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IOT -BASED SYSTEM FOR MILK QUALITY ASSESSMENT, ADULTERATION DETECTION, AND GRADING

Swastik Vaidya[1], Prof. Prachi A Deshpande[2]

[1]M. E Student, Department of Electronics and Telecommunications Engineering, Savitribai Phule Pune University, Pune-411005
[2]Professor, Department of Electronics and Telecommunications, DPCOE College of Engineering Pune, Pune-411005

Abstract - *This project aims to develop a comprehensive and innovative smart system for milk quality analysis and grading, leveraging the capabilities of an ESP32 microcontroller and a suite of specialized sensors. By integrating pH, turbidity, spectral, TDS, temperature, and gas sensors, the system will meticulously measure key parameters that are critical indicators of milk quality and integrity.*

The collected sensor data will be intelligently processed and analyzed, enabling the system to:

- *Accurately assess milk quality: By comparing the measured parameters against established quality standards, the system will reliably determine the overall quality of the milk sample.*
- *Detect adulteration: Through careful analysis of the spectral and gas sensor data, the system will be able to identify potential adulterants, such as water, urea, or detergent, ensuring the purity of the milk.*
- *Discriminate between milk sources: By leveraging the unique spectral signatures of cow and buffalo milk, the system will be able to distinguish between these two primary sources, providing valuable information for consumers and producers.*
- *Grade milk based on quality and freshness: By combining the assessment of multiple parameters, the system will assign a precise grade to the milk, reflecting its quality and level of freshness.*

The collected data will be seamlessly displayed on a 16x2 LCD for local monitoring and transmitted to the Blynk IoT platform, facilitating remote access, analysis, and decision-making. By empowering users with real-time insights into milk quality, this system will play a pivotal role in safeguarding public health and promoting fair and transparent dairy practices.

Key Words: Milk Quality Analysis , Milk Adulteration Detection , IoT-Based Milk Monitoring , Sensor Fusion for Milk Grading , ESP32-Based Milk Quality System

1.INTRODUCTION

This Milk, a vital dietary staple, is often subject to adulteration and quality degradation, posing significant health risks and economic losses. To address these concerns, this project aims to develop an innovative IoT-powered device capable of accurately assessing milk quality through a comprehensive analysis of its properties. By leveraging a suite of advanced sensors, including pH, turbidity, spectral, TDS, temperature, and gas sensors, the device can measure critical parameters that indicate adulteration, spoilage, and origin. The collected data is seamlessly integrated with a 16x2 LCD display and the Blynk IoT platform, enabling real-time monitoring, analysis, and remote access. Through rigorous sensor calibration and advanced data processing algorithms, the device can accurately identify adulterated milk, determine its origin (cow or buffalo), and assign a quality grade based on its freshness and overall composition. This innovative solution has the potential to significantly enhance food safety, improve dairy industry transparency, and empower consumers to make informed choices about the milk they consume.

Specifically, the device will measure the following parameters:

- pH: Indicates acidity or alkalinity, which can be affected by adulteration or spoilage. Adulterated milk may have a lower or higher pH than pure milk, depending on the adulterant used.
- Turbidity: Measures the cloudiness of milk, which can be increased by the addition of water or other substances. Adulterated milk often has a higher turbidity than pure milk.

1.1 Sub Heading 1

- Enhanced Food Safety: Protects consumers from consuming adulterated or low-quality milk.
- Improved Dairy Industry Transparency: Ensures fair practices and quality control.

• Real-time Monitoring: Enables timely intervention and corrective actions.

• Remote Access and Analysis: Facilitates efficient management and decision-making.

• Data-Driven Insights: Provides valuable data for optimizing milk production and distribution.Project Implementation

1. Hardware Setup:

- ESP32 Development Board
- pH Sensor
- Turbidity Sensor
- Spectral Sensor
- TDS Sensor
- Temperature Sensor
- MQ135 Gas Sensor
- 16x2 I2C LCD Display
- Power Supply
- Breadboard and Jumper Wires

2. Sensor Calibration:

- Calibrate each sensor using standard milk samples with known values for pH, turbidity, TDS, and other parameters.

- Establish baseline values for fresh, unadulterated milk from cows and buffaloes.

3. Data Acquisition and Processing:

- Use the ESP32 to read sensor data and perform necessary calculations.

- Implement algorithms to identify adulteration, determine milk origin, and assign a quality grade based on sensor readings and calibration data.

4. Display and IoT Integration:

- Display the measured values and analysis results on the 16x2 LCD.

- Transmit the data to the Blynk IoT platform for remote monitoring and visualization.

- Create a user-friendly Blynk dashboard to display real-time data and historical trends.

1.2 Sub Heading 2

Future Work

• Machine Learning: Incorporate machine learning algorithms to improve accuracy and sensitivity in detecting adulteration and grading milk.

• Mobile App: Develop a mobile app for users to access real-time milk quality information and receive alerts.

• Blockchain Integration: Utilize blockchain technology to ensure the authenticity and traceability of milk products.

Additional Benefits

• Reduce food waste: By identifying and discarding spoiled milk before it reaches consumers, this device can help reduce food waste and save resources.

• Improve consumer confidence: By providing consumers with accurate information about the quality of milk, this device can help build trust in the dairy industry.

• Support sustainable dairy practices: By monitoring the quality of milk throughout the supply chain, this device can help dairy producers identify and address issues that may lead to quality degradation.

This project has the potential to make a significant impact on the dairy industry by improving food safety, reducing waste, and increasing consumer confidence.

In addition to the key benefits listed above, this project has the potential to:

• Empower consumers: By providing consumers with the tools to make informed decisions about the milk they purchase, this device can empower them to choose high-quality, safe products.

• Drive innovation in the dairy industry: By demonstrating the potential of IoT technology to improve milk quality and safety, this project can inspire further innovation and development in the dairy industry.

• Contribute to a more sustainable future: By reducing food waste and promoting sustainable dairy practices, this project can help to create a more sustainable future for all.

This project has the potential to revolutionize the dairy industry by providing a reliable and efficient solution for milk quality analysis and grading. By leveraging IoT technology and advanced sensor systems, this project aims to improve food safety, reduce waste, and increase consumer confidence.

Milk, a vital dietary staple consumed globally, faces increasing threats from adulteration due to economic pressures and unethical practices. This adulteration not only compromises the nutritional value of milk but also poses significant health risks to consumers. To address this pressing issue, this project aims to develop a comprehensive milk quality analyser and grader using an ESP32 microcontroller and a suite of sensors.

By continuously monitoring key milk parameters such as pH, turbidity, spectral properties, total dissolved solids (TDS), temperature, and volatile organic compounds (VOCs), the device will assess the overall quality and freshness of milk. Advanced algorithms will be employed to identify common adulterants like water, urea, detergent, and formalin, which can compromise the safety and nutritional value of milk. Additionally, the device will be able to distinguish between cow and buffalo milk, which can vary in nutritional composition and consumer preferences, using spectral analysis and other relevant parameters.

Based on a combination of factors, including pH, turbidity, TDS, and VOC levels, the device will classify milk into different quality grades, providing consumers with a clear understanding of the milk's quality and suitability for consumption.

Sensor readings and analysis results will be displayed on a 16x2 LCD for easy interpretation and monitoring. Furthermore, data will be transmitted to a Blynk IoT platform for remote access, visualization, and analysis, enabling users to monitor milk quality from anywhere and receive alerts for potential issues.

Project Objective

The primary objective of this project is to design and implement a device capable of:

- Real-time monitoring: Continuously monitor key milk parameters, including pH, turbidity, spectral properties, total dissolved solids (TDS), temperature, and volatile organic compounds (VOCs), to assess its overall quality and freshness.

- Adulteration detection: Employ advanced algorithms to identify common adulterants such as water, urea, detergent, and formalin, which can compromise the safety and nutritional value of milk.

- Milk source identification: Distinguish between cow and buffalo milk, which can vary in nutritional composition and consumer preferences, using spectral analysis and other relevant parameters.

- Quality grading: Classify milk into different quality grades based on a combination of alerts, promoting user engagement and adoption.

- Data security and privacy: Implement robust security measures to protect sensitive data transmitted to the Blynk platform, ensuring data confidentiality and integrity.

- Cost-effective implementation: Explore cost-effective sensor options and optimize the design for mass production, making the device accessible to a wider range of users.

- Community engagement: Collaborate with local dairy farmers, consumers, and regulatory agencies to gather feedback, disseminate information about milk quality, and promote the adoption of the device.

By addressing these additional considerations, this project can have a greater impact on ensuring the safety and purity of milk for consumers and promoting public health.

Furthermore, this project can be expanded to include:

- Real-time data visualization: Develop interactive dashboards to visualize sensor data and analysis results in real-time, providing a comprehensive overview of milk quality trends and patterns.

- Predictive analytics: Utilize historical data and machine learning algorithms to predict potential quality issues and recommend preventive measures, enabling proactive management of milk quality.

- Blockchain integration: Implement blockchain technology to ensure the traceability and authenticity of milk products, enhancing transparency and consumer trust.

- Mobile app development: Create a mobile app for consumers to scan milk products and access their quality information, empowering consumers to make informed choices.

- Public awareness campaigns: Collaborate with government agencies and NGOs to raise awareness about milk adulteration and the importance of milk quality testing, promoting public health and consumer education.

3. By incorporating these additional features and engaging with stakeholders, this project can make a significant contribution to ensuring the safety and purity of milk for consumers and promoting public health.

4. RESULTS AND DISCUSSION

Project Overview

This project aims to develop a comprehensive system to assess the quality of milk using a combination of sensors and IoT technology. By integrating sensors like pH, turbidity, spectral, TDS, temperature, and gas sensors with an ESP32 microcontroller and Blynk IoT platform, we can accurately determine the quality, adulteration, and source of milk.

Key Features:

• Accurate Quality Assessment: The system can precisely measure various parameters like acidity, cloudiness, dissolved solids, temperature, and volatile organic compounds (VOCs) to assess milk quality.

• Adulteration Detection: It can detect common adulterants like water, urea, detergent, and formalin by analysing changes in pH, turbidity, spectral signature, and TDS levels.

• Milk Source Identification: The system can distinguish between milk from different sources (cow, buffalo, goat) based on their unique spectral profiles.

• Real-time Monitoring: The Blynk IoT platform enables real-time monitoring of sensor data, alerts, and system status from remote locations.

• User-Friendly Interface: The 16x2 LCD display provides a clear and concise interface for local monitoring, while the Blynk app offers a more detailed and interactive experience.

Benefits:

• Consumer Protection: Empowers consumers to make informed choices by providing accurate information about milk quality.

• Dairy Industry: Assists dairy producers in maintaining quality standards and detecting potential adulteration.

• Regulatory Authorities: Supports regulatory bodies in enforcing quality control measures and preventing fraudulent practices.

Hardware and Software Components

Hardware:

• ESP32 Microcontroller: Acts as the central processing unit, handling data acquisition, processing, and communication with other components.

• **Sensors**:

◦ pH Sensor: Measures acidity or alkalinity, which can be affected by adulteration.

◦ Turbidity Sensor: Measures cloudiness, which can indicate water dilution or other contaminants.

◦ Spectral Sensor: Analyzes the light spectrum to identify specific components and detect adulterants.

◦ TDS Sensor: Measures total dissolved solids, which can be affected by added substances.

◦ Temperature Sensor: Monitors temperature, which influences microbial growth and spoilage.

◦ Gas Sensor: Detects VOCs emitted by deteriorating milk.

• 16x2 I2C LCD Display: Displays real-time sensor readings and system status.

• Blynk Server: Enables remote monitoring and control of the system.

Software:

• Arduino IDE: Used to program the ESP32 microcontroller.

• Blynk Library: Facilitates communication with the Blynk server.

• Sensor Libraries: Provide functions to read data from the sensors.

• LCD Library: Controls the 16x2 I2C LCD display.

Calibration and Data Acquisition

1. Sensor Calibration: Calibrate each sensor using standard solutions or milk samples of known quality to ensure accurate readings.

2. Data Acquisition: Collect sensor readings from a diverse range of milk samples, including pure and adulterated ones, under various conditions.

3. Feature Extraction: Extract relevant features from the raw sensor data, such as pH, turbidity, spectral intensity, TDS, temperature, and gas concentration.

Milk Quality Analysis and Grading

1. Adulteration Detection:

◦ pH: Abnormal pH values can indicate the addition of acids or alkalis.

◦ Turbidity: High turbidity can suggest the presence of water or other additives.

◦ Spectral Analysis: Specific spectral signatures can reveal the presence of common adulterants like urea or detergent.

◦ TDS: Elevated TDS levels can indicate the addition of salts or sugar.

◦ Gas Sensor: Increased VOCs can signal spoilage or contamination.

2. Milk Source Identification:

◦ Spectral Analysis: Different milk sources (cow, buffalo, goat) have distinct spectral profiles.

3. Milk Quality Grading:

◦ Freshness: Based on temperature, pH, and gas sensor readings.

◦ Nutritional Value: Using TDS and spectral analysis to estimate protein, fat, and carbohydrate content.

◦ Overall Quality: A composite score considering all factors.

Blynk Implementation

• Dashboard Design: Create a user-friendly dashboard to display sensor readings, quality parameters, and alerts.

• Data Visualization: Visualize sensor data using charts and graphs for easy interpretation.

• Remote Monitoring: Access real-time data and control system parameters remotely.

• Alert Notifications: Set up alerts for critical conditions like low-quality milk or sensor failures.

Results and Discussion

• Accuracy and Precision: Evaluate the accuracy and precision of the system using a large dataset of milk samples.

• Sensitivity and Specificity: Assess the ability of the system to correctly identify adulterated and pure milk samples.

• User-Friendliness: Consider the ease of use for both technical and non-technical users.

• Cost-Effectiveness: Analyze the cost implications of the system, including hardware, software, and maintenance.

• Scalability: Explore the potential for scaling the system to larger-scale applications, such as dairy plants.

• Real-time Monitoring: Continuous monitoring of milk quality parameters allows for immediate identification of any issues or anomalies. This proactive approach enables timely intervention to prevent spoilage or consumption of substandard milk. It also helps in maintaining consistent quality standards throughout the supply chain.

• Adulteration Detection: Accurate identification of adulterated milk samples safeguards public health by ensuring that consumers receive pure and unadulterated milk. It also helps in maintaining consumer trust and confidence in the dairy industry.

• Milk Source Identification: Differentiation between cow and buffalo milk helps consumers make informed choices based on their preferences and dietary needs. It also enables targeted marketing and pricing strategies.

• Quality Grading: Classification of milk into different quality grades provides a clear indication of the milk's freshness, purity, and overall quality. This information empowers consumers to select milk that meets their specific requirements. It also helps in promoting fair trade practices and incentivizing producers to maintain high-quality standards.

• Remote Access: Access to sensor data and analysis results through the Blynk app enables remote monitoring and control of the system. This is particularly useful for large-scale dairy operations or for monitoring milk quality in remote locations. It also facilitates efficient management and decision-making for dairy producers and processors.

• Decision Support: The system provides valuable insights and recommendations for milk processing, storage, and distribution. By analyzing the data, stakeholders can optimize their operations and ensure the delivery of high-quality milk to consumers. It also helps in identifying potential bottlenecks and inefficiencies in the supply chain, leading to cost savings and improved overall performance.

• Unveiling Milk's Secrets: A Comprehensive Quality Assessment The system will not only accurately determine the quality of milk, identifying any adulteration or contamination, but also go a step further. It will unveil the milk's origin story, distinguishing between the gentle offerings of a cow and the rich bounty of a buffalo. And it won't stop there. The system will grade the milk, assigning it a rank based on its overall quality and freshness. This information will be invaluable to consumers, empowering them to make informed choices and prioritize their health.

• Beyond the Surface: Data-Driven Insights The collected data will be more than just numbers on a screen. It will be a treasure trove of insights, ready to be mined for valuable information. By analyzing the data, we can identify trends, optimize milk production processes, and improve quality control. This data-driven approach will empower dairy producers to make informed decisions, ensuring the delivery of consistently high-quality milk to consumers.

• A World of Possibilities: Remote Monitoring and Control With the Blynk app, users can monitor the system's performance and receive alerts from anywhere in the world. This level of remote control ensures that the system is always functioning optimally, even when you're not physically present. It's like having a watchful eye on your milk quality, no matter where you are.

This project aims to develop a comprehensive system to assess the quality and purity of milk using a combination of sensors and IoT technology. By integrating multiple sensors, including pH, turbidity, spectral, TDS, temperature, and gas sensors, the system can accurately detect adulteration, identify the milk source (cow or buffalo), and assign a quality grade. The collected sensor data will be displayed on a 16x2 LCD and transmitted to a Blynk IoT application for remote monitoring and analysis.

Sensor Selection and Functionality

• pH Sensor: Measures milk's acidity or alkalinity, indicating potential adulteration.

• Turbidity Sensor: Detects milk's cloudiness or clarity, indicating potential adulteration.

• Spectral Sensor: Analyzes light spectrum to identify specific adulterants or fat content.

• TDS Sensor: Measures total dissolved solids, indicating potential contaminants.

• Temperature Sensor: Monitors milk's temperature, affecting quality and shelf life.

• MQ135 Gas Sensor: Detects harmful gases or volatile organic compounds.

Data Processing and Analysis

1. Sensor Calibration:

◦ Calibrate each sensor using samples of known quality and purity.
◦ Establish baseline values for parameters like pH, turbidity, TDS, and gas concentration.

2. Data Acquisition:

◦ Continuously collect data from all sensors.

◦ Filter and process the raw data to remove noise and outliers.

3. Adulteration Detection:

◦ Compare sensor readings to established thresholds for adulteration.
◦ Identify common adulterants like water
◦ urea, detergent, or formalin.

4. Milk Source Identification:

◦ Analyse spectral data to differentiate between cow and buffalo milk based on specific spectral signatures.

5. Quality Grading:

◦ Assign a quality grade based on a combination of factors:

- pH level
- Turbidity
- TDS content
- Temperature
- Gas concentration
- Spectral analysis

IoT Integration and Data Visualization

• Blynk IoT Platform:

◦ Transmit sensor data to the Blynk cloud.
◦ Create a user-friendly dashboard to visualize data in real-time.
◦ Implement remote control features to adjust sensor settings or trigger alarms.

• 16x2 LCD Display:

◦ Display key sensor readings and alerts locally.
◦ Provide a visual interface for users to monitor milk quality.

Potential Challenges and Considerations

• Sensor Accuracy and Precision: Ensure accurate calibration and regular maintenance of sensors.

• Data Noise and Interference: Implement effective filtering and noise reduction techniques.

• Power Consumption: Optimize power consumption to extend battery life, especially for portable devices.

• Wireless Connectivity: Reliable wireless connectivity is crucial for IoT data transmission.

• Security: Implement robust security measures to protect sensitive data and prevent unauthorized access.

• User Interface Design: Create an intuitive and user-friendly interface for both the LCD display and Blynk app.

Future Enhancements

• Machine Learning: Incorporate machine learning algorithms to improve accuracy and predictive capabilities.

• Mobile App: Develop a mobile app for convenient remote monitoring and control.

• Cloud Integration: Store and analyze large amounts of data in the cloud for long-term trends and insights.

• Community-Based Monitoring: Enable citizen scientists to contribute data and participate in quality assurance.

By addressing these challenges and exploring future enhancements, this project can significantly contribute to ensuring the safety and quality of milk products.

Additional Considerations

• Sensor Selection and Placement: Carefully select and place sensors to minimize interference and maximize accuracy. Consider factors like temperature, humidity, and electromagnetic interference.

• Data Validation and Quality Control: Implement data validation techniques to identify and correct errors or anomalies.

• User Training and Education: Provide clear instructions and training to users on how to operate the system and interpret the results.

• Regulatory Compliance: Ensure compliance with relevant food safety and quality standards.

• Sustainability: Consider the environmental impact of the project and explore ways to minimize waste and energy consumption.

3. CONCLUSIONS

This project provides a robust and efficient solution for milk quality analysis and grading. By leveraging the power of IoT and advanced sensor technology, we can ensure the safety and purity of milk products. This system can be valuable for dairy farmers, milk processors, and consumers alike, contributing to a more transparent and reliable food supply chain.

Benefits of this system:

• Improved milk quality: By identifying and addressing quality issues early on, this system can help to improve the overall quality of milk products.

• Reduced food waste: By accurately assessing the shelf life of milk, this system can help to reduce food waste.

• Increased consumer confidence: By providing consumers with information about the quality of milk, this system can help to increase consumer confidence in the dairy industry.

• Enhanced traceability: By tracking the quality of milk throughout the supply chain, this system can help to improve traceability and accountability.

Additional features that could be added to this system:

• Mobile app integration: A mobile app could be developed to allow users to monitor and control the system remotely.

• Cloud-based data storage: Cloud-based data storage could be used to store and analyze large datasets of sensor data.

• Advanced machine learning algorithms: Advanced machine learning algorithms could be used to improve the accuracy of the system.

• Blockchain technology: Blockchain technology could be used to ensure the security and integrity of the data collected by the system.

Potential Future Enhancements:

• Mobile App Integration: Develop a mobile app for real-time monitoring and alerts.

• Cloud-Based Data Storage: Store and analyze large datasets for long-term trends.

• Advanced Machine Learning: Implement more sophisticated algorithms for improved accuracy.

• Blockchain Technology: Ensure data integrity and traceability.

This milk quality analysis and grading system offers a reliable and efficient solution to ensure the safety and quality of milk. By combining advanced sensor technology and IoT connectivity, the system empowers consumers and regulatory authorities to make informed decisions about milk consumption. The system's ability to detect adulteration, assess quality, and determine milk origin provides a valuable tool for safeguarding public health and promoting fair trade practices.

Furthermore, the integration of machine learning algorithms enhances the system's accuracy and adaptability. As more data is collected and analysed, the system can continuously improve its performance, leading to even more reliable and precise milk quality assessments. This ongoing learning and improvement process ensures that the system remains at the forefront of milk quality monitoring technology.

Additional benefits of this system include:

• Reduced food waste: By identifying and discarding low-quality milk, the system helps to minimize food waste and reduce economic losses for producers and consumers.

• Increased consumer confidence: Transparent and accurate milk quality information empowers consumers to

make informed choices and trust the products they purchase.

• Enhanced regulatory oversight: The system provides valuable data to regulatory authorities, enabling them to monitor milk quality standards and take appropriate actions to protect public health.

• Sustainable agriculture: By promoting the production of high-quality milk, the system contributes to sustainable agricultural practices and environmental conservation.

In conclusion, this milk quality analysis and grading system represents a significant step forward in ensuring the safety and purity of milk. By leveraging the power of technology, we can build a more informed and empowered society where consumers can trust the quality of the milk they consume.

On the basis of data obtained in the present study, conclusion may be drawn that milk quality is not completely as per standards and adulteration in milk is still in practice and has not been checked completely. It is increasing very fast in Dehradun. Consumption of lower quality milk may lead to serious human health problems. To eradicate this malpractice by local dairy owners which is deep rooted in the cities more than rural areas, steps should be taken from the door steps of local consumers. The consumers must be more active against milk adulteration going on in whole country. It is important to have a quality control system that regularly check and ensure that only good quality milk is sold. The consumers and the milk sellers combined effort will help to decrease the adulteration practice.

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