

Research Paper

# An AI and Blockchain-Based Smart Secure System for Milk Quality Detection and Authentication

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**Abstract**—Milk quality assurance is a critical challenge in the dairy industry due to the perishable nature of milk and the lack of continuous monitoring across the supply chain. Conventional quality assessment methods are manual, time-consuming, and reactive, often leading to delayed detection of spoilage, increased wastage, and reduced consumer trust. Although blockchain technology has been introduced to improve traceability and transparency in milk supply chains, existing systems primarily focus on secure data storage and lack intelligent quality analysis. This project proposes an AI and Blockchain-Based Framework for Milk Quality Assurance to ensure real-time monitoring, predictive quality analysis, and secure data management throughout the dairy supply chain. Artificial Intelligence is used to analyze key milk quality parameters such as temperature, pH, and storage time to detect abnormal conditions and predict spoilage at an early stage. Blockchain technology is integrated to store sensor data and AI-generated quality results in an immutable and tamper-proof ledger, ensuring transparency and preventing data manipulation among stakeholders. The proposed framework enables continuous quality tracking, automated alerts, and trusted traceability from milk collection to consumption. By combining AI-driven intelligence with blockchain-based security, the system reduces milk wastage, enhances food safety, and strengthens accountability across the dairy ecosystem. The solution is scalable, reliable, and suitable for real-world deployment in modern dairy supply chain management.

**Keywords**—Milk Quality Assurance, Artificial Intelligence, Blockchain Technology, Dairy Supply Chain, IoT Sensors, Spoilage Detection, Traceability, Smart Contracts, Food Safety, Real-Time Monitoring.

## I. INTRODUCTION

Milk is one of the most widely consumed and nutritionally important food products across the world. Due to its high water content and rich nutrients, milk is highly perishable and requires strict quality monitoring throughout the dairy supply chain. Factors such as temperature variations, improper handling, extended storage time, and transportation delays can lead to rapid spoilage and bacterial growth, resulting in quality degradation and health risks to consumers.

Traditional milk quality assurance methods mainly rely on manual inspection, periodic laboratory testing, and basic threshold-based monitoring. These approaches are time-consuming, prone to human error, and incapable of providing continuous real-time quality assessment. In many cases, spoilage is detected only after the milk has already deteriorated, leading to significant economic losses for farmers and dairy industries. Moreover, milk quality data is often stored in centralized systems, which lack transparency and are vulnerable to data manipulation.

Recent advancements in blockchain technology have introduced secure and transparent mechanisms for tracking milk across the supply chain. Blockchain enables immutable record keeping, traceability, and fraud prevention by securely storing transaction and quality data. However, most blockchain-based systems focus primarily on data traceability

and do not provide intelligent analysis of milk quality conditions.

Artificial Intelligence (AI) offers powerful capabilities for analyzing large volumes of sensor data and identifying complex patterns related to milk spoilage. By integrating AI with blockchain technology, it is possible to develop a smart and automated milk quality assurance system. AI can continuously analyze key quality parameters such as

Parameter	Traditional Method	Blockchain-Only System	Proposed System (IoT + AI + Blockchain)
Real-Time Monitoring	No	Partial	Yes (IoT Sensors)
AI-Based Analysis	No	No	Yes (ML Models)
Tamper-Proof Records	No	Yes	Yes (Blockchain)
QR Code Access	No	No	Yes
Automated Alerts	No	Limited	Yes
Consumer Transparency	Low	Moderate	High

temperature, pH, and storage duration to detect abnormalities and predict spoilage at an early stage, while blockchain ensures that the generated data remains secure, tamper-proof, and trustworthy.

**TABLE I. COMPARATIVE ANALYSIS OF MILK QUALITY MONITORING APPROACHES**

**A. Traceability:**

Blockchain can provide end-to-end traceability of milk, from the point of collection to the consumer. Every transaction can be recorded on an immutable ledger, allowing stakeholders to trace the origin, transportation, and storage conditions of milk — thus ensuring compliance with quality standards and building trust in this product with the consumer.

**B. Quality Assurance:**

The quality parameters of milk such as temperature and pH content can be recorded real-time with IoT devices incorporated with blockchain. It hence ensures that the milk is left at a safe consumption standpoint through the chain supply, involving neither spoilage nor waste. Bio-inspired mechatronic systems also have the potential to improve efficiency and reliability in the supply chain through insights from their biological counterparts.

**C. Payments and Contracts:**

Smart contracts on the blockchain enable the smooth payment between farmers, distributors, and retailers. Payments are automatically executed when predefined conditions are met, thereby ensuring fairness and eliminating delays.

**D. Fraud Prevention:**

With blockchain, there is no tampering since the entire record of transactions cannot be changed, and it prevents frauds. Examples include detection and prevention of adulteration of milk and mislabeling.

Challenges in blockchain over milk supply chain include:

- **Scalability:** Maintaining and handling large volumes of data from a multiplicity of stakeholders involved in the supply chain may challenge blockchain systems.

**II. PROPOSED SYSTEM**

The proposed AI and Blockchain-Based Smart Secure System for Milk Quality Detection and Authentication integrates IoT sensor networks, machine learning algorithms, and distributed ledger technology to deliver a comprehensive, end-to-end quality assurance solution for the dairy supply chain.

IoT sensors continuously monitor key milk quality parameters including temperature, pH levels, and storage duration at every stage from farm to consumer. The collected sensor data is fed into AI models trained to detect anomalies and predict spoilage events before they occur, enabling proactive quality interventions.

All quality data and AI-generated assessments are securely stored on a blockchain ledger using smart contracts, ensuring immutability, transparency, and tamper-proof record keeping across all supply chain stakeholders. Automated alerts are triggered when quality thresholds are breached, enabling timely corrective actions.

**III. METHODOLOGY**

The methodology of the proposed system consists of the following key components:

**A. IoT Sensor Integration**

IoT-enabled sensors are deployed at critical points in the dairy supply chain including milk collection centers, transportation

vehicles, storage facilities, and distribution hubs. These sensors continuously capture real-time data on temperature, pH, turbidity, and other quality indicators.

**B. AI-Based Quality Analysis**

Machine learning models, including Random Forest and Long Short-Term Memory (LSTM) networks, are trained on historical milk quality datasets to identify patterns associated with spoilage. The trained models analyze incoming sensor data in real time to classify milk quality status and predict degradation trends.

**C. Blockchain Integration**

A permissioned blockchain network is established among supply chain participants — farmers, processors, distributors, retailers, and regulatory bodies. Each quality assessment result generated by the AI module is recorded as an immutable transaction on the blockchain, accessible to all authorized stakeholders.

**D. Smart Contract Automation**

Smart contracts are programmed to automatically enforce quality agreements between supply chain partners. When AI-detected quality thresholds are violated, smart contracts trigger automated responses such as rejection notifications, payment holds, and regulatory alerts, without requiring manual intervention.

**IV. RESULTS AND DISCUSSION**

The proposed framework was evaluated through a simulated dairy supply chain environment. The AI model achieved high accuracy in milk spoilage prediction, with early warning alerts generated well in advance of actual quality degradation. The blockchain layer ensured complete auditability of all quality records, with no instances of unauthorized data modification detected during testing.

Integration of IoT sensors with the AI module enabled continuous, real-time quality tracking that significantly outperformed traditional periodic inspection methods. Smart contracts successfully automated quality-triggered business processes, reducing manual intervention and processing delays.

The system demonstrated scalability across multiple supply chain nodes and showed robust performance under simulated high-data-volume conditions, validating its suitability for real-world deployment.

**V. CONCLUSION**

This paper presented an AI and Blockchain-Based Smart Secure System for Milk Quality Detection and Authentication. The proposed framework addresses the critical limitations of existing milk quality assurance systems by combining AI-driven predictive analytics with blockchain-based secure data management.

By enabling real-time monitoring, early spoilage detection, and tamper-proof quality record keeping throughout the dairy supply chain, the system significantly reduces milk wastage, enhances food safety, and strengthens accountability among stakeholders. The integration of smart contracts further automates quality enforcement, making the system efficient and reliable.

Future work will focus on expanding the sensor modalities, refining the AI models with larger real-world datasets, and deploying the system across live dairy supply chain networks for full-scale validation.

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