this context. Rupali Patil et al.[9] adopted electronic sensory system with diversified sensors.

Researchers employed machine learning to predict food adulteration. Instead of using simple sensors, they have also taken the benefits from the evolution of the Internet of Things(IoT). Authors[11,12] applied analytic and machine learning approaches for detecting adulteration in cinnamon. Convolution Neural networks are employed during their experimentation. S. P. S. Brighty et al.[13] proposed a machine learning-based model for detecting adulteration in fruits. Authors[14,15] focused on honey adulteration and suggested hyperspectral imaging and artificial neural networks for effective machine learning. Neto H.A et al.[16,17] employed deep and ensemble learning for milk adulteration.In their study, Author [18] employed artificial intelligence-based techniques for detecting adulteration and defects within the food and agricultural industry.

Authors [19,20] employed multi spectral concept in their image analysis. Latha S.B et al.[21] applied machine learning ,cloud IoT approach for groundnut crop image analysis. Authors[22,23] applied deep learning concepts in their applications. G.M Rao et al.[24] used sign gestures in video to provide visual communications with machine learning.

Although numerous machine learning techniques exist for detecting food adulteration, their direct implementations are often hindered by the factors such as their inherent complexity or the specificity required in their application. Addressing this challenge, we introduce a comprehensive Framework that leverages spectral analysis, pH measurements, ultrasonic sensing, and the power of cloud computing through the Internet of Things (IoT). To enhance the robustness of our Framework, we have integrated a cost-effective, adaptable ESP32 microcontroller, which offers scalability and flexibility.

Our proposed approach aims to bridge the gap between the advanced capabilities of machine learning algorithms and the practical feasibility of their deployment. By combining spectral analysis, pH measurement, and ultrasonic sensing, we can capture a broader spectrum of potential adulterants and irregularities in food products. These techniques collectively contribute to a more comprehensive and accurate assessment of food quality. Furthermore, integrating cloud computing within the IoT paradigm enhances the capabilities of our

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Framework. It allows for Real-time data processing, analysis, and storage, irrespective of geographical limitations. Cloud computing ensures that the collected data is processed efficiently and effectively, enabling prompt detection of adulteration events and rapid decision-making processes. Central to our Framework's functionality is utilizing a low-cost and flexible ESP32 microcontroller. This microcontroller acts as the control hub, orchestrating the data collection from the spectral, pH, and ultrasonic sensors. Its versatility and scalability make it an ideal choice for accommodating the various sensing modalities and managing the complexity of the data integration process.

In the following sections, we will explore the current methodologies for detecting food adulteration, emphasizing their challenges and limitations, as well as introducing our proposed framework. By showcasing the strengths and innovations of our approach, we aim to present a compelling case for adopting our holistic Framework, which capitalizes on the synergy of multiple sensing techniques, cloud computing, IoT, and a resilient micro-controller architecture. This amalgamation promises not only enhanced accuracy in food adulteration detection but also a pathway toward feasible and practical implementation in real-world scenarios.

Incorporating IoT sensors, ML algorithms, and Real-time monitoring are all part of the proposed system for food adulteration detection using IoT and ML, which attempts to solve the shortcomings of the existing system. The system improves the effectiveness and accuracy of adulteration detection by the collection of Real-time data, analysis of it using ML algorithms, and usage of a user-friendly interface. It encourages customer confidence in food safety, makes preventive steps possible, and guarantees regulatory compliance.

3 Proposed Architecture

Incorporating IoT sensors, ML algorithms, and Real-time monitoring are all part of the proposed system for food adulteration detection using IoT and ML, which attempts to solve the shortcomings of the existing system. The system improves the effectiveness and accuracy of adulteration detection by the collection of Real-time data, analysis of it using ML algorithms, and usage of a user-friendly interface. It encourages customer confidence in food safety, makes preventive steps possible, and guarantees regulatory compliance. The suggested system's connection with the food supply chain and methods for ongoing improvement further boost its efficiency in identifying and averting incidences of adulteration. Figure 2 illustrates the architecture.

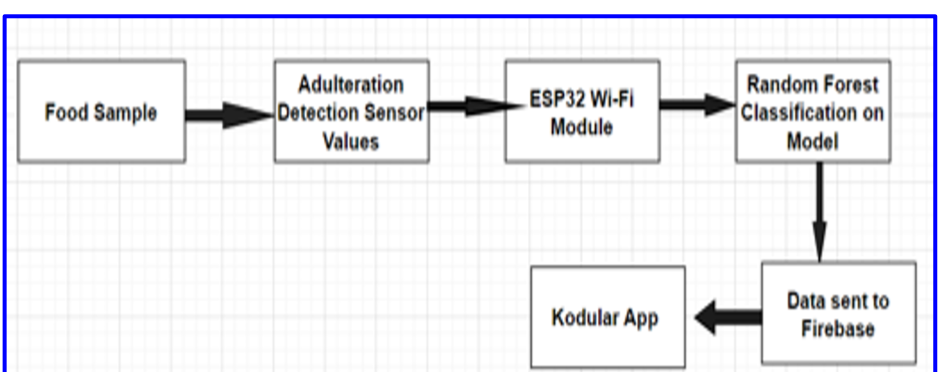

Fig 2. Architectural Framework

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3.1 ESP 32

ESP32 is a low-cost, low-power system on a chip microcontroller featuring built-in Wi-Fi and dual-mode Bluetooth.

Xtensa® single-/dual-core 32-bit LX6 microprocessor(s)
34 × programmable GPIOs
12-bit SAR ADC up to 18 channels
2 x 8-bit DAC

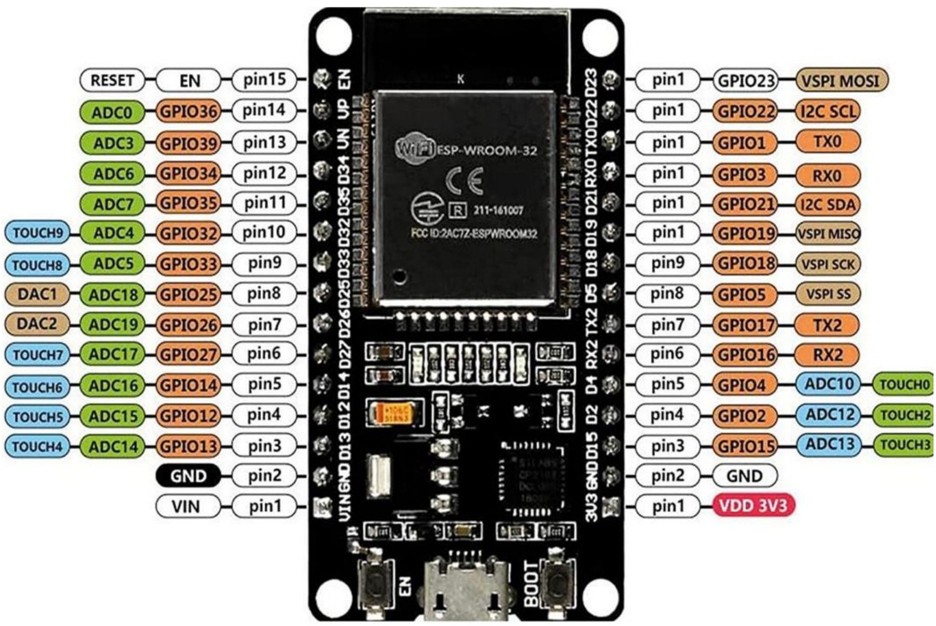

Fig 3 ESP 32 Micr-controller

3.2 pH Sensor-

A sensor that determines a substance's acidity or alkalinity by detecting the concentration of hydrogen ions. A linear pH reading in the range of 0pH to 14pH is provided using an analog pH sensor. It has a built-in straightforward, handy, and useful connection and uses an industry electrode. It is ideal for long-term online monitoring because of its long lifetime. An LED on the signal connector board serves as the power indicator. Additionally, the board contains a pH sensor interface and a BNC-type connector. Simply attach the pH sensor using a BNC connector, then insert the pH interface into any microcontroller's analog input port to use it. The output voltage can be obtained using a multimeter.Sensor is powered by external 9V DC supply and conned to virtual pin (A0) of ESP 32. Figure 4 indicates pH sensor and associated driver circuit.

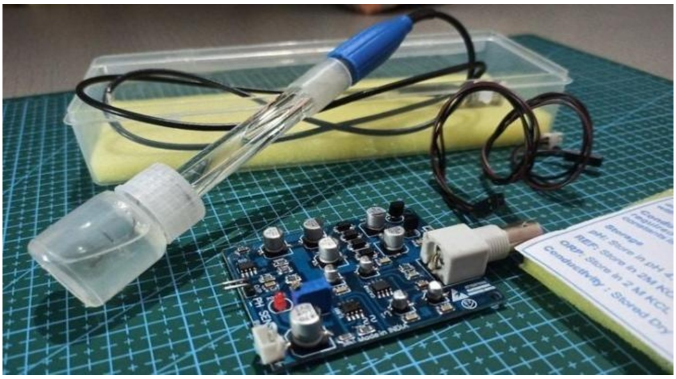

Fig 4. pH Sensor

3.3 APDS-9960

The Broadcom APDS-9960 is an 8-pin device that combines a digital RGB, ambient light, proximity, and gesture sensor. Red, green, blue, and clear (RGBC) as well as proximity and gesture sensing via an IR LED are all provided by the device's I2C- compliant interface. Figure 5 illustrates the sensor.

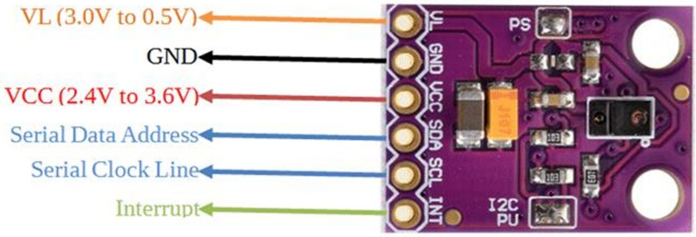

Fig 5. APDS-9960 sensor

3.4 MQ4 Sensor

The MQ4 methane gas sensor is an analog voltage-generating MOS (metal oxide semiconductor) type sensor used to measure the amount of methane gas in the air at either homes or industries. The concentration range for this sensor is between 300 pm and 10,000 ppm,will detect the gas leakages.
Methane (CH4), is used as a measurement for food quality and Freshness, is one of the gases that the MQ4 sensor is specifically intended to detect. This sensor operates based on the principle of gas conductivity. It consists of a sensitive material that changes resistance when it comes close to the target gas. Figure 6 depicts the Gas sensor.

Fig 6. MQ4 Gas sensor

3.5 Arduino IDE

The software platform known as Arduino IDE, or Integrated Development Environment, is used to program and create applications for Arduino boards. An open-source electronics platform called Arduino makes it possible to build interactive Frameworks and prototypes.
An easy-to-use interface is provided by the Arduino IDE for creating, compiling, and uploading code to Arduino boards. Due to its simplicity and adaptability, it is frequently used by both novices and professionals and is compatible with a variety of Arduino board models. Figure 7 denotes Arduino IDE which is the basics for Framework development.
Users can create programs in a language like C and C++ using the Arduino IDE. It is made simpler to interact with the hardware connected to an Arduino board, such as sensors, actuators, and displays, thanks to a set of libraries and functions offered by the IDE

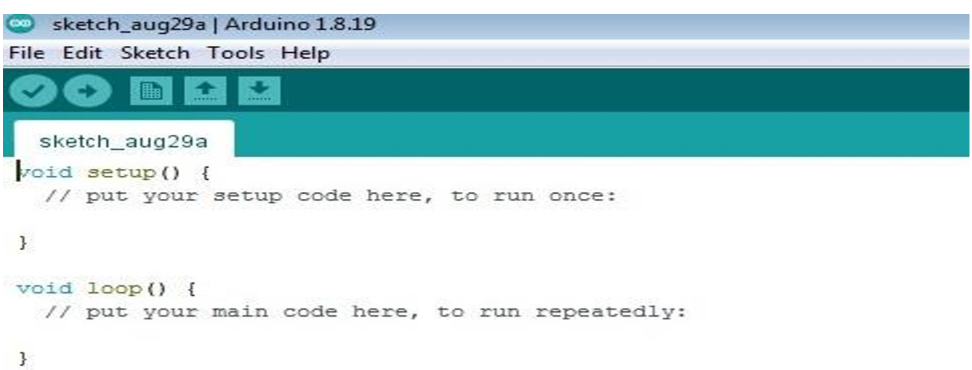

Fig 7 Arduino IDE

3.6 Firebase

Google offers a complete mobile and web development platform called Firebase. It provides tools and services that aid in the more effective development, enhancement, and scaling of applications. To meet the needs of various application scenarios, Firebase offers a backend infrastructure, development SDKs, and ready-to-use functionality.
Here are some of Google Firebase's principle elements and attributes:

With Firebase Authentication, developers can quickly add user authentication to their apps using techniques like email/password, social logins, and more. It also offers user authentication and identity management services.
Real-time data synchronization between clients and devices is made possible via the Firebase Real-time Database, a NoSQL cloud-hosted database. It supports offline use and uses a JSON data format. Figure 8 provides Real time database of Google Firebase database.

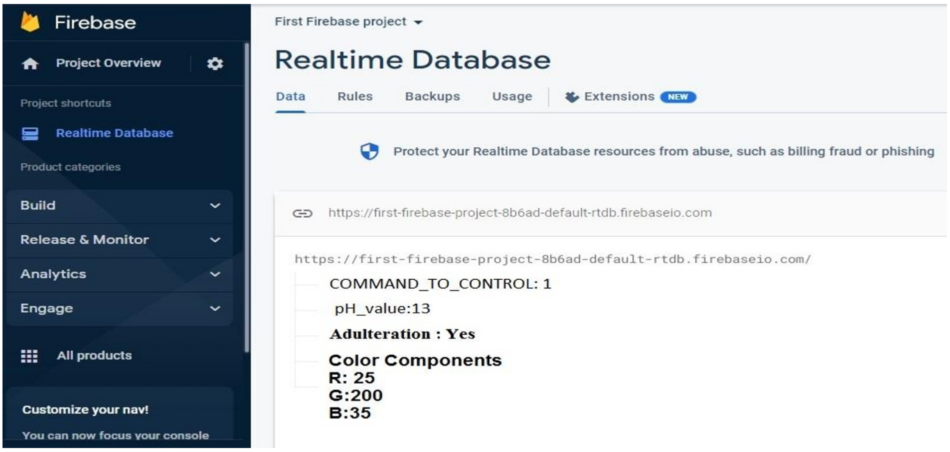

Fig 8. Firebase Real-time Database

3.7 Kodular Creator:

Using Kodular Creator, users can build mobile applications without the requirement for conventional coding. It offers user-friendly interface for creating Android apps. Users can choose and organize pre-built components using the drag-and-drop feature of Kodular Creator to develop the functionality needed of their application. These parts consist of more complex features like databases, device sensors, and media controls as well as user interface elements like buttons, labels, and text inputs. .By arranging components and specifying their properties, users of Kodular Creator can create the layout of their app screens. By visually specifying events and actions, they may determine how these components should behave. Figure 9 illustrates the Kodular environment.

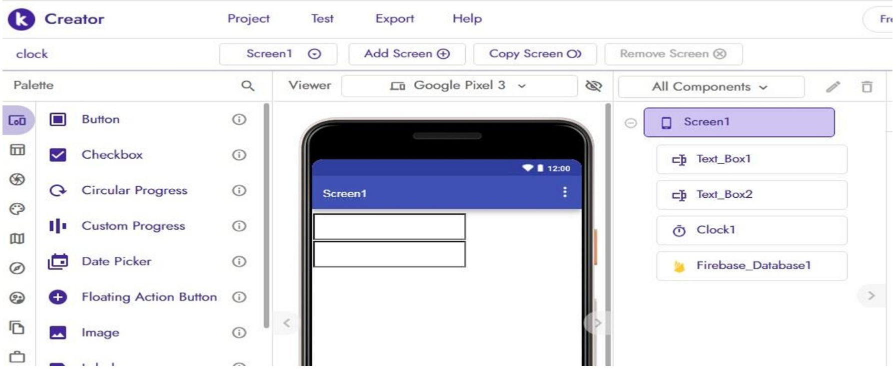

Fig 9. Kodular Environment

3.8 Google Colab

In a Jupyter Notebook setting, users can develop and execute Python code jointly using Google Colab, a tool made available by Google. With access to potent hardware resources like CPUs, GPUs, and TPUs, it offers a hosted runtime environment. Due to its simplicity of use and connectivity with other Google services, Google Colab is well-liked by researchers, data scientists, and machine learning practitioners.

4 Experimentation and Results

Figure 10 indicates the interfacing of ESP 32 with various sensors.

Interfacing of pH Sensor:

- To power the pH Sensor, use an external 9V battery or a 9V DC Supply.
- Connect the output pin of the pH Sensor signal board to VP of ESP32, which can be used as an A0 pin.

Interfacing of APDS9960:

Connect the VCC pin of the APDS9960 sensor to the 3.3V pin of the ESP32.
Connect the GND pin of the APDS9960 sensor to the GND pin of the ESP32.
Connect the SDA pin of the APDS9960 sensor to the SDA pin of the ESP32. The SDA pin is usually GPIO21 on the ESP32.
Connect the SCL pin of the APDS9960 sensor to the SCL pin of the ESP32. The SCL pin is usually GPIO22 on the ESP32.

Interfacing of the MQ4

The MQ-4 sensor module usually has four pins: VCC, GND, AOUT, and DOUT.
The VCC and GND pins should be connected to the 3.3V and GND pins on the ESP32, respectively.
The AOUT pin is connected to an analog input pin 36 of the ESP32.
The DOUT pin can be left unconnected if you don't plan to use it.

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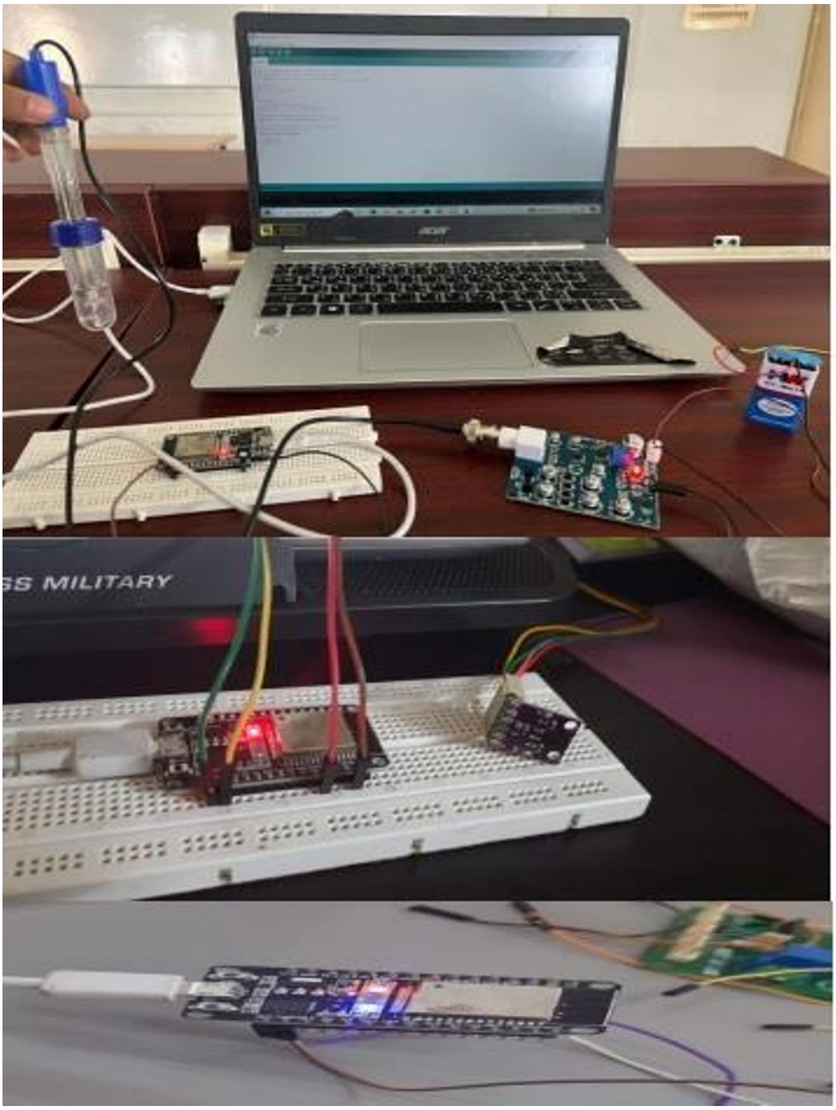

Fig 10. Sensor Interfacing

4.1 Creation of Firebase:

- Sign in to Firebase.
- Click Go to console menu.
- Click the + Add Framework option and create a Framework.
- Enter the name of your Framework
- Once the Framework is created, the Framework configuration page is open.
- You can open Framework settings and create a Real-time database to store values in the database.

- In the service accounts menu you can access the authentication key to your firebase project.

4.2 Creation of Kodular App:

Figure 11 indicate Mobile APP development for our frame work

- Open Kodular Creator, Login to the website
- Frameworks screen will be opened
- Click on + New Framework button to create a Framework.
- Enter the name of your Framework
- Framework will be created
- In the design screen, you can add components to your Framework to build User Interface
- In the Blocks screen, you can design how the Components respond to various actions and events in the app.

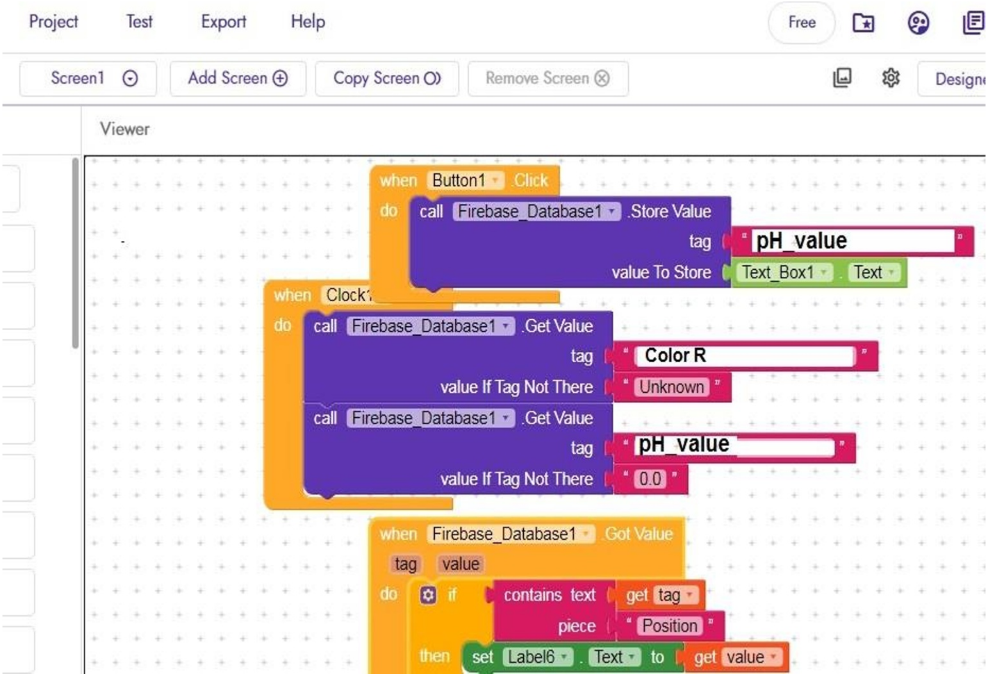

Fig 11. Mobile App Development

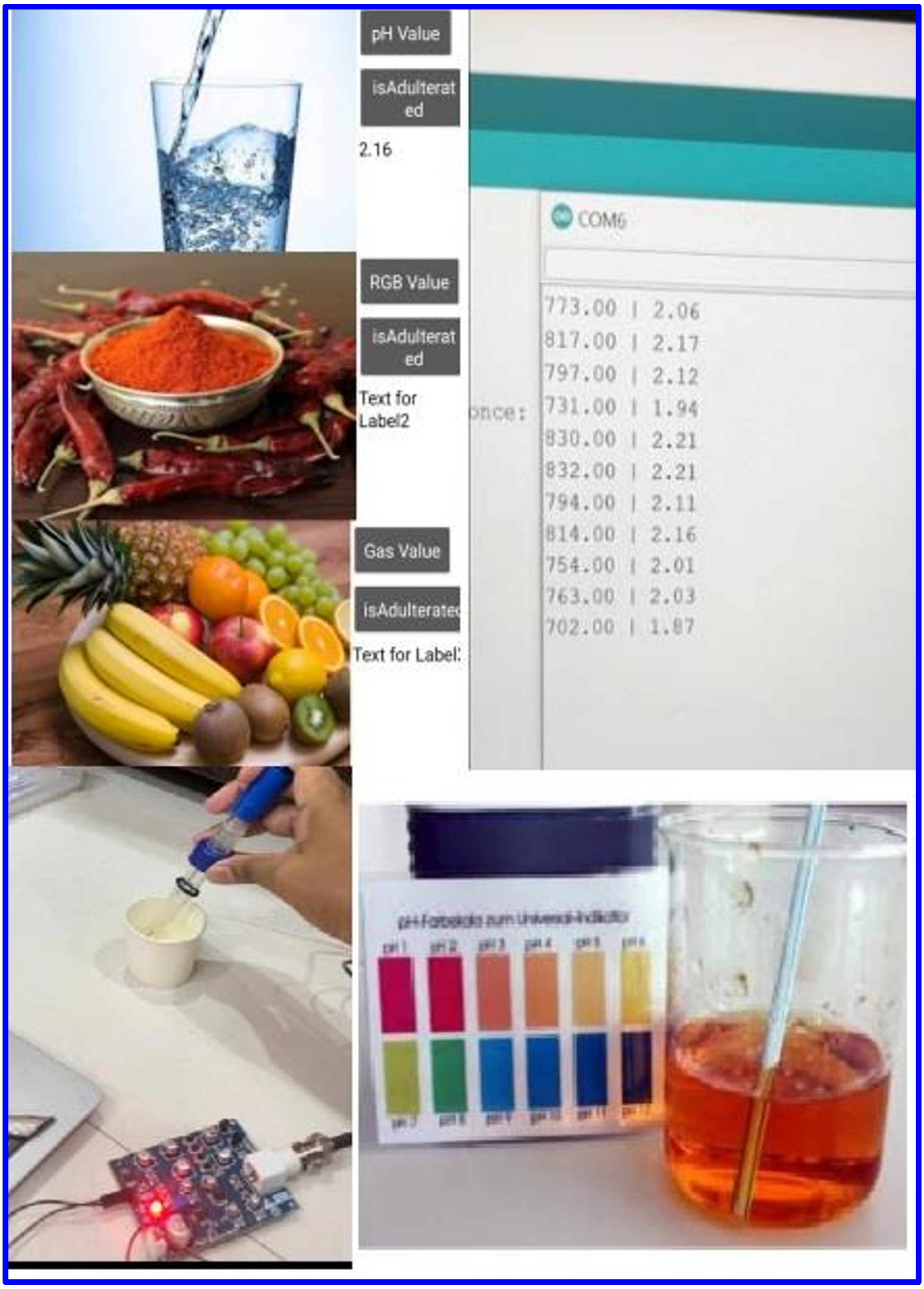

Fig 12 Adulteration Water with acid

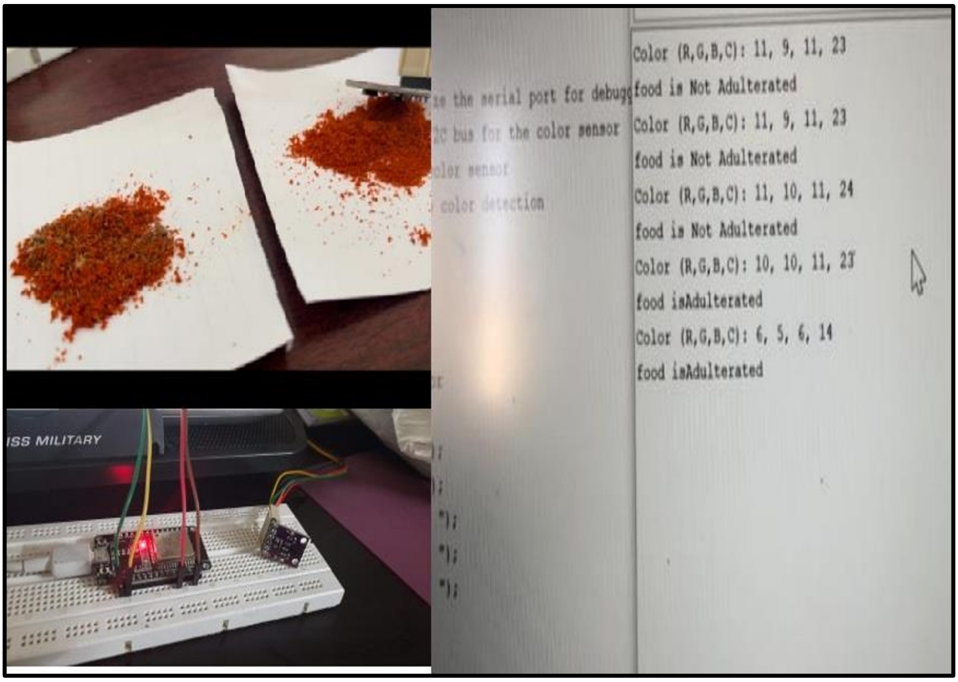

Fig 13. Chilli power adulteration

Fig 14. Fruit Freshness Detection

5 Conclusion and Scope

IoT sensors, machine learning techniques, and a Kodular app are all combined in the Smart Framework for Food Adulteration Detection using IoT and ML, a promising initiative that seeks to identify and track food adulteration. The system can gather Real-time data on many food factors by utilizing IoT sensors. After that, this data is evaluated using ML algorithms, like Random Forest, to spot probable adulteration patterns and set classification thresholds. The outcomes are presented in a user-friendly Kodular app, giving stakeholders practical knowledge to reduce the dangers of food adulteration. This Framework helps to ensure consumer wellbeing by providing an effective and novel solution to the essential problem of food safety. To improve the system's accuracy, additional testing, validation, and modifications are required. Figures 13 & 14 illustrate testing the Framework against food adulteration for Milk with urea, Chilli powder and Freshness of fruits.

The Smart Framework for Food Adulteration Detection using IoT a has additional potential applications, such as integrating sophisticated sensors and ML methods, putting Real-time alerts into place, improving the Kodular app's user interface, integrating with the food supply chain, supporting regulatory compliance, enabling continuous data collection and model improvement, and investigating collaborations for data sharing and knowledge exchange. These upgrades would increase the system's precision, expandability, usability, and capacity to proactively identify and reduce the hazards of food adulteration, ultimately resulting in safer and healthier food for customers. Experts can use this machine learning model to further examine their predictions and observations.

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