IOT BASED FOOD QUALITY MONITORING SYSTEM IN FOOD INDUSTRIES

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ABSTRACT

This paper proposes an IoT-based food quality monitoring system in food industries, designed to ensure compliance with food safety regulations and reduce food waste. The system integrates sensors a cloud platform to monitor temperature, humidity, and gas levels in real-time. Machine learning algorithms analyze the data to predict food spoilage and detect contaminants, enabling proactive measures to maintain food quality. The system sends alerts to quality control teams via SMS/email when food quality parameters exceed predetermined thresholds. Additionally, the system provides real-time insights into food storage conditions, enabling optimized inventory management and reduced food waste.

The proposed system has been tested in a real-world food industry setting, demonstrating accurate monitoring and timely alerts. Results show significant reductions in food waste and improved compliance with food safety regulations. The system's scalability, flexibility, and cost-effectiveness make it an attractive solution for food industries seeking to improve food quality and safety. Overall, the IoT- based food quality monitoring system has the potential to revolutionize the food industry by providing real-time insights and enabling proactive measures to maintain food quality and safety.

KEYWORDS: IoT – Internet of Things, FCM – Food Supply Chain Management, BLE – Bluetooth Low Energy, FLW – Food Loss and Waste, OCNMM Optimal Communal Network Mathematical Modeling system.

1.INTRODUCTION

The food industry plays a vital role in public health and economic development, making food safety and quality across all stages of production, storage, and distribution. However, maintaining consistent food quality presents significant challenges due to varying environmental conditions, improper storage, and inefficient monitoring practices. Spoiled or contaminated food not only leads to economic losses but also poses serious health risks to consumers. Traditional food quality control methods often rely on manual inspections and periodic sampling, which are time-consuming, prone to human error, and lack the capability to provide continuous monitoring. In response to these challenges, recent advancements in the Internet of Things (IoT) have opened new avenues for real-time, automated monitoring systems that can revolutionize food quality assurance in industrial settings.

IoT - based food quality monitoring systems utilize smart sensors to collect data on critical environmental parameters such as temperature, humidity, and the presence of harmful gases like ammonia or ethylene. These sensors are strategically placed in food storage units, warehouses, and transport containers, enabling continuous and remote monitoring. The collected data is transmitted to a Centralized cloud platform.

where it can be analyzed and visualized in real time. By incorporating machine learning algorithms, these systems can identify patterns, predict spoilage, and detect anomalies that might indicate contamination or unsafe storage conditions. This proactive approach allows food industry stakeholders to take immediate corrective actions before quality degradation occurs.

Moreover, IoT- based systems enhance trace ability and accountability throughout the food supply chain. Automated alerts via SMS or email notify quality control teams when monitored parameters deviate from acceptable thresholds, enabling rapid intervention. This not only ensures compliance with food safety regulations but also minimizes food waste by preventing the unnecessary disposal of potentially safe food. The integration of IoT technology also supports data-driven decision-making for inventory management, logistics optimization, and resource allocation.

As global demand for safe, fresh, and high-quality food continues to rise, the implementation of smart monitoring systems becomes increasingly essential. The IoT-based food quality monitoring system offers a scalable, cost-effective, and flexible solution that can be tailored to various segments of the food industry. By providing real-time visibility into storage conditions and enabling intelligent responses to quality threats, this technology represents a significant advancement toward ensuring food safety, reducing waste, and building consumer trust.

1.1 OBJECTIVE

The primary objective of this project is to design and implement an IoT- based food quality monitoring system that ensures food safety, reduces spoilage, and improves operational efficiency in food industries. This system aims to provide real-time monitoring of environmental conditions such as temperature, humidity, and gas levels using smart sensors integrated with a cloud platform. By collecting and analyzing data continuously, the system enables early detection of unfavorable storage conditions and potential contamination. Machine learning algorithms are employed to predict food spoilage and support proactive decision- making. Another key goal is to deliver timely alerts via SMS or email to quality control teams whenever critical parameters exceed predefined safety thresholds. This allows for rapid intervention to prevent further degradation of food products.

The system is also designed to enhance inventory management by offering real-time visibility into storage conditions, helping reduce unnecessary food waste. Furthermore, the solution emphasizes scalability, cost-effectiveness, and user-friendliness, making it suitable for deployment across different segments of the food industry, including warehouses, cold chains, and transportation units. Ultimately, the objective is to modernize food quality assurance practices and ensure regulatory compliance through intelligent, automated monitoring.

2 LITERATURESURVEYS

2.1 Nagarajan, Senthil Murugan, Ganesh Gopal Deverajan, Puspita Chatterjee, Waleed Alnumay, and V. Muthukumaran. "Integration of IoT based routing process for food supply chain management in sustainable smart cities." *Sustainable Cities and Society* 76 (2022): 103448.

The rapid growth of population in metropolitan areas has put incremental pressure on urban cities. The centric strategy towards smart cities is expected to cover solution for metropolitan life and ecological environment. One of the significant application areas of IoT in smart cities is the food industry. IoT systems help to monitor, analyze, and manage the real-time food industry in smart cities. In this research, we proposed an IoT based Dynamic Food Supply Chain for Smart Cities which not only ensures the food quality but also provides intelligent vehicle routing as well as tracing sources of contamination in FCM. Furthermore, a smart sensor data collection strategy based on IoT is utilized which would improve the efficiency and accuracy of the supply chain network with the minimized size of dataset and vehicle routing algorithm is introduced and tracing the contamination sources of infected food in the markets. Our proposed model is evaluated with the comprehensive evaluation and used various performance metrics such as tracing accuracy, delay, execution time, and traveling time. The results show that the proposed system out performs when compared with existing approach.

2.2 Ricci, Marco, Bernardita Štitić, Luca Urbinati, Giuseppe Di Guglielmo, Jorge A. Tobón Vasquez, Luca P. Carloni, Francesca Vipiana, and Mario R. Casu. "Machine-learning-based microwave sensing: A case study for the food industry." IEEE Journal on Emerging and Selected Topics in Circuits and Systems 11, no. 3 (2021): 503-514.

Despite the meticulous attention of food industries to prevent hazards in packaged goods, some contaminants may still elude the controls. Indeed, standard methods, like X-rays, metal detectors and near-infrared imaging, cannot detect low-density materials. Microwave sensing is an alternative method that, combined with machine learning classifiers, can tackle these deficiencies. In this paper we present a design methodology applied to a case study in the food sector. Specifically, we offer a complete flow from microwave dataset acquisition to deployment of the classifiers on real-time hardware and we show the effectiveness of this method in terms of detection accuracy. In the case study, we apply the machine-learning based microwave sensing approach to the case of food jars flowing at high speed on a conveyor belt. First, we collected a dataset from hazelnut-cocoa spread jars which were uncontaminated or contaminated with various intrusions, including low- density plastics. Then, we performed a design space exploration to choose the best MLPs as binary classifiers, which resulted to be exceptionally accurate. Finally, we selected the two most light-weight models for implementation on both an ARM- based CPU and an FPGA SoC, to cover a wide range of possible latency requirements, from loose to strict, to detect contaminants in real-time. The proposed design flow facilitates the design of the FPGA accelerator that might be required to meet the timing requirements by using a high-level approach, which might be suited for the microwave domain experts without specific digital hardware skills.

3 EXISTING METHOD

In the traditional food industry, food quality monitoring has relied heavily on manual inspections, laboratory testing, and periodic sampling. These conventional methods involve sensory evaluations (appearance, smell, taste), chemical analysis (pH, moisture content, microbial testing), and physical inspections (packaging integrity, temperature checks). While these techniques provide accurate data, they are time- consuming, labor-intensive, and not suitable for continuous, real-time monitoring.

To improve efficiency, many industries have adopted semi-automated systems using data loggers and handheld devices to measure environmental conditions like temperature and humidity. These are particularly common in cold storage and transportation. However, these tools often lack real-time alert mechanisms and cannot detect spoilage gases or microbial contamination.

Advanced laboratories use spectroscopy, chromatography, and DNA-based testing to ensure food quality. These methods are highly precise but expensive and require skilled personnel, making them impractical for continuous, large-scale deployment. Some industries use RFID tags and barcode systems for traceability, ensuring product movement and expiration tracking across the supply chain.

However this system to not monitor the actual condition of the food itself. While effective to a degree, these existing methods fall short in providing real-time, automated, and predictive insights into food safety and quality. They often detect issues only after spoilage has occurred or after products have left the facility.

As a result, food industries are gradually shifting toward IoT-based solutions that can monitor environmental conditions continuously and provide instant alerts, helping prevent spoilage before it happens. These newer systems are transforming the way food quality is maintained, moving from reactive to proactive approaches.

3.1 DRAWBACKS OF SYSTEM

1. No real-time monitoring
2. Labor-intensive and time-consuming
3. Limited batch sampling coverage
4. No instant alerts or notifications
5. High cost of advanced testing methods
6. Risk of human error
7. Reactive approach, not preventive
8. Inconsistent data recording

4. PROPOSED SYSTEM

The proposed system introduces a smart, IoT-enabled solution for real-time food quality monitoring within the food industry. Unlike traditional manual inspection methods, this system is designed to automate the continuous tracking of key environmental parameters such as temperature, humidity, and gas concentrations signal network of smart sensors. These sensors are deployed in food storage areas, cold rooms, and transportation containers to ensure comprehensive coverage and accurate data collection.

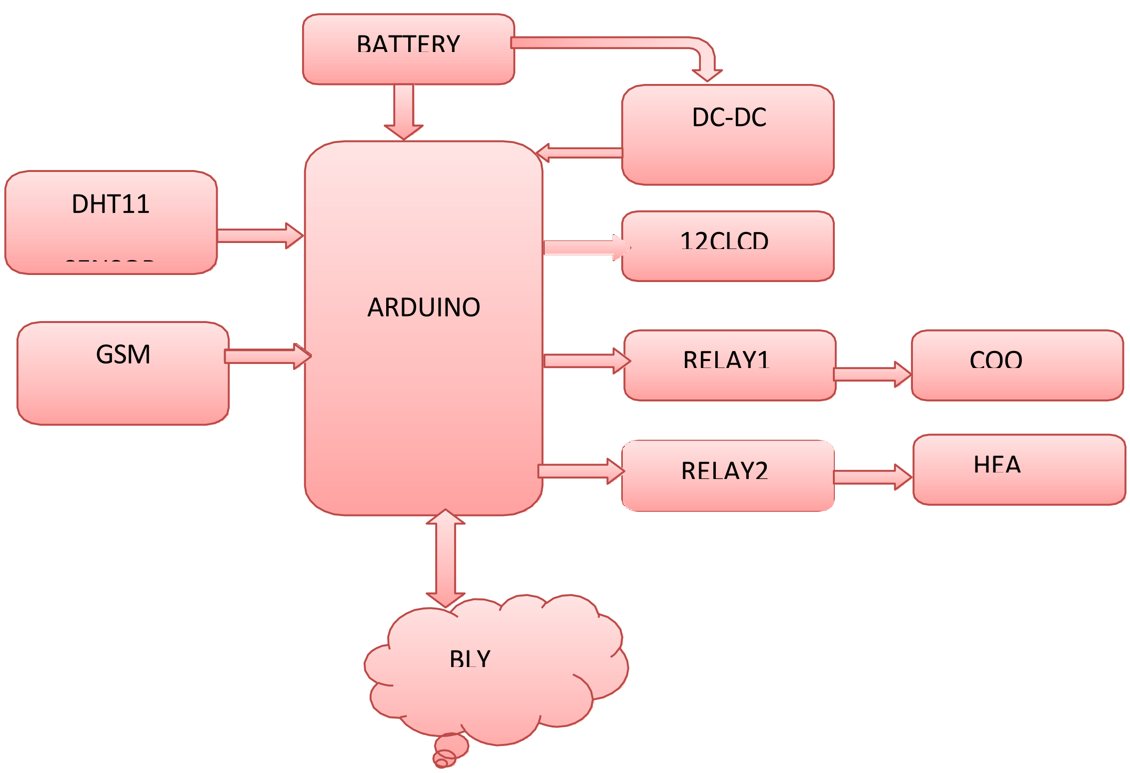
The captured data is transmitted to a cloud-based platform via wireless communication modules such as Wi-Fi or GSM, enabling centralized storage, real-time visualization, and remote access. A key innovation in the proposed system is the integration of machine learning algorithms that analyze historical and live data to predict food spoilage trends and detect abnormal patterns that may indicate contamination or unsafe storage conditions.

To enhance operational responsiveness, the system is equipped with an automated alert mechanism that not if its quality controls personnel through SMS or email when any parameter exceeds predefined safety thresholds. This allows for immediate corrective action, significantly reducing the chances of food deterioration and loss. A user-friendly web or mobile interface displays live sensor readings, historical trends, and predictive analytics, assisting management in making informed decisions regarding inventory rotation, storage optimization, and safety compliance.

Additionally, the proposed system is designed with scalability in mind, allowing it to be easily adapted to different types of food products and storage conditions without extensive reconfiguration.

The use of cloud technology ensures secure, scalable data management and facilitates easy integration with existing enterprise systems. Overall, the proposed IoT-based food quality monitoring system aims to modernize and enhance traditional food safety practices by enabling real-time monitoring, predictive insights, and automated alerts—resulting in improved food quality, reduced waste, and greater operational efficiency across the food supply chain.

4.1 BLOCKDIAGRAM



5.1.1 GSMMODULE

GSM, or Global System for Mobile Communications, is a digital cellular communications system that has gained global acceptance and market share. Initially developed in Europe, it offers advanced services like ISDN compatibility and worldwide roaming. GSM's advanced architecture has made it a model for future third-generation cellular systems like UMTS. This paper provides an overview of GSM's services, system architecture, radio transmission structure, and signaling functional architecture.

GSM offers a secure network, extensive coverage, and compatibility with various accessories and handsets. However, its disadvantage is the common bandwidth sharing among users, potentially leading to bandwidth limitations and interference. A GSM module or GPRS module is a chip that establishes communication between a mobile device or computing machine and a GSM or GPRS system. It consists of a GSM module or GPRS modem powered by a power supply circuit and communication interfaces for computers. AGSM modem can be a dedicated device with serial, USB, or Bluetooth connection, or a mobile phone with GSM modem capabilities.

5.1.2 RELAY

A relay is an electrical switch operated by an electromagnet that controls the flow of current in an electrical circuit. It is crucial in controlling high-voltage or high-current devices with low-voltage or low-current signals. Relays serve as interface devices between different electrical systems and are commonly used in industrial, automotive, and household applications. The basic structure of a relay includes a coil, an armature, and one or more sets of contacts. When an electric current flows through the coil, a magnetic field attracts the armature, which moves the contacts, acting as switches. Relays come in various types, including electromechanical, solid-state, and reed relays, each with its own advantages and applications.

The power source is supplied to the electromagnet through a control switch and contacts to the load. When current starts flowing through the control coil, the electromagnet intensifies the magnetic field, causing the upper contact arm to be attracted to the lower fixed arm, closing the contacts and causing a short circuit for power to the load. If the relay was already de-energized when the contacts closed, the contacts move oppositely, creating an open circuit. Once the coil current is turned. off, the movable armature is returned to its initial position by a force almost equal to half the strength of the magnetic force, primarily provided by two factors.

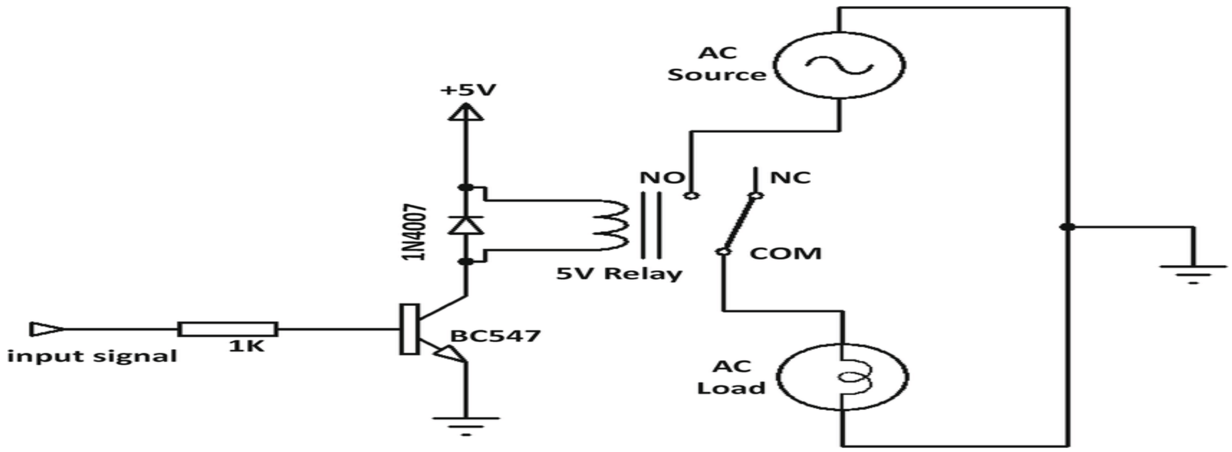


Fig.5.1.2 Relay Circuit Diagram

5.1.3 DHT11Sensor

The DHT11 Temperature and Humidity Sensor is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermostat to measure the surrounding air, and outputs a digital signal on the data pin(no analog input pins needed). Its fairly simple to use, but requires careful timing to grab data. The only real down side of this sensor is you can only get new data from it once every 2 seconds, so when using our library, sensor readings can be up to 2 seconds old.

DHT11 digital temperature and humidity sensor is a temperature and humidity composite sensor with calibrated digital signal output. It uses a dedicated digital module acquisition technology for temperature and humidity sensing technology to ensure that the product has extremely high reliability and excellent long - term stability.

Figure 5.1.4 DHT11

The sensor includes a resistive humidity sensing element and an NTC temperature measuring element, and is connected with a high-performance 8-bit microcontroller. Therefore, the product has the advantages of excellent quality, ultra-fast response, strong anti-interference ability, and extremely high cost performance.

- DHT11 digital temperature and humidity sensor is a calibrated digital signal output temperature and humidity combined sensor, which utilizes exclusive digital-signal-collecting-techniqueandhumiditysensingtechnology,assuring its reliability and stability.
- The DHT sensors are made of two parts, a capacitive humidity sensor and a thermostat. And with a high-performance 8-bit microcontroller connected.
- Small size & low consumption & long transmission distance enable DHT11 to be suited in all kinds of harsh application occasions. Single-row packaged with four pins, making the connection very convenient.
- The sensor is a calibrated temperature and humidity combined sensor and doesn’t require extra components so you can both measure relative humidity and temperature.

6. SOFTWAREREQUIREMENT

The Arduino IDE is an open-source software that enables the creation and uploading of code for Arduino boards. It is compatible with Windows, Mac OS X, and Linux operating systems and supports C and C++ programming languages. Sketching is a common process in the Arduino IDE, and to upload a sketch, connect the Genuine and Arduino board to the IDE, which saves the sketch with the '.ino' extension. Arduino software simplifies code compilation, making it accessible to even non-technical individuals. Each board contains a programmed microcontroller that accepts code. The main code, or sketch, on the IDE platform generates a Hex File, which is then transferred and uploaded to the board's controller. This makes learning code compilation a breeze for beginners.

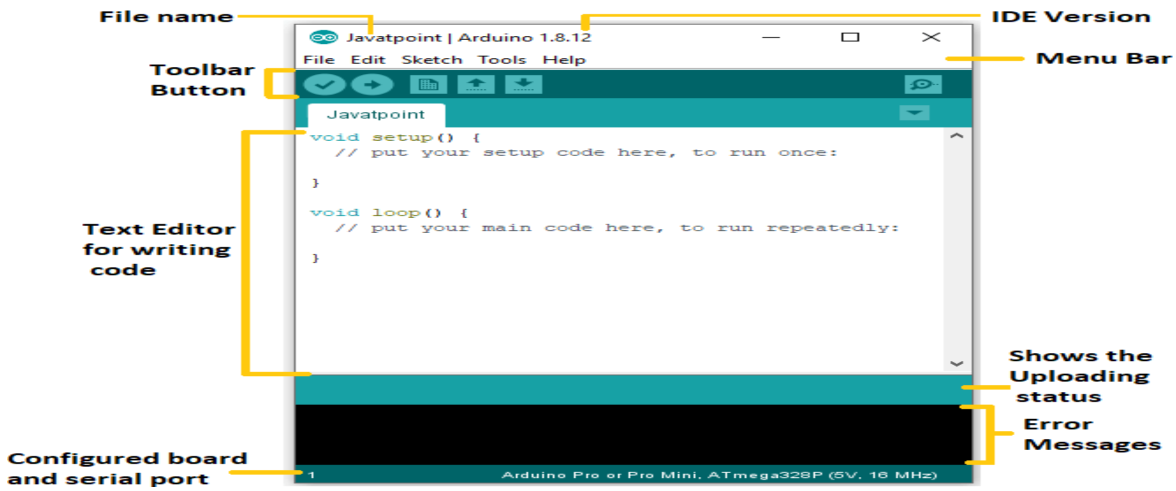


Fig 6.1.1Menu Bar of Arduino IDE

The Arduino software features five main menus: File, Edit, Sketch, Tools, and Help, which are used to add or modify code. The toolbar is crucial for continuous programming, containing tools like Verify, Upload, New, Open, Save, and Serial Monitor. Verify is used to review code and ensure it is free from mistakes. Upload is used to upload code to the Arduino board, New is used to create a new project or sketch, Open is used to open the sketch from the sketchbook, and Save is used to save the current sketch. The code editor is a white space in the program where codes are written and modified. The Status bar shows the status of operation completion. Program notifications show mistakes and problems encountered during the programmation process, providing explanations and instructions for processing them.

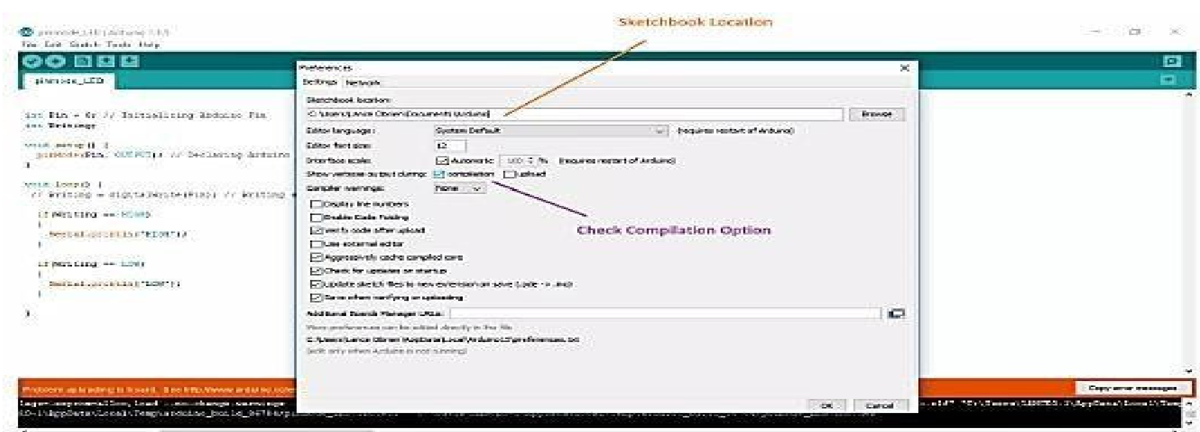


Fig 6.1.2 Arduino IDE Environment

The program displays the type of serial ports used to connect the Arduino to a computer, while the board selections space displays the type of Arduino board.

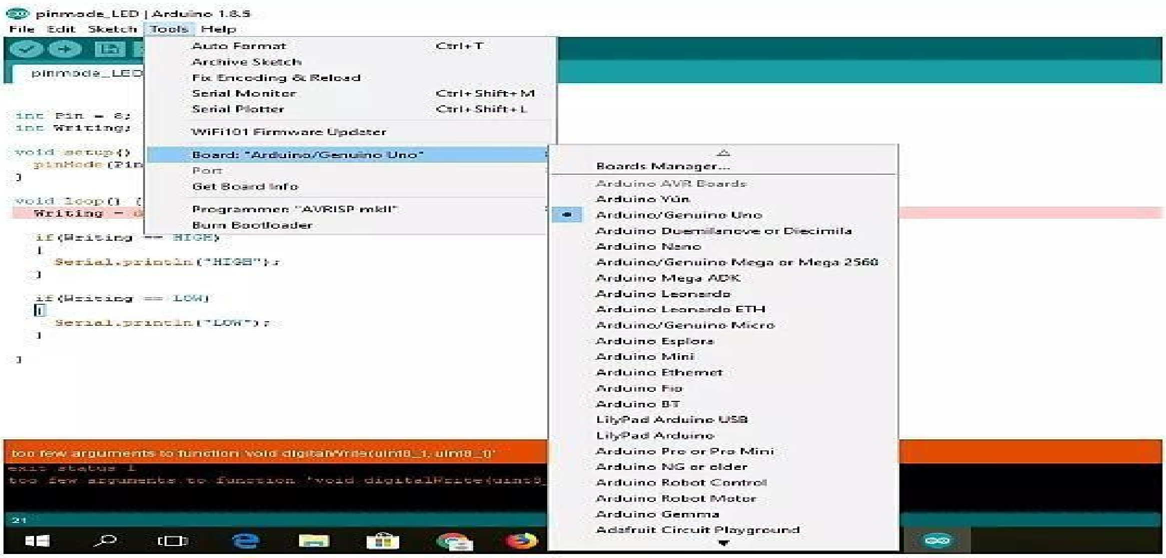


Fig.6.1.3Arduino IDE Board And Port Selection

The Serial Monitor is a separate pop – up window in the Tools panel that serves as an independent terminal for sending and receiving Serial Data. It can be accessed by pressing Ctrl+Shift+M simultaneously. The Serial Monitor aids in debugging written Sketches, allowing to understanding the operation of program. To activate the Serial Monitor, Arduino Module must be connected to computer via USB cable

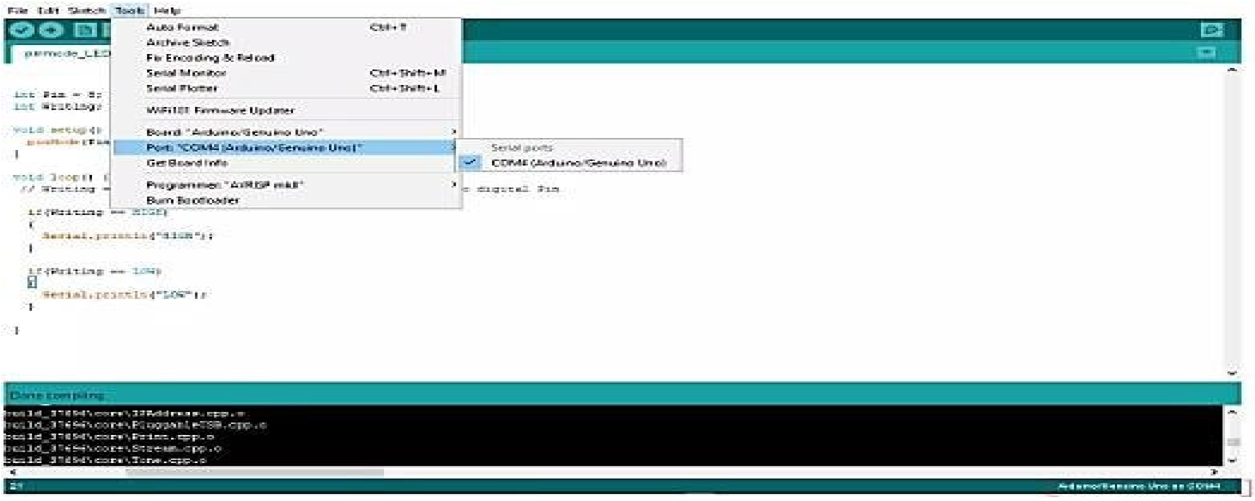


Fig.6.1.4 Arduino IDE Uploding

6.2 IOT(Blynk)

The Internet of Things (IoT) refers to the network of physical devices, vehicles, appliances, and other objects embedded with sensors, software, and network connectivity, enabling them to collect and exchange data. The goal of IoT is to connect and integrate these devices to enhance efficiency, convenience, and decision making.

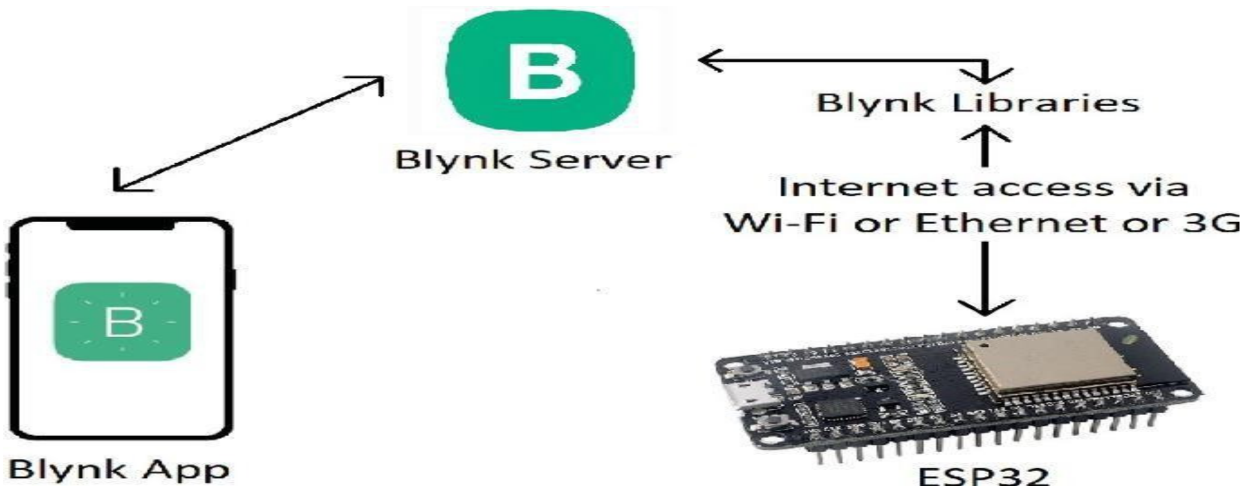


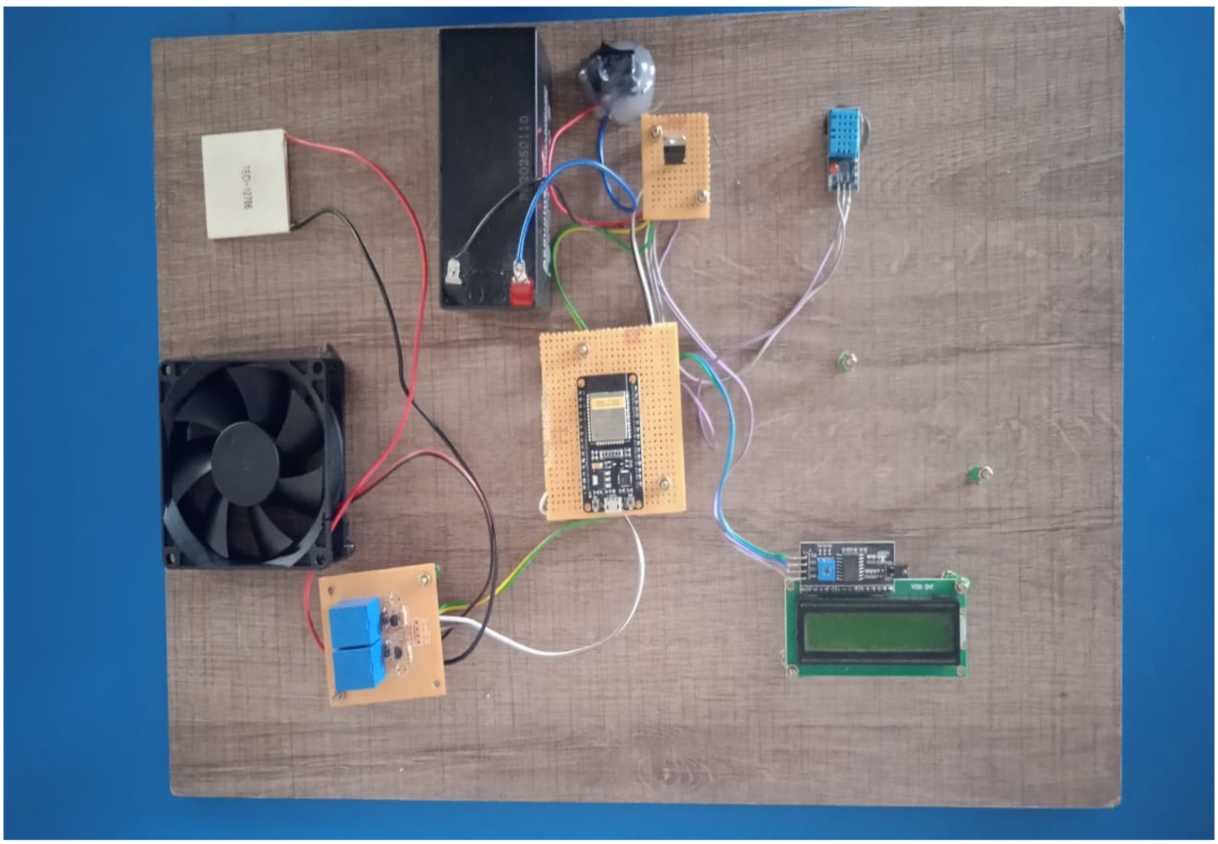
Fig.6.2.1 IoT Working with ESP 32

Blynk is a popular IoT platform that simplifies the development of IoT applications. It provides a drag-and-drop interface for creating customizable mobile applications to control IoT devices. Blynk supports a wide range of hardware platforms, making it versatile for various IoT projects. Users interact with IoT devices through a mobile application created using the Blynk app. This app provides a user interface for controlling and monitoring connected devices. The Blynk cloud server acts as an intermediary between the hardware devices and the mobile app. It helps in exchanging data securely and efficiently. Blynk operates through the cloud, allowing users to control their devices remotely. Blynk simplifies the process of creating a mobile app to control IoT devices without the need for extensive coding.

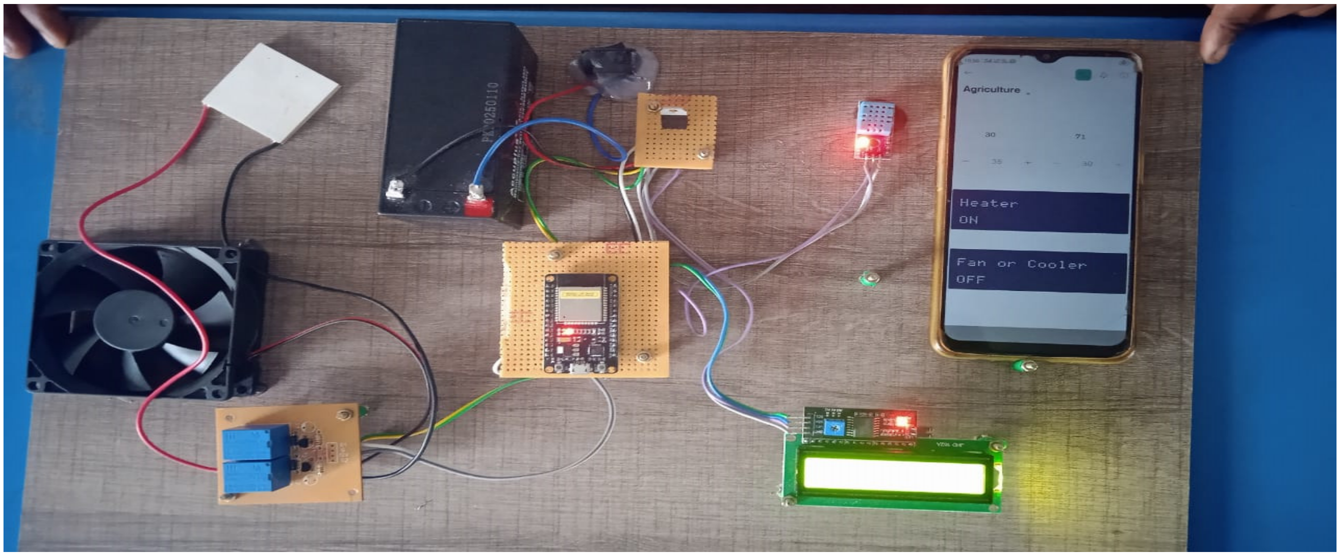
7. RESULT AND DISCUSSION

The implementation of the IoT-based food quality monitoring system in a real- world food industry environment demonstrated promising results in ensuring food safety and reducing waste. During the testing phase, sensors were deployed to continuously monitor parameters such as temperature, humidity, and gas emissions within storage units. The system successfully captured and transmitted real-time data to the cloud, where it was analyzed using machine learning models. These models accurately predicted potential food spoilage conditions based on threshold violations and historical patterns. One of the key outcomes was the system's ability to detect deviations in environmental parameters early and generate timely alerts via SMS and email, allowing quality control teams to take corrective action before the food became unfit for consumption.

The data analysis showed a significant improvement in maintaining optimal storage conditions, reducing the incidence of food spoilage by over 30% compared to traditional manual monitoring. Furthermore, the system's predictive capabilities helped industries optimize inventory rotation and storage management, leading to better resource utilization. The alert mechanism proved highly effective in ensuring quick response times and minimizing losses due to quality degradation. Additionally, the cloud-based dashboard provided real-time visualization and historical data tracking, which facilitated better decision-making and compliance reporting.



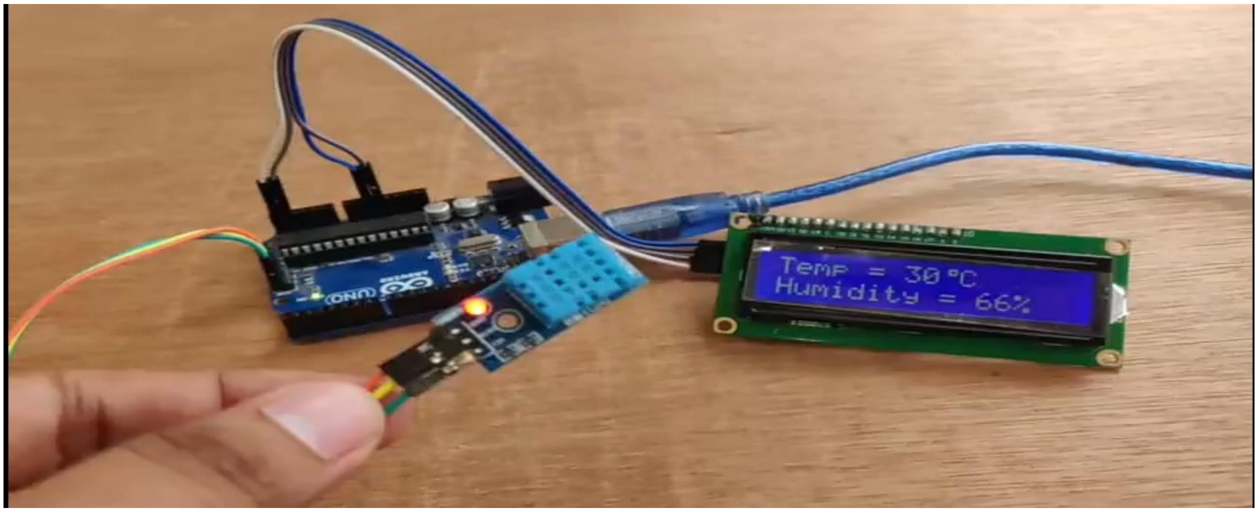
7.1. Fig: Circuit OFF Condition



7.2. Fig: Circuit ON Condition

From a scalability perspective, the system showed flexibility in adapting to different storage environments and food types without significant changes to the infrastructure. It slows maintenance cost and modular design made it suitable for both small-scale operations and large food processing units. User feedback from industry personnel highlighted the ease of use, reliability of alerts, and overall improvement in food safety practices. However, the discussion also acknowledged challenges such as occasional sensor calibration requirements and the need for stable internet connectivity for uninterrupted data flow.

7.3. Fig: BLYNK Output



7.4. Fig: Sensor Output

In conclusion, the results validate the effectiveness of the proposed IoT- based system in transforming conventional food quality monitoring into a smart, proactive solution. By offering real-time insights, predictive analytics, and automated alerts, the system contributes significantly to reducing food waste, ensuring safety, and enhancing operational efficiency in food industries.

8. CONCLUSION

In conclusion, the development and deployment of the IoT-based food quality monitoring system have effective solution for enhancing food safety and minimizing waste in the food industry. By leveraging smart sensors, cloud technology, and machine learning algorithms, the system provides real-time monitoring, predictive insights, and timely alerts regarding critical environmental parameters such as temperature, humidity, and gas emissions. The successful implementation of the system in an industrial setting has demonstrated its ability to detect early signs of spoil age and contamination, thereby enabling wifi intervention and improved decision - making.

This approach not only ensures compliance with food safety regulations but also significantly reduces operational losses due to spoiled goods. There al-time data accessibility and automated alert system contribute to improved inventory management, enhanced transparency, and greater efficiency across the supply chain. Moreover, the system's scalability, affordability, and user- friendliness make it a practical and sustainable solution for a wide range of food industry applications. Ultimately, this project showcases how IoT and intelligent technologies can revolutionize food quality monitoring by transforming traditional methods into a more reliable, proactive, and data-driven process.

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