Compact Device for Milk Quality Testing

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Abstract: Maintenance of milk quality is a top priority for consumer protection and industry practices, and the traditional approach to measuring parameters such as fat, SNF, protein, and adulteration is typically tedious and entails several devices. The present paper introduces a revolutionary, compact device combining sophisticated sensors and AI technology for end-to-end milk quality analysis in a single device. Loaded with cutting-edge sensors, the gadget measures important parameters and identifies usual adulterants with great accuracy. Through AI-based algorithms, data is efficiently processed and showcased on an easily operable screen. Portability facilitates usage across diverse environments, while IoT supports real-time transmission of data to enable remote tracking. This technology streamlines milk testing, improving accuracy and speed, and is an economic solution for dairy farmers and quality assurance laboratories. Its creation is a dramatic improvement in the dairy business, leading to enhanced public health and consumer confidence through the provision of accurate and complete tests of milk quality.

Keywords: Fat, SNF (Solids-Not fat), Protein, Adulteration, AI-based algorithms, User-friendly interface

1. INTRODUCTION

This Device aims to develop a new innovation, miniaturized device for analayzing critical milk qualities like fat, SNF, protein, and adulteration and serving as an aesthetic, modular structure for retailing milk and milk products. The device shall be equipped with multi-parameter testing through several sensors and electrodes. For SNF determination, the instrument will utilize graphene-coated electrodes and ion-selective electrodes to measure the electrical conductivity and impedance of the milk. The results will be utilized to calculate the SNF content accurately. For adulteration detection, the device will employ an IoT-based system using biosensors and chemical reagents to identify common adulterants such as water, detergent, urea, and starch. The IoT connectivity will provide wireless data transfer, allowing real-time monitoring and analysis of milk quality. The modular design will allow for the exchange of modules committed to single tests, which will be easy to upgrade and replace. The product will have a touch-screen interface, IoT connectivity for wireless data transmission, and a rechargeable battery for portability. It will also have an in-built sales system with an attractive display, automatic packaging, and customer interaction functions.

1.1.HARDWARE DEVICE

Hardware will include graphene-coated electrodes for SNF measurement, NIR and IR spectroscopy sensors for protein and fat content analysis, and temperature and pH sensors for thorough milk quality determination. The microcontrollers and signal conditioning circuits will handle data processing while machine learning algorithms will be integrated within firmware for precise prediction and calibration. Prototyping will include sensor accuracy and calibration lab testing followed by field trials with milk vendors and dairy farmers to ensure usability, durability, and battery life are optimized. The smart milk quality analyzer will be a one-stop solution for milk quality analysis and product selling, ensuring quality and safety of milk and the improved customer experience for consumers, vendors, and dairy farmers.

2. RELATED STUDIES

A. FAT

Milk fat testing is crucial to determine its nutritional status. Milk fat content represents the percentage of fat present in milk by weight. In typical cow’s milk, this amounts to about 3.25% to 4% in whole milk, whereas skim milk is adjusted to less than 0.5% fat. To test milk fat content, traditional methods such as the Gerber and Babcock techniques are widely used

B. SNF(Solids-Not-Fat)

Whole cow's milk generally contains around 8.5% to 9% solids-not-fat (SNF), including proteins, lactose, minerals, and vitamins. To measure this, one of the methods is initially the removal of fat by methods such as the Gerber test. Once the fat is removed, the remaining solids are weighed to calculate the SNF content. New techniques such as infrared spectroscopy now provide a quick, non-destructive means of measuring SNF as well as other milk constituents simultaneously.

C. PROTEIN

Milk is generally 3.0% to 3.5% protein, which translates to 3 to 3.5 grams of protein per 100 grams of milk. One popular technique to quantify this is the Kjeldahl method, where the quantity of nitrogen in the milk is determined and the protein content calculated with a conversion factor. Newer methods, such as infrared spectroscopy, provide a quicker and non-destructive means of testing protein and other constituents.

D. ADULTERATION

Adulteration of milk is the addition of material that should not be present in pure milk, like additional water, urea, detergents, or artificial fats. These adulterants are introduced to add bulk technicians can employ chemical reagents that react with certain compounds—if the reagent turns color, it means there is an adulterant present. New methods such as infrared spectroscopy or chromatography also assist by examining the milk's distinctive chemical fingerprint and rapidly identifying any foreign components. These tests guarantee that the milk is pure and safe for consumption.

E. Water (H□O) - DILUTION

Why is it added? For increasing milk quantity and returns. How does it impact milk? To Decreases the nutrient value. Heightens the potential for water-borne illnesses in case of contamination. Detection Technique Lactometer test determines the density of milk (Pure milk approximately 1.028 - 1.030 g/ cm^3). TDS Sensor – indicates total dissolved solids to find additional water.

F. DETERGENT - FOAMING AGENT

Why is it added? To enhance the foaminess of milk, making it appear rich and creamy. How does it affect health? It causes gastrointestinal problems like nausea, vomiting, and diarrhea. Long-term exposure can lead to kidney damage. Detection Method: Foam Test – Shake the milk; excessive foaming indicates detergent presence. pH Sensor – Detergents alter the pH (pure milk pH: Approximately 6.5–6.7). Conductivity Sensor – Detergents increase the electrical conductivity of milk.

G. STARCH - THICKENING AGENT

Why is it added? To artificially thicken and make diluted milk more consistent. How does it affect health? Hard to digest, particularly for infants, and causes indigestion and stomach disorders. Detection Method: Iodine Test – Adding iodine solution makes adulterated milk blue/black, and Turbidity Sensor – Detects changes in milk clarity.

H. UREA - PROTEIN SUBSTITUTE

It is used to add nitrogen content to milk so that it looks protein-rich. From a health perspective, it can damage the kidneys because of the excess accumulation of nitrogen and cause liver damage with long-term exposure. To detect, DMAB (Dimethyl Amino Benzaldehyde) Test turns yellow if urea is added, and a Urea Sensor identifies ammonia-based substances in milk.

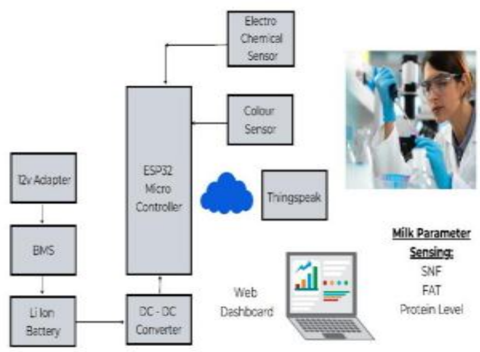
3. METHODOLOGY

In This Device aims to develop a new innovation, miniaturized analyzer that tests for key milk characteristics, including fat, SNF, protein, and adulteration, and also serves as an aesthetic, modular platform for the retailing of milk and milk products. The device will be equipped with multi-parameter testing through multiple sensors and electrodes. To measure SNF, the equipment will utilize ion-selective electrodes and graphene-coated electrodes to measure the electrical conductivity and impedance of the milk. The readings will be employed to accurately quantify the SNF levels for the detection of adulteration, the device will make use of an IoT-based platform that uses biosensors and chemical reagents to identify common adulterants such as water, detergent, urea, and starch. The IoT connectivity will provide wireless data transmission, supporting real-time monitoring and milk quality analysis. The modular design will allow for easy replacement of modules devoted to separate tests, thus facilitating upgrades and replacements. The product will also have a touch-screen interface, IoT connectivity for wireless data transmission, and a rechargeable battery for portability. It will also have an integrated sales system with a compelling display, automatic packaging, and customer interaction. Hardware will consist of graphene-coated electrodes for SNF measurement, NIR and IR spectroscopy sensors for protein and fat content, and temperature and pH sensors for complete milk quality determination. Data processing will be taken care of by the microcontrollers and signal conditioning circuits, and machine learning algorithms will be incorporated within firmware for accurate prediction and calibration. Prototyping will involve laboratory testing of sensor accuracy and calibration followed by field testing with dairy farmers and milk vendors to guarantee usability, durability, and battery life are maximized. Smart milk quality analyzer will be a one-stop solution for milk quality testing and product selling, guaranteeing milk safety and quality as well as enhanced customer experience for vendors, consumers, and dairy farmers.

3.1 BLOCK DIAGRAM

Electrochemical Sensors Optimized for the quick determination of adulterants and chemical factors. Optical/Colour Sensors Engineered to evaluate physical properties and differences that could represent changes in fat (FAT), solids-not-fat (SNF), and protein content. Multi-Parameter Testing That unit is structured to evaluate FAT, SNF, protein, and adulterants in one step to allow thorough quality evaluation. Being a multi-sensor unit implies faster analysis and instantaneous results without having to use various instruments.

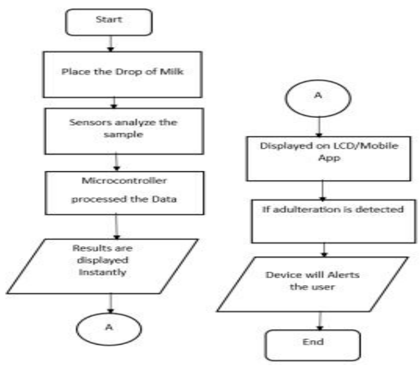
A 12V Adapter triggers the cascade of energy into a Battery Management System (BMS) in conjunction with a Li-Ion Battery. A DC-DC Converter provides each component—from sensors to the microcontroller—with a stable and regulated power supply. Real-Time Data Acquisition: The microcontroller quickly processes the input from the sensors, inferring the quality parameters for milk.



IoT Integration: The integrated Wi-Fi capability enables the product to transfer testing data to a cloud platform such as Thing-speak. This makes remote monitoring seamless, offers storage, and allows for real-time analysis. User Interface: Visualizing data plays a vital role in both monitoring and consumer satisfaction. The live metrics may be shown on a built-in touchscreen or mirrored across a web dashboard, bringing transparency that will be appreciated by consumers in today's digital era. Advanced Sensor Fusion: Broadening the array of sensors to track further quality factors like microbial load, freshness markers, or even temperature-driven spoilage. Mobile Application Integration: An app specifically designated could enable alerts, historical analysis viewing, and even interactive educational material on milk quality, further raising consumer interest. Scalability and Adaptation: Being modular, the device can be scaled for different sizes ranging from small household dairies to big retail chains so that all points in the supply chain enjoy enhanced safety and quality assurance.

3.2 PROGRAM FLOW CHART

In order to make the device operational, we initialize it and proceed with utilizing the touchscreen or screen to choose the function of interest, like testing the quality of milk or selling milk products. After this, we take a sample of milk and prepare it for testing by measuring it, filtering it, or treating it. We measure the fat content of the milk, Solids-Not-Fat (SNF), and protein content of the milk using sensors, as well as check for adulteration. AI interprets the sensor data, adjusts the system for precision, and gives analysis reports.



The test results are shown on the user interface in real-time. The data is either saved on the device or in the cloud for retrieval and access at any time. The device is connected to other devices or networks through Wi-Fi or Bluetooth for data transfer and remote monitoring. The device's modular design is designed to hold and dispense milk products, with the ability to customize and scale. Users can engage with the device for retail use, including processing transactions and inventory management. The system is now prepared for the subsequent operation.

4.EXISTING SYSTEM

The current system of bovine mastitis detection, presented in the IEEE paper, takes advantage of the milk's electrical conductivity (EC) as a key indicator. As a cow gets mastitis, milk composition changes, and most importantly, sodium and chloride ion concentrations rise, thus increasing conductivity. Mastitis also causes an increase in somatic cell count (SCC), an indicator of the white blood cells present in milk. While SCC is a conventional detection technique, it tends to be time-consuming and costly. The system successfully integrates EC measurements and SCC correlation, providing a faster, less costly method for estimating SCC and detecting mastitis at an early stage. Sensors are used to measure the EC of milk, either using portable devices or systems incorporated into milking lines. This provides real-time tracking, enabling prompt detection of mastitis, saving economic losses, and enhancing overall dairy cattle health.

5.PROPOSED WORK

We suggest creating one, small device based on the electrode technique to analyze all major milk qualities—fat, solids-not-fat (SNF), protein, and adulteration. The device will function by applying electrodes to measure the electrical characteristics of milk, which vary according to its composition. For example, fat and protein content, as well as any introduced impurities, influence the conductivity of milk. Through the study of these electrical signals, the gadget can rapidly and accurately determine milk quality. Furthermore, the device will be made modular and aesthetically pleasing so that it not only offers quality testing but also acts as a beautiful unit for selling milk and milk products. This two-in-one design makes it perfect for dairy farms and retail outlets so that only quality milk is sold to customers while improving the overall market presentation.

6.RESULT

Our new gadget combines two necessary functions into one compact system. On the one hand, it employs the electrode approach to examine milk quality in real time. Electrodes within the gadget pass a minimal electric current through the milk and measure how effectively the milk conducts electricity. As all these factors—fat, solids-not-fat (SNF), protein, and even adulterants—have an influence on the electrical properties of the milk, the device is able to measure all these parameters rapidly and precisely. What this implies is that rather than using individual machines for each test, you receive instant feedback regarding the general quality and safety of the milk from a single set of readings.

On the other hand, the machine is built with a contemporary, modular design that makes it desirable and functional for retail settings. Its slim appearance and versatile setup enable it to be not only a testing device but also a desirable display unit for the sale of milk and milk products. This dual-use design consolidates operations for both retailers and dairy farmers by conserving equipment expense and space, while building consumer confidence through clear, hi-tech quality control. Overall, this combined solution makes quality control easier and product presentation better, making dairy products more reliable and appealing to consumers—all in one intelligent, cost-saving system.

7.CONCLUSION

In summary, our breakthrough solution effectively unites two fundamental elements of the dairy business product presentation and quality assurance into a single, space-saving, dual-purpose device. Through the use of the electrode method, the device effectively measures vital milk characteristics—fat, SNF, protein, and adulteration—and delivers quick and accurate quality determination. This capability for real-time testing obviates the use of several stand-alone machines, ultimately saving money and simplifying on-farm operations. Concurrently, the device's compact, modular design turns it into a stylish display unit for retailing milk and milk products. This double role not only enhances operational effectiveness but also enhances consumer confidence by openly combining sophisticated quality control with retail appeal. As a whole, this combined solution establishes a new benchmark for the dairy sector, providing a functional, cost-efficient, and visually appealing solution that enhances both quality assurance and marketability.

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