

NutriMilk Guard: Breast Milk Storage and Quality Monitoring

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Abstract - Breast milk is the most important and natural source of nutrition for infants, providing essential nutrients, antibodies, proteins, and immune-supporting components required for healthy growth and development. Ensuring the quality and safety of stored breast milk is a significant challenge, particularly for working mothers, as improper storage conditions can result in bacterial contamination, nutrient degradation, and milk spoilage. To address this issue, this project proposes “NutriMilk Guard: Smart Breast Milk Storage and Quality Monitoring,” an intelligent IoT-based system designed to monitor and preserve the quality of stored breast milk. The proposed system continuously monitors critical parameters such as temperature, humidity, pH level, and storage duration using smart sensors connected to a microcontroller such as ESP32 or Arduino. The collected sensor data is processed and transmitted to a cloud platform or mobile application, enabling real-time monitoring and remote access. Whenever abnormal storage conditions, potential spoilage, or quality deterioration are detected, the system instantly notifies the mother through the connected application, ensuring timely corrective action.

Keywords - Breast milk storage, IoT, ESP32, Arduino, temperature monitoring, pH sensor, humidity sensor, cloud monitoring, smart alerts, infant healthcare, milk quality monitoring, real-time monitoring.

I. INTRODUCTION

Breast milk is considered the most complete and essential source of nutrition for infants, providing vital nutrients, antibodies, proteins, vitamins, and immune-supporting components necessary for healthy growth and development. It plays a significant role in strengthening the infant's immune system, supporting brain development, and promoting overall health during the early stages of life. However, maintaining the quality and safety of expressed breast milk during storage is a major challenge, particularly for working mothers and caregivers who rely on refrigeration for later feeding. Improper storage conditions such as temperature fluctuations, high humidity, prolonged storage duration, contamination, and repeated warming can lead to nutrient degradation, bacterial growth, and reduced milk quality. In many situations, it is difficult for mothers to determine whether stored breast milk remains fresh, safe, and nutritionally suitable for infant consumption.

Conventional storage methods mainly rely on refrigerators and manual inspection, which do not provide continuous monitoring or real-time quality assessment of the stored milk. This project, “NutriMilk Guard: Smart Breast Milk Storage and Quality Monitoring,” aims to develop an intelligent and user-friendly IoT-based system for monitoring and preserving the quality of stored breast milk. The proposed system utilizes smart sensors, a microcontroller such as ESP32 or Arduino, cloud connectivity, and real-time alert mechanisms to continuously monitor storage parameters including temperature, humidity, pH level, and storage duration. The collected data is analyzed and displayed through a mobile application or cloud platform, enabling mothers to monitor milk quality remotely and receive instant notifications whenever abnormal storage conditions or possible spoilage are detected. The primary objective of this project is to improve infant healthcare, reduce breast milk wastage, ensure safe storage practices, and support mothers by providing a reliable, efficient, and technology-driven breast milk quality monitoring solution using modern IoT technology.

II. LITERATURE SURVEY

1. A Case Study of Human Milk Banking with Focus on the Role of IoT Sensor Technology

Author Name: R. K. et al.

Year: 2023

This study focuses on the application of Internet of Things (IoT) technology for monitoring and maintaining the quality of human milk in milk banking and transportation systems. The research highlights the importance of continuously monitoring environmental conditions that may affect milk quality, particularly temperature and humidity. IoT sensors were used to collect temperature and humidity data during the transportation of human milk between donors, hospitals, and human milk banks. The collected data was transmitted to a cloud-based system for continuous monitoring, and an alert mechanism was used to identify temperature conditions that exceeded predefined limits. The study demonstrated that IoT-based monitoring can improve quality control, reduce milk wastage, and provide better visibility throughout the human milk supply chain. This research provides a strong foundation for applying IoT technology to smart breast milk storage and monitoring systems.

2. Storage of Unfed and Leftover Mothers' Own Milk

Author Name: A. M. et al.

Year: 2017

This study investigated the effects of different storage conditions on the bacteriological and immunological characteristics of mothers' own milk. Milk samples were stored under different temperature conditions, including room temperature, refrigeration, and freezing, and were subsequently analyzed for changes in quality. The study found that storage temperature has an important influence on the stability and quality of human milk. The research emphasizes the importance of appropriate storage conditions and provides evidence supporting the need for reliable monitoring of temperature during breast milk storage. The findings demonstrate that maintaining suitable storage conditions is essential for preserving the safety and quality of stored breast milk.

3. Recommendations for the Establishment and Operation of a Donor Human Milk Bank

Author Name: World Health Organization-related guidance and collaborators

Year: 2023

This study provides recommendations for the safe handling and storage of donor human milk in human milk banks. It emphasizes the importance of dedicated refrigerators and freezers equipped with temperature monitoring systems and alarm mechanisms. The recommendations indicate that real-time temperature monitoring and alerts can help identify abnormal storage conditions and prevent the deterioration of stored human milk. The study also highlights the importance of maintaining controlled refrigeration and freezing conditions throughout the storage process. These recommendations demonstrate the importance of automated temperature monitoring and alert systems for maintaining human milk quality and safety.

4. Rapid Methods and Sensors for Milk Quality Monitoring and Spoilage Detection

Author Name: Review study on milk quality sensors and spoilage detection

Year: 2019

This review examines the use of rapid sensing technologies for monitoring milk quality and detecting spoilage. The study discusses chemical sensors, biosensors, electronic noses, and electronic tongues that can identify changes associated with microbial growth and milk deterioration. Parameters such as pH, conductivity, impedance, dissolved oxygen, and carbon dioxide are considered useful indicators for monitoring milk quality. The review highlights that sensor-based systems can provide rapid responses, require minimal sample preparation, and have the potential for real-time monitoring. Although the study focuses on milk quality in general, its findings provide useful technical guidance for selecting suitable sensing parameters for smart breast milk quality monitoring systems.

5. Intelligent Packaging Sensors for Real-Time Milk Freshness Monitoring

Author Name: Review study on intelligent packaging and

milk freshness sensors

Year: 2026

This recent review explores the development of intelligent packaging technologies for real-time monitoring of milk freshness and quality. The study highlights the use of sensors and indicators capable of monitoring changes in milk quality without requiring complex laboratory testing. Such technologies can provide real-time information about freshness and help reduce milk spoilage and improve food safety. The research demonstrates the growing potential of integrating sensing technologies with intelligent monitoring systems to provide continuous information about milk quality. These concepts can be adapted to the development of smart systems for monitoring stored breast milk.

III. PROPOSED METHODOLOGY

The proposed NutriMilk Guard system consists of sensor-based data acquisition, microcontroller processing, IoT-based cloud communication, quality analysis, and alert generation modules. The system architecture is designed to provide continuous, automated, and real-time monitoring of breast milk storage conditions using IoT technology.

Existing System

The existing breast milk storage system mainly depends on conventional refrigerators and freezers for preserving milk for later use. Mothers generally store breast milk in containers and manually monitor the storage duration and refrigeration conditions. However, these traditional methods do not provide continuous or real-time monitoring of important storage parameters such as temperature, humidity, freshness, or milk quality. As a result, mothers may find it difficult to determine whether the stored breast milk is still safe and suitable for infant consumption.

Traditional storage methods also lack an automated mechanism to detect abnormal temperature fluctuations, improper storage duration, repeated heating, or possible spoilage. Changes in storage conditions can affect the freshness and nutritional quality of breast milk, while manual monitoring may lead to errors or missed changes in storage conditions. In addition, conventional systems do not provide instant alerts or notifications when unsafe storage conditions occur.

Existing methods mainly focus on cooling and storing breast milk without integrating IoT-based monitoring, sensor-based quality analysis, cloud connectivity, or smart notification mechanisms. They also do not provide an intelligent system for estimating milk freshness and quality based on continuously collected storage data. Therefore, there is a need for an automated and intelligent monitoring system that can continuously observe breast milk storage conditions, identify possible quality changes, and provide real-time alerts to help ensure safe breast milk preservation and infant feeding.

Proposed System

The proposed system, "NutriMilk Guard: Smart Breast Milk Storage and Quality Monitoring," is an IoT-based intelligent monitoring system designed to ensure the safe storage and quality preservation of breast milk. The system continuously monitors important parameters such as temperature, humidity, pH level, and storage duration using sensors

integrated with a microcontroller such as ESP32 or Arduino. The collected sensor data is processed and transmitted to a cloud platform or mobile application for real-time monitoring and analysis.

The proposed system analyzes the collected sensor readings to estimate the freshness and quality of stored breast milk based on storage conditions. Parameters such as temperature variations, pH level, and storage duration are considered to identify possible spoilage or reduction in milk freshness. The system also compares the monitored values with predefined safe storage limits to detect abnormal conditions.

Whenever abnormal storage conditions, possible spoilage, or reduced milk freshness are detected, the system automatically generates alerts and sends real-time notifications to the mother through the connected mobile application. The system can also maintain historical sensor data to help monitor changes in storage conditions over time. Compared to conventional breast milk storage methods, the proposed system provides continuous monitoring, intelligent quality analysis, and real-time alert mechanisms. By integrating IoT sensors, wireless communication, cloud monitoring, and smart notifications, the proposed system aims to reduce manual monitoring efforts, minimize milk wastage, and improve the safety and preservation of stored breast milk. The system ultimately supports mothers in effective breast milk storage management and contributes to improved infant healthcare.

• Data Collection

The data collection process is one of the important stages in the proposed NutriMilk Guard: Smart Breast Milk Storage and Quality Monitoring system. The system continuously collects important parameters such as temperature, humidity, pH level, and storage duration using IoT sensors integrated into the breast milk storage unit. These parameters are used to monitor the storage conditions, freshness, safety, and quality of stored breast milk.

The collected sensor data is transferred to the microcontroller for processing and analysis. The data helps in identifying changes in storage conditions and estimating possible milk quality variations. The collected information is also used for real-time monitoring, quality analysis, and alert generation. Proper and continuous data collection improves the reliability and effectiveness of the proposed smart breast milk storage and quality monitoring system.

• Sensor Integration and Monitoring

The proposed system uses sensors such as temperature sensors, humidity sensors, and pH sensors to continuously monitor the storage conditions and quality-related parameters of stored breast milk. These sensors are integrated with a microcontroller such as ESP32 or Arduino, which collects and processes the sensor readings.

The temperature sensor monitors the storage temperature, while the humidity sensor measures the humidity conditions inside the storage unit. The pH sensor is used to monitor changes in the pH level of the stored breast milk, which can help in estimating possible changes in milk quality. The storage duration is also tracked to determine the length of time the milk has been stored. The collected sensor readings are sent to the microcontroller for further processing and analysis. Continuous monitoring of these parameters helps the system

identify abnormal storage conditions and supports the estimation of milk freshness and quality.

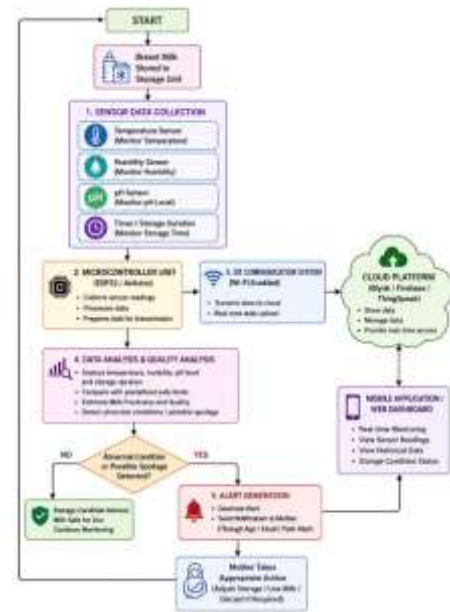


Fig 1: Flow Diagram

IV. IMPLEMENTATION

Breast milk is an important source of nutrition for infants, and maintaining its quality and safety during storage is essential for healthy feeding. However, conventional storage methods mainly depend on refrigeration and manual monitoring, which may not provide continuous information about storage conditions or milk freshness. Temperature fluctuations, improper storage duration, and possible contamination can affect the quality of stored breast milk. Therefore, an IoT-based smart monitoring system is required to continuously monitor storage conditions and provide timely information about the quality and freshness of stored milk.

The implementation of the NutriMilk Guard system uses IoT sensors and a microcontroller such as ESP32 or Arduino to collect important parameters including temperature, humidity, pH level, and storage duration. The collected data is analyzed to estimate milk freshness and quality based on predefined storage conditions. The system provides real-time monitoring through a cloud platform or mobile application and generates alerts whenever abnormal conditions or possible spoilage are detected. The requirements of the proposed system are divided into functional and non-functional requirements to ensure effective monitoring, reliable operation, and user-friendly breast milk storage management.

Functional Requirements

The functional requirements define the core operations and capabilities of the NutriMilk Guard system. The system shall continuously monitor important storage and quality parameters using suitable sensors. It shall collect temperature, humidity, pH level, and storage duration data and transmit the collected information to the microcontroller for processing.

The system shall analyze the collected sensor data to estimate the freshness and quality of stored breast milk. It shall

compare the monitored values with predefined safe storage limits to identify abnormal conditions and possible spoilage. The system shall provide real-time monitoring of storage conditions through a cloud platform or mobile application. The system shall generate instant alerts and notifications whenever abnormal temperature conditions, possible spoilage, or reduced milk freshness are detected. It shall also maintain historical sensor data to help users monitor changes in storage conditions over time.

1. Sensor Monitoring

- The system shall continuously monitor temperature and humidity conditions inside the storage unit.
- The system shall monitor the pH level of stored breast milk using a suitable pH sensor.
- The system shall track the storage duration of breast milk.
- The system shall collect and transmit sensor readings to the microcontroller.

2. Data Processing and Quality Analysis

- The system shall process the collected sensor data using a microcontroller such as ESP32 or Arduino.
- The system shall analyze temperature, humidity, pH level, and storage duration to estimate milk freshness and quality.
- The system shall compare sensor readings with predefined safe storage limits.
- The system shall identify abnormal storage conditions and possible milk spoilage.

3. IoT Communication and Monitoring

- The system shall transmit sensor data through a Wi-Fi-enabled microcontroller.
- The system shall upload the collected data to a cloud platform or connected mobile application.
- The system shall provide real-time visualization of storage conditions and sensor readings.
- The system shall maintain historical data for monitoring changes in storage conditions over time.

4. Alerts and Notifications

- The system shall generate alerts when storage conditions exceed predefined safe limits.
- The system shall notify the mother whenever possible spoilage or reduced milk freshness is detected.
- The system shall provide timely notifications to help users take appropriate action and prevent unsafe feeding conditions.

Non-Functional Requirements

Non-functional requirements define the quality attributes and operational characteristics of the NutriMilk Guard system. The system should provide reliable and continuous monitoring of breast milk storage conditions with minimum manual intervention. The system should be easy to use and provide information through a simple and user-friendly mobile or cloud-based interface.

The system should provide reliable sensor readings and ensure that collected data is transmitted accurately to the monitoring platform. It should be scalable enough to support

additional sensors and monitoring parameters in the future. The system should also be designed to operate continuously and generate alerts without significant delays. Security is an important requirement for the system, particularly when storing user information and monitoring data on cloud platforms. Data transmission should be protected to prevent unauthorized access. The system should also be maintainable and allow additional sensors, monitoring features, and intelligent analysis methods to be integrated in the future.

Performance Requirements

- **Real-Time Monitoring:** The system should continuously monitor temperature, humidity, pH level, and storage duration.
- **Alert Response:** The system should generate and deliver notifications promptly whenever abnormal conditions are detected.
- **Accuracy:** The sensors should provide reliable measurements for monitoring storage and quality-related parameters.
- **Reliability:** The system should operate continuously and provide consistent monitoring of stored breast milk.
- **Scalability:** The system should support the integration of additional sensors and monitoring features when required.
- **Usability:** The monitoring application or platform should provide a simple and user-friendly interface for mothers.
- **Data Availability:** Sensor readings and historical monitoring data should be available through the connected cloud platform or mobile application.
- **Maintainability:** The system should allow easy maintenance, updates, and integration of additional IoT and quality monitoring components.

IoT Communication System

The IoT communication system is used to transfer the sensor data collected from the breast milk storage unit to a cloud platform or mobile application for real-time monitoring. A Wi-Fi-enabled microcontroller such as ESP32 is used to establish wireless communication and transmit the collected sensor readings.

The sensor data, including temperature, humidity, pH level, and storage duration, is uploaded to an IoT platform such as Blynk, Firebase, or ThingSpeak. The connected platform allows users to monitor the storage conditions and quality-related information remotely. The mother can access the live storage information through the connected application and receive notifications whenever abnormal conditions are detected. The IoT communication system enables continuous data transmission and remote monitoring, reducing the need for manual checking of storage conditions.

Model Evaluation

The proposed NutriMilk Guard system will be evaluated based on its ability to continuously monitor breast milk storage conditions and identify possible changes in milk quality. The sensor readings collected from parameters such as temperature, humidity, pH level, and storage duration will be analyzed to estimate the freshness and quality of stored breast milk.

The proposed system will compare the collected sensor values with predefined safe storage limits to identify abnormal

storage conditions. Temperature fluctuations, changes in pH levels, and excessive storage duration will be considered during the quality analysis process. Whenever the monitored parameters exceed the defined safe limits, the system will identify a possible reduction in milk freshness or possible spoilage and will generate an alert or notification.

The effectiveness of the proposed system will be evaluated based on the accuracy and reliability of sensor readings, its ability to detect abnormal storage conditions, and the timely generation of alerts and notifications. Historical sensor data will also be maintained and analyzed to observe changes in storage conditions over time. This evaluation will help determine the reliability and efficiency of the proposed system in supporting safe breast milk storage and quality monitoring.

V. CONCLUSION AND FUTURE SCOPE

The proposed NutriMilk Guard: Smart Breast Milk Storage and Quality Monitoring system successfully integrates IoT sensors, microcontroller processing, and cloud-based communication to develop an efficient, reliable, and intelligent solution for safe breast milk storage. The system continuously monitors important parameters such as temperature, humidity, pH level, and storage duration using suitable sensors and IoT technology.

The integration of real-time monitoring, quality analysis, and instant alert mechanisms enhances the reliability and usability of the system. Whenever abnormal storage conditions or possible spoilage are detected, the system generates alerts and sends timely notifications to the mother through a connected mobile application or monitoring platform, helping to reduce manual monitoring efforts and minimize milk wastage.

By integrating IoT communication, cloud monitoring, and smart alert mechanisms, the proposed system provides mothers with a smart, user-friendly, and real-time solution for managing breast milk storage conditions. Overall, the project improves the safety and preservation of stored breast milk, supports mothers in effective storage management, and contributes to improved infant healthcare through the application of IoT-based monitoring technology.

FUTURE SCOPE

i. Multi-Sensor and Multi-Parameter Integration

Future enhancements can integrate additional sensors such as bacterial contamination sensors and spectroscopic quality sensors into a unified framework. Combining multiple sensing modalities can improve milk quality estimation accuracy and provide a more comprehensive understanding of storage conditions.

ii. AI-Based Predictive Spoilage Detection

The system can be expanded to incorporate machine learning models that analyze historical sensor trends to predict possible spoilage before safe limits are breached. This would enable proactive alerts and earlier corrective action.

iii. Mobile and Cloud-Based Deployment

A dedicated mobile application with push notifications can be developed to provide remote breast milk monitoring services across platforms. This would improve accessibility and provide mothers with a more seamless monitoring experience.

iv. Integration with Hospital and Pediatric Healthcare Systems

The system can be integrated with Electronic Health Record (EHR) systems and pediatric healthcare platforms for automated infant feeding record management and streamlined clinical workflows.

v. Solar-Powered and Portable Storage Units

A lightweight, solar-powered, and portable version of the storage unit can be developed to support usage in areas with limited or unreliable power supply, improving accessibility for a wider range of users.

vi. Multi-Unit and Multi-Baby Monitoring

The framework can be extended to simultaneously monitor multiple storage units, supporting use cases such as daycare centers, hospitals, and human milk banks where several containers must be tracked at once.

vii. Historical Data Analytics and Reporting

Advanced analytics dashboards can be incorporated to generate periodic quality reports and storage trend summaries for mothers and healthcare providers, supporting better long-term storage decisions.

viii. Voice Assistant and Multi-Channel Alerts

Future systems can integrate voice assistants and multi-channel alert mechanisms such as SMS and email, in addition to app notifications, to ensure timely awareness of abnormal storage conditions.

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