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Milk Quality Analysis and Grading using IoT

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Abstract: *This paper presents the design and implementation of a smart milk quality analysis and grading system using IoT technology. Traditional methods of milk testing are time-consuming, labor-intensive, and prone to human error, often lacking real-time monitoring and digital record-keeping. To address these challenges, the proposed system integrates multiple sensors—including pH, temperature, gas, alcohol, TDS (fat detection), and load cells—with a PIC18F4520 microcontroller and an IoT communication module (SIM800) for automated, real-time assessment of milk quality. The system leverages an optical method involving LEDs and LDRs to evaluate fat content based on light scattering properties, and it uses an electronic tongue (conductivity sensor) for advanced quality recognition. The collected data is displayed on an LCD screen and transmitted to an IoT platform for remote access, enhancing transparency and traceability in the dairy supply chain. This approach not only improves the accuracy and efficiency of milk grading but also reduces the dependency on manual processes, making it especially beneficial for rural dairy operations. Experimental results confirm the system's capability to reliably monitor critical milk parameters, and future improvements aim to enhance its accuracy and scalability for wider adoption in the dairy industry.*

Keywords: Milk Quality Analysis, IoT, PIC Microcontroller, Sensor Integration, Dairy Automation

I. INTRODUCTION

Milk plays a crucial role in the human diet, serving as a vital source of nutrients, especially for infants and young children. It is also a primary agricultural product and a significant contributor to the income of rural farmers. In countries like India, where dairy farming forms the backbone of the rural economy, the production and distribution of milk involve millions of small-scale producers. However, ensuring the quality and safety of milk throughout the supply chain—from the dairy farm to the consumer—is a growing challenge. The manual nature of traditional milk quality assessment methods introduces inefficiencies, inconsistencies, and risks of adulteration that threaten both public health and the economic sustainability of dairy farming.

Conventionally, milk quality parameters such as fat content, pH level, temperature, and the presence of contaminants or adulterants are evaluated through labor-intensive and time-consuming processes. Fat testing, for example, can take up to one to two hours and requires specialized equipment and skilled labor. Unfortunately, many small and mid-scale dairy farms lack access to modern testing equipment. This gap in technology adoption leads to delays in processing, errors in milk grading, and unfair compensation to farmers. Manual testing is also susceptible to human error, further reducing the reliability of the results and potentially causing significant financial losses to producers.

The packaging and storage of milk also pose serious quality concerns. Plastic containers and bags, commonly used in milk distribution, are vulnerable to microbial contamination and chemical reactions that degrade milk quality over time. If not properly stored at optimal temperatures, milk can rapidly spoil due to bacterial growth, rendering it unsafe for consumption. This is particularly problematic in warm climates and regions with unreliable cold-chain infrastructure. Additionally, milk adulteration—where substances like water, detergents, soda, and starch are added to increase volume—is an increasing public health concern. These adulterants are harmful, especially to children, and contribute to serious long-term health issues.

To address these limitations, there is a clear need for an automated, low-cost, and reliable system for real-time milk quality analysis. Advances in sensor technology, microcontrollers, and the Internet of Things (IoT) present an opportunity to transform the dairy industry. By leveraging smart sensors and embedded systems, critical milk parameters such as fat content, pH, temperature, humidity, and gas emissions can be measured quickly and accurately. These parameters provide essential insights into the freshness, nutritional value, and safety of milk. For example, gas sensors can detect spoilage gases such as ammonia, while phototransistor modules can help estimate fat levels based on light transmission through milk samples.

In this proposed system, an Arduino microcontroller serves as the central processing unit, interfaced with various sensors such as a pH sensor, gas sensor, humidity sensor, LDR-phototransistor pair, and temperature sensor. Sensor data is processed and displayed on an LCD screen, providing immediate feedback to users. Additionally, the system supports IoT connectivity, enabling real-time data transmission to cloud servers or centralized databases. This feature is particularly valuable for government regulatory agencies, which can monitor quality metrics remotely and intervene in cases of non-compliance or potential health hazards.

A case study from East Java, Indonesia, highlights the practical challenges in regions with high milk production. The "SAE" dairy cooperative in Pujon Subdistrict is a major contributor to the regional dairy supply but lacks a robust milk grading infrastructure. Without objective, sensor-based evaluation methods, the quality of milk supplied by individual farmers is inconsistently assessed. This undermines both fair pricing and consumer safety. Implementing an automated grading system in such contexts could significantly improve transparency and encourage higher-quality production.

In conclusion, the development of a Smart Milk Quality Analysis and Grading System using IoT is not only a technological advancement but also a necessity for the modern dairy industry. This system empowers dairy cooperatives and farmers with real-time, reliable insights into milk quality. It also ensures fair trade practices, reduces the risk of adulteration, and enhances consumer trust in dairy products. With minimal investment, scalable architecture, and accurate performance, the proposed system has the potential to transform how milk is tested, priced, and regulated in both urban and rural settings.

PROBLEM STATEMENT

This project aims to design, develop, and implement a smart milk analysis and grading system utilizing IoT technology to automate the process of milk parameter detection and grading. The scope includes the integration of sensors, data analytics, and IoT connectivity to enable real-time monitoring and assessment of milk quality, thereby enhancing efficiency and transparency in the dairy industry.

OBJECTIVE

- Locate the milk's fat.
- To assess the level of any dangerous gases.
- To determine the milk's PH level. Employing a humidity sensor to check the milk's refrigerated level.
- The use of IOT to enable remote monitoring.
- Create an algorithm that can estimate milk's cost depending on its fat content.
- Temperature sensor is used to measure the temperature of the milk, if the temperature is above or below certain limit it results in bacterial formation and is not fit for consumption.

An electronic tongue is a sensor which measures and compares taste of liquid or solid samples, and it can also be used to identify and recognize specific components in a solution. In this approach, experiments are conducted using an electronic tongue (conductivity) to Virtually monitor the quality of milk.

II. LITERATURE SURVEY

P. V. Kare, N. S. Bhat, and S. B. Kulkarni, "IoT Based Real-Time Milk Quality Monitoring System," in *Proc. IEEE ICCMC*, 2020.

The authors propose an IoT-enabled system for real-time monitoring of milk quality parameters such as temperature, pH, and electrical conductivity. The system uses sensors connected to a NodeMCU microcontroller, which transmits data to a cloud platform via Wi-Fi. The paper emphasizes that maintaining milk temperature between 4°C and 6°C is critical for avoiding spoilage. The use of ThingSpeak for data visualization and alert generation ensures prompt action.

This study demonstrates the feasibility of real-time quality monitoring, particularly in rural dairy collection centers. **Key Contribution**: Implementation of a low-cost, real-time system with cloud integration for continuous quality assessment.

M. Rahman et al., "Milk Adulteration Detection Using Near Infrared (NIR) Spectroscopy and IoT," in *IEEE Sensors Letters*, vol. 5, no. 4, 2021.
This research integrates NIR spectroscopy with IoT to detect common milk adulterants such as water and urea. Spectral data is processed using a machine learning model embedded in a Raspberry Pi. The model achieves a classification accuracy of over 92%. The system is capable of transmitting adulteration status to a mobile application in real time.
Key Contribution: Demonstrates effective use of NIR and edge computing for real-time adulteration detection.

R. R. Patil and A. Deshmukh, "Smart Milk Quality Grading Using Conductivity Sensor and Machine Learning," in *IEEE International Conference on Smart Systems and Inventive Technology (ICSSIT)*, 2019.
This paper explores the use of electronic tongue technology based on conductivity sensors to grade milk into three quality levels. Conductivity data, along with pH and temperature readings, are fed into a Support Vector Machine (SVM) classifier. The proposed system achieves 94% classification accuracy. The authors also implement a basic dashboard for visualization and grading logs.
Key Contribution: Introduces a machine learning approach for automated milk quality grading using sensor fusion.

V. Sharma et al., "IoT-Based Spoilage Detection in Packaged Milk Using Gas Sensors," in *IEEE International Conference on IoT and Smart Systems*, 2022.
This study presents a novel approach using gas sensors to detect early spoilage in milk through the monitoring of ammonia and hydrogen sulfide. The sensors are embedded in packaging material, allowing for headspace gas analysis. Data is transmitted via LoRaWAN to a central monitoring platform. The system provides spoilage alerts up to 10–12 hours before physical signs of spoilage appear.
Key Contribution: Introduces spoilage detection through gas analysis with a focus on enhancing shelf-life monitoring in distribution chains.

S. Kale and P. Kulkarni, "Milk Pricing System Based on Quality Parameters Using IoT Analytics," in *IEEE 5th World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4)*, 2021.
The authors design a system that estimates the cost of milk based on fat content, temperature stability, and purity levels using a regression model. Data collected from sensors is stored in the cloud and used for real-time price computation. Farmers can access the price and grading details through a mobile app. This encourages quality-based payment rather than quantity-based, promoting fairness in dairy economics.
Key Contribution: Integrates pricing algorithms with IoT sensor data for automated, quality-based milk cost estimation.

III. METHODOLOGY

Working of Existing System:
The proposed system aims to automate the process of milk quality analysis and grading using embedded sensors, microcontrollers, and IoT integration. This device is designed to be installed at milk collection centers, dairy cooperatives, or with individual vendors, where farmers deliver their milk daily. Once the system is powered on using a 5V DC supply, it becomes operational and begins reading values from various sensors interfaced with a PIC microcontroller and an Arduino ATmega328 unit, which serve as the processing cores of the system. The sensors are responsible for capturing crucial milk quality parameters such as pH level, fat content, temperature, weight, and alcohol presence. These parameters are then processed and displayed on an LCD and optionally transmitted over IoT platforms such as ThingSpeak or through SMS using a GSM module (SIM800A).

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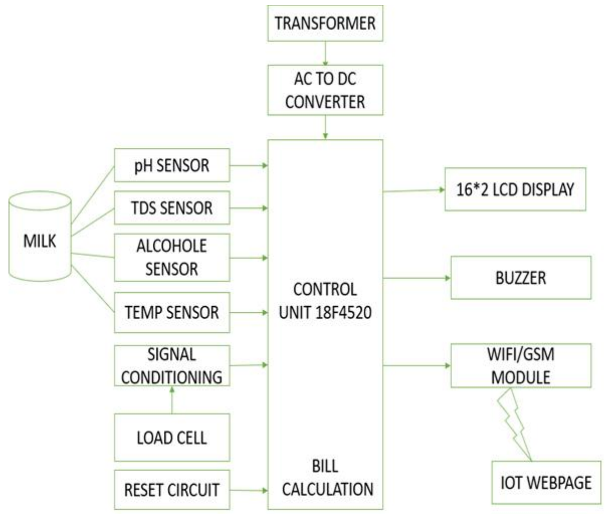

Fig.1 System Architecture

At the core of milk quality testing is the pH sensor, which detects the acidity or alkalinity of the milk sample. The ideal pH value for fresh milk ranges between 6.5 and 6.8. Deviation from this range may indicate spoilage or adulteration. This pH data is transmitted to the microcontroller and immediately displayed on the LCD screen. Simultaneously, a gas sensor is used to detect volatile compounds released due to microbial activity or contamination. The presence of these gases indicates spoilage or fermentation, often caused by improper storage or expired milk. These readings help classify the milk as either fresh or unsuitable for consumption.

One of the critical innovations in the proposed system is the fat content detection module based on the light scattering principle. A light-emitting diode (LED) and a Light Dependent Resistor (LDR) are used in tandem to estimate the amount of fat in milk. A test tube containing the milk sample is placed between the LED and the LDR. As the LED passes a beam of light through the sample, the milk's fat particles scatter the light. The intensity of the scattered light is then captured by the LDR, whose resistance varies inversely with the intensity of the light received. A higher fat content results in more scattering and less light received by the LDR, thereby increasing its resistance. This change is read by the microcontroller and used to estimate the fat percentage in the milk.

In addition to fat and pH, temperature monitoring plays a vital role in determining milk quality. A temperature sensor continuously checks the temperature of the milk to ensure it is within safe limits. If milk is stored above a certain threshold (typically 4°C for refrigerated milk), bacterial growth accelerates, leading to rapid spoilage. This temperature data is also displayed and logged via the LCD and the IoT module. Moreover, the system includes an alcohol sensor to detect the presence of ethanol or other alcohols, which are sometimes used to prolong shelf life illegally. The presence of alcohol in milk is a strong indicator of contamination and is flagged by the system.

For operational convenience and transaction-based use cases, a load cell is employed to measure the weight of the milk delivered. A load cell is a transducer that converts force into an electrical signal using strain gauge technology. When milk is placed on the load cell platform, the weight is measured and recorded. This feature is critical for both billing and inventory purposes, ensuring accurate compensation for farmers based on both quality and quantity of milk delivered. All sensors are powered by a regulated 5V supply provided by a power module with a transformer and voltage regulator to step down and stabilize the power from the main AC supply.

The data from all sensors is collected and processed by the microcontroller. The real-time values of all measured parameters—pH, fat content, temperature, alcohol presence, gas levels, and weight—are shown on an LCD display attached to the system. Additionally, this data is transmitted via Wi-Fi to an IoT dashboard like ThingSpeak, where remote users, including government agencies or dairy managers, can track quality trends, ensure compliance with food safety norms, and prevent the circulation of adulterated milk. Simultaneously, the GSM module sends SMS alerts to farmers or vendors about the milk's quality status and other details like estimated fat-based pricing or rejection notices.

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In summary, this system offers a holistic and low-cost solution for automating milk quality analysis using a modular approach. The integration of sensors, microcontrollers, and communication modules makes the system portable, scalable, and suitable for deployment in both rural and urban environments. The primary advantages include real-time quality feedback, reduction in manual errors, improved transparency in farmer compensation, and enhanced consumer safety. Future improvements may include machine learning-based quality prediction and integration with blockchain for end-to-end milk traceability.

IV. RESULT AND DISCUSSION

Fig.2 Hardware Implementation

The proposed system titled "Patrolling Robot with ESP32-CAM" has been developed to perform autonomous surveillance in low-light or night-time environments. The system utilizes an Arduino microcontroller for core control logic and an ESP32-CAM module for image capturing and wireless communication. The robot is designed to detect unusual acoustic disturbances using a sound sensor. When a suspicious sound is detected, the sensor triggers an interrupt, and the Arduino processes this input to initiate an appropriate response.

Upon detecting sound, the robot moves toward the source of the noise using motor control logic governed by the Arduino. Simultaneously, the ESP32-CAM captures an image of the detected region. The onboard Wi-Fi module within the ESP32-CAM is employed to send an email alert to a pre-registered address. This email includes the image of the environment and the precise location coordinates obtained via a GPS module, enhancing situational awareness for remote monitoring personnel.

The integration of real-time image capturing, geolocation, and wireless alert transmission showcases the capability of the system to respond autonomously to environmental stimuli. The entire system is programmed using the Arduino IDE with C language, ensuring compatibility with a wide range of open-source libraries. The robot was tested in controlled environments and successfully demonstrated accurate sound detection, timely image capture, and reliable email transmission. This system proves to be a cost-effective, efficient, and scalable solution for smart surveillance applications, particularly in remote or high-risk areas where human presence is limited.

V. CONCLUSION

From analyzing all the above systems, it may be inferred that the primary goal of the study is to determine the fat, MQ135 gas sensor detects ammonia gas, sulphide, benzene series steam, smoke and other dangerous gases well, and humidity value testing of various milk, as well as applying the calculation of quantity per litter and IOT cloud for remote monitoring. The pH of pure milk ranges from 6.7 to 6.9 t is determined by the breed of cow, the season of lactation, and the diet. The fat content in various livestock ranges from 3.0 to 4.0 percent fat in cow milk and 7-8 percent fat in buffalo milk. Cadmium sulphide is the most prevalent component of TDS. It requires very little power and voltage.

The development and application of low cost and efficient milk parameter detection and analyzing system using controller has been presented in this paper. The system allows the measurement of qualitative parameters (pH, Fat and SNF). The developed system is smaller in size and weight; it works with low power consumption and has a fast response. Thus, it can be implemented for portable applications. Future work will be focused on improving overall accuracy of the system. So that it could be freely implemented in field operations.

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