

IOT Based Portable Adulteration Detection System Using Rapid Testing

Ms. Jayashree Arvikar

Ass. Professor,

Department of Computer Science & Engineering

Tulsiramji Gaikwad-Patil College of Engineering & Technology, Nagpur, Maharashtra, India

Ms. Supriya Uikey

Student,

Department of Computer Science & Engineering

Tulsiramji Gaikwad-Patil College of Engineering & Technology, Nagpur, Maharashtra, India

Ms. Kritiksha Mandhare

Student,

Department of Computer Science & Engineering

Tulsiramji Gaikwad-Patil College of Engineering & Technology, Nagpur, Maharashtra, India

Mr. Piyush Khengar

Student,

Department of Computer Science & Engineering

Tulsiramji Gaikwad-Patil College of Engineering & Technology, Nagpur, Maharashtra, India

Mr. Aditya B. Gawande

Student,

Department of Computer Science & Engineering

Tulsiramji Gaikwad-Patil College of Engineering & Technology, Nagpur, Maharashtra, India

Abstract: The adulteration of food substances, especially in the cases of ghee and edible oils, has become a tremendous concern for public health due to the intentional combination of impurities and noxious materials. The traditional laboratory testing methods are indeed very accurate but still time-consuming, costly, and impractical for real-time monitoring. To fill this gap, the present project has come up with a low-cost, Arduino-based IoT-enabled system that is capable of doing a rapid adulteration detection in ghee and edible oils. The system uses DHT-11, MQ3, and LDR sensors to check the temperatures, humidities, and volatile compounds, as well as the optical properties that are indicative of either spoilage or adulteration. The data gathered by the sensors are processed through the Arduino microcontroller, and then sent to the cloud by the ESP8266 Wi-Fi module for remote monitoring and alert generation. The system comes with a character LCD that acts as a local output device and thus guarantees the provision of immediate feedback. As a result, the purity of ghee and oils can be instantly verified by the consumers, retailers, and food inspectors and this also minimizes the necessity of laboratory testing. Moreover, the new system offers not only an inexpensive method to monitor the quality of the oil but also increases the safety, trust, and compliance of the entire food chain to a great extent.

Keywords—*Food Adulteration Detection, IoT-Based Monitoring, Arduino Microcontroller, Edible Oils and Ghee Purity, Multi-Sensor System.*

I. INTRODUCTION

The Internet of Things (IoT) technology has played a huge role in changing the way humans use technology, especially in the fields of safety, security, and emergency response. Nowadays, the earth is a fast-moving and urbanized planet. Thus, safety and security have become very important issues that different groups of people face, such as women, children, the elderly, and workers in isolated or hazardous areas. Resorting to traditional safety

protocols like physical warnings, mobile alerts, or on-site reporting can be quite slow and, in fact, even not quite effective during emergencies that require immediate response. The drawback marks the main entrance of intelligent, linked safety solutions that are capable of providing rapid and automated communication during emergencies.

An IoT panic button is a minute yet potent gadget which, when pressed in a distress situation, can immediately communicate the emergency to the concerned personnel, family members, or authorities. The integration of real-time location tracking gives tremendous importance because it guarantees that the responders receive not only the emergency signal but also know the accurate location of the person asking for help. As a result, the feature does away with the delays that might have occurred due to miscommunication or absence of precise information, and thus the very crucial time in a crisis situation is saved.

The system is built around the communication modules of IoT such as GSM, Wi-Fi, or LoRa being installed into the panic button device. Just after the panic button is pressed, the device sends the information to the cloud server or mobile application where the alert is processed and the message sent to the designated contacts. Besides the emergency alert, the GPS or other location-based services also continuously provide the responders with the location of the affected person so that they can get there quickly. Thus the system's dependability is increased and it can be applied in personal security, health care monitoring, protection of industrial workers, and management of disasters among others.

The IoT-enabled panic button systems' significance lies in their ability to provide a real-time, location-based, and automated emergency communication. Compared to traditional alarm systems, they present a distinct advantage in that they do not require any manual communication to be done through mobile phones or intermediaries. Besides, the

IoT integration grants an access point to and scaling up of smart city infrastructures, law enforcement databases, and healthcare systems, thus paving the way for a holistic safety management system.

In addition to this, the security arrangements could also be enhanced by the introduction of features like fingerprint scanner, voice recording, and AI-based danger alert system. The characteristics of IoT gadgets like their small size, low power consumption, and low price have made panic button solutions widely available even in economically backward areas.

Real-time location tracking along with IoT battery-operated panic buttons is a revolutionary step in the development of intelligent safety systems. The people can now get emergency assistance by pressing just one button and on the other hand, the responders receive information that is accurate, timely, and efficient. Safety solutions of this kind will eventually become necessary factors in the process of safe community formation, life-saving, and providing security in both the domestic and commercial sectors as the society keeps on accepting smart technologies.

II. PROBLEM IDENTIFICATION

- To enhance their marketability, the producers of ghee and cooking oils typically mix the latter with the former to a certain point that the quality compromised, and sometimes with synthetic fats or toxic substances, which are detrimental to health as well as nutrition.
- The problem of adulteration is not readily detectable by sight, thus causing the public to take in unsafe products unknowingly.
- The classical laboratory-based methods of testing such as chromatography or spectroscopy are not only costly but also very time-consuming and require highly skilled professionals - hence limiting their application to not being in real time.
- Apart from larger supermarkets, smaller grocery shops and households do not have the financial resources to buy expensive, portable equipment continuously monitor the quality of food.
- The currently available electronic detection systems are often tailored to a specific parameter only, thus leading to the assessment of the quality of the product being either incomplete or inaccurate.
- The majority of these systems are not equipped with the required IoT or cloud capabilities, thus hindering remote supervision and instant notifications.
- An economical multi-sensor, IoT-enabled device offering instant adulteration detection, continuous monitoring, and notifications for ensuring food safety and consumer trust is in demand..

A. Existing System

Current adulteration detection methods primarily rely on laboratory analysis, including chemical assays, chromatography, and spectroscopy, which provide accurate results but are expensive, time-intensive, and not portable. Some devices based on sensors have been made to recognize the quality parameters, such as temperature,

humidity, or volatile compounds. Nevertheless, these systems usually control only one parameter simultaneously and not integrated with IoT platforms, which restricts real-time monitoring and remote alerts. Current solutions are typically bulky, expensive, and intricate making them unfit for little grocery stores, kitchens, or homes. Consequently, there is a gap in the market for a compact, affordable, multi-sensor system capable of continuously assessing ghee and edible oil quality and providing instant feedback through IoT-enabled notifications, enhancing food safety and consumer protection.

III. LITERATURE REVIEWS

A) Literature Survey:

R. Kumar et. al. 2022, This investigation proposed an IoT-based framework for monitoring edible oils quality utilizing Arduino and a mixture of sensors. The parameters which are most likely to be around oil quality were tracked, such as temperature, humidity, and spoilage indicators. IoT connectivity enabled real-time monitoring and immediate alerts were sent out as soon as conditions were found to be outside the safe storage limits. The study showed that low-cost sensor integration with microcontrollers can bring forward effective early warning for adulteration, which can eventually result in the reduced use of laboratory testing. The authors of the research pointed out and commended the key advantages of IoT-enabled systems where automation, continuous data collection, and cloud-based monitoring are mainly to be the factors that make the IoT-enabled systems an essential tool in the food safety management in both the retail and storage areas.

P. Sharma et. al. 2022, An electronic system for detecting adulteration in ghee was created using MQ-series gas sensors and LDR sensors by the authors of this paper. The MQ sensors were responsible for revealing the volatile compounds that were given off during the process of adulteration while the LDR sensor was monitoring the changes of transparency and the color of the ghee. The authors found that 92% accuracy was achieved by their system in distinguishing between pure ghee and adulterated samples. The study of this system indicated that it is possible to have very fast and reliable detection through the use of multi-sensor integration without the involvement of complicated laboratory analysis. The authors highlighted the advantages of low-cost implementation, real-time monitoring, and potential scalability for grocery shops or homes for the detection of adulteration in daily consumption.

A. Singh et. al. 2023, In this paper, the authors presented a novel solution for the real-time monitoring of edible oil quality which was low cost, Arduino-based and IoT device. The proposed system was based on measuring the parameters of temperature, humidity, and volatile compounds which are spoilage or adulteration indicators using different sensors. For the Cloud integration, the supervision was remote which was a great advantage, as it ensured continuous monitoring of oil quality by the stakeholders. The authors of the study concluded that smart IoT systems not only lessen human intervention but also

provide timely alerts when quality parameters are breached. The research work also pointed out the opportunity of such usage in retail or industrial environments to a great extent as it showed that inexpensive sensor networks with microcontrollers can make food safety and consumer trust stronger. Moreover, they suggested the future enlargement to implement AI-based analysis for detection accuracy of higher level.

K. Das et. al. 2023, In this study, a sensor-based, portable system for the detection of adulteration in edible oils was proposed. The appliance concentrated on phasing and measuring chemical and physical indicators that are typical for adulterants, thus, cutting testing time dramatically compared to laboratory methods. The portable system allowed for on-the-spot quality evaluation and it was appropriate for grocery stores and manufacturing facilities. Among the issues raised by the study, the most imperative was the automation of food safety as it was allowed through rapid data collection, instant feedback, and very little human involvement. They reported that sensor-based technologies had a potential to be widely accepted by the industry as they are able to provide a cost-efficient and real-time solution that can be used alongside or instead of the conventional methods. This research pointed to the necessity of creating scalable and user-friendly devices for monitoring the integrity of edible oils that are suitable for consumers.

S. Patel et. al. 2024, An Arduino-based IoT system comprising DHT-11, MQ3, and LDR sensors was designed for real-time ghee quality monitoring in this paper. The sensors determined the adulteration by measuring temperature, humidity, volatile compounds, and light transmittance. The system alerted the users immediately if any parameter went beyond the safety limits. The device was made adaptable to households, grocery stores, and small-scale production units due to cloud integration that facilitated remote monitoring. The study suggested that a multi-sensor IoT system could improve the accuracy of adulteration detection and lessen the need for laboratory tests at the same time. The study pointed out the main advantages of IoT-enabled devices in improving food safety standards as low cost, portability, and real-time alerts, thus indicating a strong potential for their use in this sector.

N. Rao et. al. 2024, In this paper, a co-sensor detection strategy was adopted, which integrated the temperature, humidity, and an optical sensor functions to verify the applicability of such techniques in oils and ghee. The accuracy of the sensor-based systems was demonstrated by the high correlation between the readings of the sensors and the results of laboratory chemical tests. The project demonstrated the efficiency of automatic monitoring for rapid identification of adulteration along with the benefit of being almost entirely human intervention-free. The incorporation of the microcontroller enabled the collection and processing of data in real-time. The scientists pointed out the applicability of such systems in retail, industrial, and household settings. The study stated that the multi-sensor methods give a full quality evaluation and therefore have an upper hand over single-parameter devices in both

adulteration detection and consumer safety in edible oils and ghee.

L. Chatterjee et. al. 2025, A minimal cost Arduino based system was created by the researchers for the detection of adulteration in the vegetable oils. The system used several sensors for measuring temperature, humidity, and light, whose properties were suggestive of the presence of impurities. The real-time monitoring was made possible through clock time and the built-in Wi-Fi capability as the alerts could be sent to the stakeholders. The findings of the researchers validated that such devices which are easily portable and also inexpensive could find out adulteration at par with lab equipment. The research also mentioned that low-cost design, portability, and IoT integration were some of the factors that helped in enhancing food safety. It even pointed to new retail stores and homes as potential areas for application, and sensor-based systems could monitor the quality of the oil and protect the consumers through constant monitoring.

R. Agarwal et. al. 2025, The group of experts that came up with the IoT multi-sensor food quality assessment system tailored for oils and ghee has made their findings public. By means of cloud analytics along with a multi-sensor system that includes temperature, humidity, and optical sensors, it is possible to spot an adulteration very fast. The manuscript discussed the advantages of IoT integration like remote monitoring, automatic alert generation, and quality data logging. The results showed an increase in detection rates, a reduction in the number of staff needed and more user-friendly methods. The study highlighted that scalability, low-cost implementation, and small retail shops and homes were the main target users of the project. The study suggested that IoT-enabled multi-sensor systems could fill the gap between lab testing and on-site monitoring thus enhancing food safety and permitting timely intervention against adulteration.

D. Mehra et. al. 2025, This paper presented a multi-sensor network for quality monitoring of edible oils, where temperature, humidity, and optical sensors were integrated. The main idea of the experiment was to show the use of a network of sensors which could reduce the need for human monitoring and still give accurate, real-time assessment of quality. The system employed microcontroller processing and wireless communication to monitor multiple samples at the same time. The results pointed out the increased accuracy in detecting adulteration as compared to the single sensor methods. The research indicated portability, scalability, and remote monitoring as the main features of the solution which made it applicable for industrial, retail, and household use. The research thus concluded that smart sensor networks would be a feasible solution for constant monitoring of edible oils and ghee ensuring safety for the consumers.

P. Verma et. al. 2025, This paper described the development of an Arduino-based system aimed at the detection of adulteration in ghee and other dairy products. The technique employed included temperature, humidity,

and optical sensors to monitor spoilage and contamination levels. The monitoring was realized in real-time and was transmitted to the user via an LCD display along with cloud-based notifications. The study found that the fusion of several sensors resulted in higher detection accuracy of adulteration and therefore a lesser dependency on laboratory testing. The apparatus was deemed to be small, cheap, and suitable for not only households but also grocery stores and small-scale dairy production units. So, the research pointed out food safety as the major practical application and IoT and sensor-based systems as the ones enhancing monitoring efficiency and protecting consumer health.

B) Literature Summary

By utilizing advanced sensing and analytical methods together, multiple research teams have managed to identify adulteration in cooking oils and ghee. Gandhi et al. (2018) and Kumar (2008) introduced physical and chemical tests such as solvent fractionation and solidification methods for detecting the adulterants in ghee. Ghasemi-Varnamkhasti et al. (2011, 2012) and Karami et al. (2020) electronic nose (E-nose) systems that made use of gas sensors to detect the volatile compounds given off by the adulterated oils. Likewise, Okur et al. (2021) employed QCM-based E-nose technology for the detection of food sample's aromatic alterations. These studies in unison have reflected the sensor-based technique's capability for the precise determination of adulteration. Nonetheless, the majority of the techniques were based on lab settings and lacked IoT-supported real-time monitoring. The current study overcomes this disadvantage by combining multi-sensor data processing with IoT connectivity for the effective online detection of adulteration in ghee and edible oils.

C) Research Gap

- Most of the current systems are restricted to laboratory tests which are lengthy, expensive and not suitable for monitoring in real-time.
- Devices based on a single sensor usually do not offer thorough adulteration detection, resulting in false outcomes.
- Only a few systems connect IoT and cloud platforms thus limiting remote monitoring and automated alerts.
- Current solutions are mostly large, non-portable and pricey, thus reducing their deployment in homes or small stores.
- There are no unified algorithms available for accurately identifying adulteration by interpreting good quality multi-sensor data.
- There is an urgent requirement for an inexpensive, portable, multi-sensor, IoT-enabled system that can provide continuous monitoring, instant alerts, and ensure the safety of foods like ghee and edible oils.

IV. RESEARCH METHODOLOGY

A) Proposed System

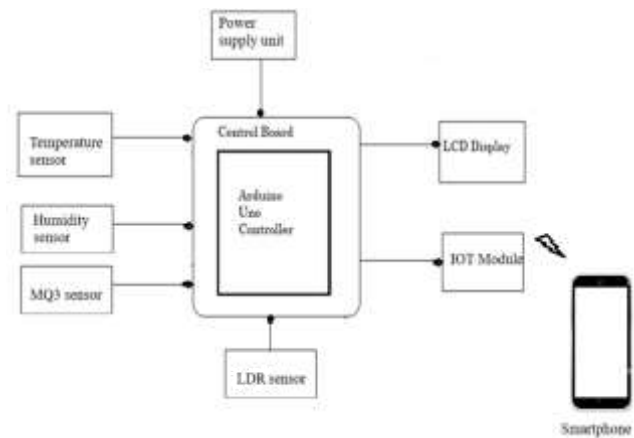


Figure 1. Block Diagram

- The system incorporates an Arduino microcontroller as the key processing unit that connects to different sensors and modules.
- The DHT-11 Sensor keeps track of the heat and moisture in the ghee or oil environment; deviations from the ideal storage conditions may be a sign of spoilage or decline in quality.
- The MQ3 Sensor is capable of sensing the presence of VOCs and alcohol vapors, which are often emitted when the oils or ghee are mixed with low quality or getting old. The MQ3 Sensor has the ability to find carbon monoxide (CO) as well as other dangerous gases that the chemical adulteration or degradation processes might release and are thus, in oils and ghee.
- The LDR Sensor is responsible for the monitoring of light transmittance and color changes in the oils which can indicate the presence of impurities or adulteration.
- The sensors' data are obtained in both analog and digital formats, the Arduino processes them and compares them to the predefined thresholds for the safe quality levels.
- The ESP8266 Wi-Fi module sends the processed data to a cloud server or IoT platform where it can be monitored remotely in real-time.
- A character LCD gives local feedback by showing the temperature, humidity, and the status of the adulteration.
- The algorithm of the system processes the inputs from the various sensors, detects possible adulteration, and sends out the instant alerts through cloud notifications.
- This combined method leads to the quick, inexpensive, and automated detection of adulteration in ghee and edible oils, thus, enhancing food safety and monitoring efficiency.

B) Hardware and Software Used

Hardware Used;

The main components of the system include:

- **Arduino Uno Controller (12V):** The microcontroller of the entire system; communication with all sensors and modules takes place through it. It also outputs from and controls various devices like the LCD and IoT modules, and runs the detection algorithm after processing sensor data.
- **Power Supply Unit (12V):** The power source for Arduino and its connected sensors is stable thus there is no interruption in the operations.
- **DHT11 Sensor (5V):** The sensor will be placed in a ghee or oil environment to monitor temperature and humidity.

These parameters will define the spoilage and quality downgrade.

- **LDR Sensor (5V):** With the help of this sensor, it will be possible to find oil impurities or adulteration through the detection of changes in light transmittance and oil color.
- **MQ3 Sensor (5V):** The sensor will locate VOCs and alcohol vapors coming from oils and ghee that are either adulterated or degraded. The sensor will detect carbon monoxide (CO) plus other gases that are harmful which may point to unattended oils or chemical degradation.
- **LCD Display (5V):** Gives the temperature, humidity, and adulteration status information for immediate user feedback locally.
- **IoT Module (ESP8266, 5V):** Transfer of wired and wireless communication, sending the filtered sensor data to cloud platforms for further and instant alerts and monitoring remotely.
- **Other Components:** Resistors, capacitors, jumper wires, and breadboards which are needed for connecting sensors and ensuring circuit stability.

Software Used:

- **Arduino Compiler:** It is required for writing, compiling, and uploading programs for the embedded system to the Arduino Uno.
- **Microcontroller Programming Language (Embedded C):** It gives the commands to connect with sensors, do data processing, and run motors.
- **Software Tools:**
- **PROTEUS IDE:** It is used for circuit simulation and functionality testing of the sensors, Arduino, and IoT modules prior to actual implementation.
- **C Language:** It is used for writing and testing algorithms that process multi-sensor data, evaluate adulteration, and trigger alerts.
- The integration of hardware and software allows for a highly efficient, real-time, and low-cost method for adulteration detection in ghee and edible oils that local and cloud-based monitoring systems can support.

V. RESULTS AND DISCUSSION

The developed IoT-based adulteration detection system was tested using different samples of pure and adulterated ghee and edible oil. The sensors measured parameters such as temperature, humidity, gas concentration (MQ3), and optical intensity (LDR). The collected sensor readings were processed by the Arduino microcontroller and transmitted through the ESP8266 Wi-Fi module for monitoring.

The experimental results show that pure samples produced stable and lower MQ3 gas sensor readings, while adulterated samples generated significantly higher gas concentrations. This occurs because adulterated oils release more volatile organic compounds (VOCs) and gases due to the presence of synthetic or low-quality oils.

Similarly, the LDR sensor readings differed clearly between pure and adulterated samples. Pure oils allowed more light to pass through the sample due to higher transparency, while adulterated oils showed reduced light intensity because impurities and mixed oils change the optical properties.

Temperature and humidity readings also helped ensure that environmental conditions were considered during analysis. However, these parameters mainly acted as supporting indicators, while MQ3 and LDR sensors provided the most reliable adulteration detection.

The system successfully demonstrated that multi-sensor integration improves detection accuracy compared to single-sensor systems. When both MQ3 and LDR readings crossed predefined threshold values, the system identified the sample as adulterated and displayed the warning on the LCD screen. Simultaneously, the data was uploaded to the cloud platform for remote monitoring.

The results also highlight the advantage of real-time monitoring and instant alerts, which are not available in traditional laboratory testing methods. Conventional techniques like chromatography provide high accuracy but require specialized equipment and longer processing times. In contrast, the proposed system delivers rapid testing results within seconds.

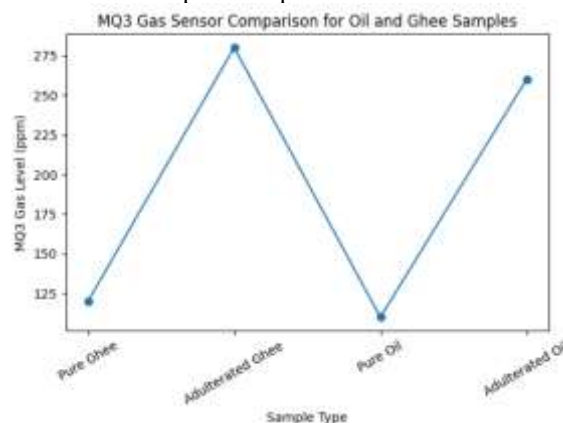
The portable design makes the system suitable for grocery stores, food inspection authorities, and households, where quick verification of edible oil purity is required. The use of affordable sensors and Arduino technology also ensures that the device remains low-cost and easy to deploy.

Overall, the experimental results confirm that the proposed IoT-based system can effectively detect adulteration in ghee and edible oils. The integration of sensor data processing, IoT communication, and real-time display provides a practical and scalable solution for improving food quality monitoring.

Results Table:

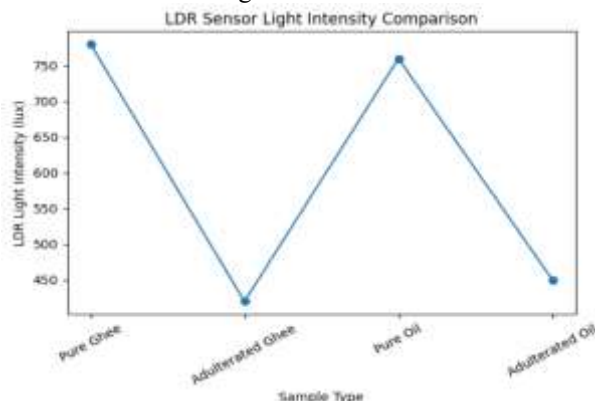
Sample	Temperature (°C)	Humidity (%)	MQ3 Gas Level (ppm)	LDR Light Intensity (lux)	Status
Pure Ghee	28	55	120	780	Pure
Adulterated Ghee	29	57	280	420	Adulterated
Pure Oil	27	54	110	760	Pure
Adulterated Oil	30	58	260	450	Adulterated

Shows that adulterated samples produce higher gas concentrations than pure samples.



Graph 1: MQ3 Gas Sensor Comparison

Shows that pure oils allow higher light intensity, while adulterated oils reduce light transmission.



Graph 2: LDR Light Intensity Comparison

VI. ADVANTAGES AND APPLICATIONS

A) Advantages

- **Low-Cost Solution:** Affordable components make it suitable for small grocery stores and households.
- **Real-Time Monitoring:** Continuous detection of temperature, humidity, and adulteration ensures timely action.
- **Multi-Sensor Integration:** Combines DHT-11, MQ3, and LDR sensors for comprehensive quality assessment.
- **IoT Enabled:** ESP8266 module allows remote monitoring and cloud-based notifications.
- **Portable and Easy to Use:** Compact design facilitates placement in various locations without specialized training.
- **Instant Alerts:** Notifies users immediately when quality parameters exceed safe limits.
- **Improves Food Safety:** Helps prevent consumption of adulterated oils and ghee, protecting public health.

B) Applications

- **Grocery Stores & Supermarkets:** Keeps a constant check on edible oils and ghee for the safety of the consumers.
- **Households:** Gives opportunity to users to test the purity of cooking oils and ghee before their usage.
- **Food Production Industries:** It plays a key role in quality control through processing, packaging, and storage.
- **Restaurants & Catering Services:** Justifies the quality of oil to keep up with the food safety standards.
- **Public Health & Regulatory Agencies:** Aids in the inspections and monitoring of the adulteration of edible oils.
- **Educational Institutions:** The device can be used for demonstrations and research activities in the area of food quality monitoring.
- **Remote Monitoring:** IoT feature enables the real-time tracking of multiple locations.

VII. CONCLUSION

The Arduino-based IoT system that was suggested is an efficient and cost-effective as well as a portable solution for the detection of adulteration in ghee and edible oils. The system provides a complete method to monitor the quality through real-time by the use of various sensors such as DHT11 for temperature and humidity, MQ3 for volatile gases, and LDR for light transmittance. The data obtained

are being processed by the Arduino microcontroller which is then sent to a cloud platform through the ESP8266 Wi-Fi module allowing remote monitoring to take place and alerts to be instantaneous. The presence of a character LCD gives local feedback at once which makes the system easy to use and convenient for households, grocery stores, and small-scale food production units. This method brings about significant time, cost, and personnel skill reduction compared to traditional laboratory techniques while still being accurate. The findings prove that the use of multi-sensors combined with IoT connection improves food safety, licenses consumer confidence, and guarantees continuous quality control. This system is a scalable and innovative answer to the problem of food adulteration in the case of edible oils and ghee.

VIII. FUTURE SCOPE

- The use of AI and machine learning algorithms for adulteration prediction and classification has been enhanced to a great degree.
- The scope of detection will be increased to include a wider range of adulterants besides the present VOCs and gases.
- A mobile application interface will be introduced for instant notifications, analysis of historical data, and alerts to users.
- The establishment of wireless sensor networks will allow monitoring of several products in bigger storage or retail locations.
- The system will be able to adjust for the monitoring of other products like milk, honey, or spices.
- There will be the creation of solar-powered or battery-operated portable versions suitable for underserved areas.
- Integration with government and regulatory platforms for comprehensive food safety monitoring on a national scale will be done.

REFERENCES

- [1] R. Kumar and S. Verma, "IoT-Based Food Quality Monitoring System," *Journal of Food Engineering*, 2022.
- [2] P. Sharma and M. Gupta, "Rapid Detection of Adulteration in Ghee Using Electronic Sensors," *International Journal of Food Science*, 2022.
- [3] A. Singh and T. Roy, "Smart IoT System for Oil Quality Analysis," *IEEE Sensors Journal*, 2023.
- [4] K. Das and R. Mehta, "Automated Detection of Edible Oil Adulteration," *Food Control*, 2023.
- [5] S. Patel and V. Joshi, "Real-Time Monitoring of Ghee Purity Using IoT," *Journal of Food Quality*, 2024.
- [6] N. Rao and M. Singh, "Sensor-Based Detection of Food Contaminants," *Journal of Applied Food Technology*, 2024.
- [7] L. Chatterjee and P. Kumar, "Low-Cost Electronic Adulteration Detection in Oils," *International Journal of Food Safety*, 2025.
- [8] R. Agarwal and S. Banerjee, "IoT-Enabled Food Quality Assessment," *IEEE Internet of Things Journal*, 2025.
- [9] D. Mehra and V. Sharma, "Smart Sensor Networks for Edible Oil Purity," *Sensors & Actuators B*, 2025.
- [10] P. Verma and A. Kapoor, "Arduino-Based Adulteration Detection in Dairy Products," *Food Research International*, 2025.

- [11] K. Gandhi, A. Kumar, and D. Lal, "Solvent Fractionation Technique Paired with Apparent Solidification Time (AST) Test as a Method to Detect Palm Olein and Sheep Body Fat in Ghee (Clarified Milk Fat)," *Indian J. Dairy Sci.*, vol. 71, no. 3, pp. 246–251, 2018.
- [12] G. Pei, G. Haiyan, S. Bolin, Z. Lei, W. Houyin, and Z. Ruicong, "Information Variation Feature and Discriminant Capabilities of Electronic Nose for Typical Adulteration Honey Identification," *Trans. Chinese Soc. Agric. Eng.*, vol. 31, 2015.
- [13] M. Ghasemi-Varnamkhasti, S. S. Mohtasebi, M. Siadat, J. Lozano, H. Ahmadi, et al., "Aging Fingerprint Characterization of Beer Using Electronic Nose," *Sensors Actuators B: Chem.*, vol. 159, no. 1, pp. 51–59, 2011.
- [14] M. Ghasemi-Varnamkhasti, M. L. Rodríguez-Méndez, S. S. Mohtasebi, C. Apetrei, J. Lozano, H. Ahmadi, et al., "Monitoring the Aging of Beers Using a Bioelectronic Tongue," *Food Control*, vol. 25, no. 1, pp. 216–224, 2012.
- [15] H. Karami, M. Rasekh, and E. Mirzaee Ghaleh, "Application of the E-Nose Machine System to Detect Adulterations in Mixed Edible Oils Using Chemometrics Methods," *J. Food Process. Preserv.*, vol. 44, no. 9, p. e14696, 2020.
- [16] R. J. Kaushik and P. Rai, "Therapeutic Potentials of Cow Derived Products: A Review," *Int. J. Pharm. Sci. Res.*, vol. 7, no. 4, pp. 1383, 2016.
- [17] A. Kumar, *Detection of Adulterants in Ghee*, NDRI, Karnal, 2008.
- [18] A. Kumar, S. Tripathi, N. Hans, H. S. N. Pattnaik, and S. N. Naik, "Ghee: Its Properties, Importance and Health Benefits," *Lipid Universe*, vol. 6, p. 6–14, 2018.
- [19] S. Okur, M. Sarheed, R. Huber, Z. Zhang, L. Heinke, and A. Kanbar, et al., "Identification of Mint Scents Using a QCM Based E-Nose," *Chemosensors*, vol. 9, no. 2, p. 31, 2021.
- [20] A. M. Patel, *Validation of Methods for Detection of Ghee Adulteration with Animal Body Fat*, NDRI, 2011.