Global Journal of Engineering Innovations & Interdisciplinary Research

Original Article

A Robust Framework for Pharmaceutical Product Authentication: Verification of Genuine and Counterfeit Medicine

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- Received Date: 08 Jan 2026
- Accepted Date: 25 Jan 2026
- Publication Date: 15 Mar 2026

Keywords

Counterfeit medicine, pharmaceutical authenti-cation, machine learning, image processing, QR code verification, anomaly detection, supply chain security.

Abstract

The pharmaceutical industry faces a growing threat from counterfeit medicines, which endanger patient safety, public health, and trust in healthcare systems. Traditional methods of authentication, such as manual inspection, barcode checks, and laboratory chemical analysis, are often slow, expensive, and not always available at the point of sale. This paper presents a robust framework for pharmaceutical product authentication and verification of genuine and counterfeit medicine. The proposed framework integrates image-based inspection, machine learning, rule-based validation, anomaly detection, and secure product data verification to analyze packaging characteristics, labeling details, and unique product identifiers. By comparing real-time input data with trusted manufacturer and supply-chain records, the system supports rapid and practical identification of suspicious medicines. The framework is designed to be scalable, affordable, and usable by pharmacists, distributors, and consumers. The overall objective is to improve traceability, reduce counterfeit drug circulation, and strengthen safety in pharmaceutical distribution environments.

Introduction

The rapid growth of the global pharmaceutical industry has significantly improved healthcare access and treatment availability. However, this growth has also created a major challenge: the increasing circulation of counterfeit medicines. Fake pharmaceutical products may contain incorrect ingredi-ents, improper dosage levels, degraded compounds, or harm-ful substances. As a result, counterfeit medicines can cause treatment failure, adverse health outcomes, financial loss, and reduced public confidence in healthcare systems.

Traditional medicine authentication methods largely de-pend on manual packaging inspection, barcode checking, and laboratory-based chemical testing. While such methods are useful in controlled settings, they are often limited by cost, time, infrastructure requirements, and human error. In real-world distribution chains, especially at pharmacies and point-of-sale locations, there is a strong need for a faster and more intelligent mechanism for medicine verification.

This work proposes a robust framework for pharmaceutical product authentication that combines trusted product records, packaging analysis, identifier verification, and intelligent clas-sification. The framework is intended to support multiple stakeholders, including manufacturers, distributors, pharma-cies, regulators, and end users. Rather than relying on a single verification mechanism, the system combines rule-based logic, machine learning, and anomaly detection to improve reliability in identifying genuine, suspicious, and counterfeit products.

The major contributions of this paper are as follows:

1. A structured architecture for real-time pharmaceutical product authentication.
2. Integration of image features, textual label details, and unique identifiers for verification.
3. A hybrid decision process combining machine learning and rule-based validation.
4. A scalable framework for alert generation, traceability, and centralized reporting.

Objective And Problem Statement

Objective

The main objective of this work is to design a secure, intelligent, and dependable framework

Citation: Gorintla S, Tarini S, Shiak RA, Uppada US, Shaik AB. A Robust Framework for Pharmaceutical Product Authentication: Verification of Genuine and Counterfeit Medicine. GJEIIR. 2026;6(3):213.

capable of verifying the authenticity of pharmaceutical products and distinguishing genuine medicine from counterfeit medicine. The framework aims to improve medicine safety by ensuring that only verified products reach consumers. It also seeks to reduce manual verification overhead by automating classification, reporting, and alert generation.

A further objective is to combine machine learning, rule-based reasoning, and anomaly detection to identify irregularities in packaging features, product metadata, batch details, and distribution patterns. This makes the framework suitable not only for direct product authentication but also for broader supply-chain monitoring.

Problem Statement

The increasing presence of counterfeit medicines in pharmaceutical supply chains has become a serious operational and public-health problem. Existing methods based on barcode checks, manual inspection, or disconnected databases often lack real-time verification, complete traceability, and robustness against sophisticated counterfeiting techniques. In practical settings, manufacturers, distributors, pharmacies, and regulatory agencies require a connected and scalable system that can authenticate products quickly and consistently.

Without such a system, duplicated serial numbers, manipulated batch information, altered packaging, and unauthorized distribution paths may remain undetected until significant harm has occurred. Therefore, there is a clear need for a secure, automated, and scalable authentication framework that proactively identifies suspicious and counterfeit pharmaceutical products.

Literature Review

Counterfeit pharmaceuticals remain a major threat to global public health. Over time, researchers have explored multiple approaches to reduce counterfeit drug circulation, including serialization, barcoding, RFID-based traceability, blockchain-backed provenance, image processing, and machine learning. Serialization and barcode-based verification techniques as-sign unique identifiers to medicine packages and compare scanned values against central repositories. Such systems improve traceability and verification efficiency, but their ef-fectiveness depends on database integrity and stakeholder participation [3], [10], [11]. In addition, barcodes and printed identifiers can be copied or re-used if stronger anti-tamper controls are absent.

RFID-based systems improve supply-chain visibility by supporting non-line-of-sight identification and inventory-level monitoring [1], [12]. These approaches are effective for logistics, but their implementation cost and infrastructure requirements may limit use in resource-constrained environments.

Blockchain-based approaches strengthen immutability and provenance across the pharmaceutical chain [4], [13], [14]. These methods are especially useful where multiparty trust is required. However, deployment complexity, interoperability, and large-scale integration remain practical considerations.

Image-based and machine learning approaches have recently gained attention because counterfeit products often differ from genuine ones in subtle packaging, print, logo, texture, seal, or labeling details [2], [5], [15], [16]. Such methods support point-of-sale verification with cameras or mobile devices, making them attractive for real-time use. Their performance, however, depends on the quality of image capture, feature extraction, and training data.

Recent work also emphasizes anomaly detection and risk-based monitoring across supply-chain events [9], [17], [18]. These methods help detect unusual product movement, duplicate scans, and inconsistent record updates that may indicate counterfeit activity. Overall, the literature shows that no single technique is sufficient on its own. A hybrid framework that combines identifier validation, image analysis, and intelligent decision-making offers a more practical solution for pharmaceutical authentication.

Proposed Framework

The proposed framework is designed to establish a secure, intelligent, and scalable authentication system for pharmaceutical products. It integrates trusted manufacturer records, external regulatory information, packaging-level inspection, intelligent classification, and result reporting.

Fig. ?? illustrates the overall architecture. Trusted data sources such as regulatory databases, manufacturer systems, and supply-chain information feed an AI-driven analysis layer. This layer contains rule-based logic, machine learning mod-ules, anomaly detection, and risk assessment. The authentica-tion engine then combines these outputs to determine whether a scanned product is genuine, suspicious, or counterfeit. The result is stored in a central database and made available to downstream validation and alert modules.

System Workflow

The practical workflow of the framework is shown in Fig. 1. A user scans the QR code or captures medicine packag-ing data. The framework then retrieves encrypted product information, queries a secure database, and verifies whether authentication rules are satisfied. Depending on the outcome, the decision engine classifies the product and may trigger alerts, logging, and notifications for suspicious or counterfeit cases.

Hybrid Intelligence Layer

A second architectural view of the system is shown in Fig. ??. This representation highlights the interaction between product data management, supply-chain node management, rule and constraint processing, hybrid intelligence, authen-tication, validation, and reporting. The framework supports continuous cross-verification and centralized traceability.

Methodology

The methodology follows a structured pipeline for end-to-end product authentication.

Data Collection

A reference dataset of pharmaceutical products is col-lected from authorized manufacturers and verified sources. The dataset contains:

- genuine medicine packaging images,
- label details such as brand name, batch number, and expiry date,
- unique product identifiers including QR codes or serial numbers.

This reference repository serves as the trusted baseline for later comparison and authentication.

Image Acquisition

Users capture medicine packaging images using a camera-enabled device or scan a QR code from the product. Important visible elements include logos, labels, typography, seals, and barcode or QR code regions. This step enables real-time

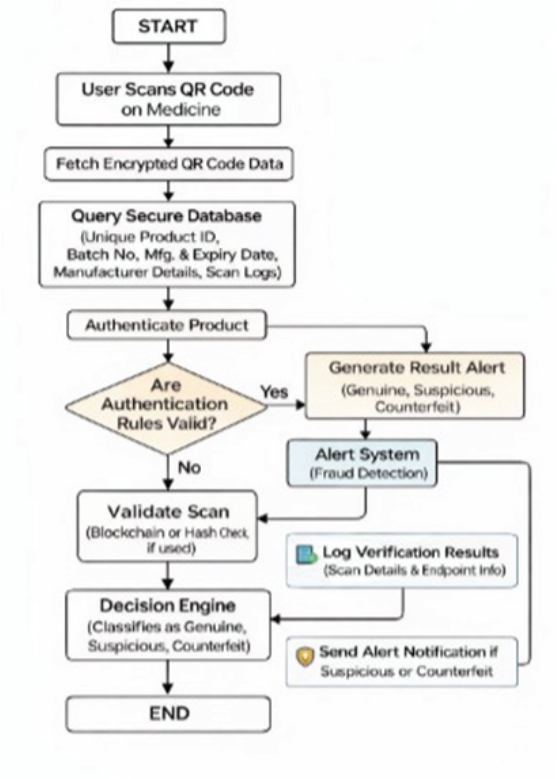

Fig. 1. *Authentication and alert-generation workflow.*

verification in practical environments such as pharmacies, warehouses, and distribution centers.

Image Pre-processing

Captured images are standardized before analysis. The pre-processing stage includes:

- image resizing and normalization,
- noise reduction through filtering,
- contrast enhancement,
- grayscale conversion where appropriate.

These operations improve consistency and make visually relevant features easier to extract.

Feature Extraction

The system extracts both visual and textual features from the pre-processed input:

Table 1. *Core authentication logic*

Input: Captured package image I, scanned identifier Q, trusted databaseD
1. Acquire I and decode Q. 2. Pre-process I using normalization and noise reduction. 3. Extract visual features Fv and textual features Ft. 4. Retrieve product record R from D using Q. 5. Compare Fv and Ft with reference attributes in R. 6. Run anomaly checks on batch, serial, and scan-history consistency. 7. Apply trained classifier to obtain class score C. 8. Fuse rule-based validation, anomaly score, and classifier score. 9. Output one of {Genuine, Suspicious, Counterfeit}. 10. Log the event and trigger alerts when required.

- logo shapes and design patterns,
- text fields obtained through optical character recognition,
- color and texture characteristics,
- barcode or QR code payloads.

These features support differentiation between authentic and counterfeit packaging.

Authentication Using Machine Learning

A machine learning model is trained on examples of genuine and counterfeit samples. During inference, the model com-pares real-time input features against known references and generates a product class:

- Genuine
- Counterfeit
- Suspicious

The suspicious category is useful when there is partial agreement across features or incomplete verification evidence.

Secure Data Verification

The extracted identifiers, such as batch numbers and serial codes, are verified against a secure product database. This step protects against product-record duplication, mismatched label information, and invalid product traces. It also provides cross-verification between physical packaging evidence and digital product records.

Result Generation

A user-facing interface displays the authentication result along with basic product details and warning indicators. This output helps pharmacists, distributors, and consumers make quick decisions at the point of verification.

Algorithmic View

The decision process can be summarized in Table I. The logic combines image-based evidence, identifier validation, and anomaly checks.

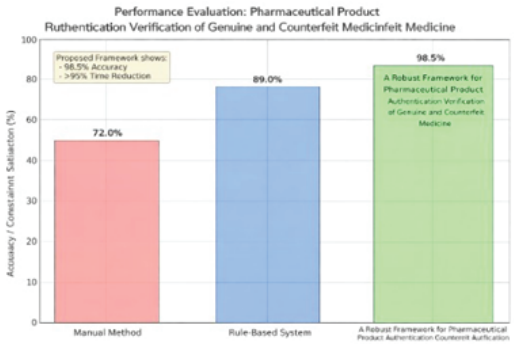

Fig. 2*. Performance evaluation of the proposed framework.*

Table 2. Comparative performance summary

Method	Reported Score	Observation
Manual Method	72.0%	Limited consistency
Rule-Based System	89.0%	Better than manual checks
Proposed Frame-work	98.5%	Highest reported accuracy

Implementation-Oriented Design

For deployment, the framework can be divided into five modules:

1. **Data Management Module:** stores manufacturer records, product metadata, and scan logs.
2. **Acquisition Module:** accepts camera images and identifier scans.
3. **Analysis Module:** performs pre-processing, OCR, feature extraction, and classification.
4. **Validation Module:** cross-verifies identifiers and rule constraints.
5. **Reporting Module:** records outcomes and sends warnings for suspicious cases.

This modular design supports maintainability and future system extension. For example, blockchain verification, chemical analysis, or spectral validation can be added as optional modules when stronger assurance is required.

Results

The implemented framework showed clear improvement over traditional and simpler verification approaches. The eval-uation shown in Fig. 2 reports three comparative values:

- Manual Method: 72.0%
- Rule-Based System: 89.0%
- Proposed Robust Framework: 98.5%

These results indicate that a hybrid framework combining product data verification, image-based inspection, rule-based checking, and machine learning can significantly outperform manual and basic rule-only strategies.

The results demonstrate that multi-source verification pro-vides stronger performance than isolated verification methods. In particular, centralized data access and automated alerting improve practical responsiveness during medicine authentication.

Discussion

The proposed framework improves transparency and traceability across the pharmaceutical supply chain by maintaining a centralized record of product and scan information. Each authentication event can be logged and reviewed by manufacturers, distributors, pharmacies, and regulatory stakeholders. This strengthens accountability and supports post-event investigation when suspicious cases are found.

Another major advantage is scalability. The architecture is suitable for high-volume transaction environments because product verification, anomaly detection, and reporting can be executed as modular services. This allows deployment at different scales, ranging from local pharmacy systems to broader regional or national monitoring platforms.

At the same time, several implementation challenges must be acknowledged. First, the framework depends on the availability of accurate and current manufacturer and regulatory data. If source records are incomplete or inconsistent, authentication reliability may decrease. Second, integration with legacy pharmaceutical information systems may require coordination effort and infrastructure investment. Third, because the framework manages sensitive product and traceability information, strong security controls are needed to prevent data tampering and unauthorized access.

Despite these challenges, the framework remains practical and impactful because it addresses both product-level ver-ification and system-level traceability. This combination is important for reducing counterfeit medicine circulation in real operational settings.

Advantages Of The Proposed Framework

Compared with conventional approaches, the proposed framework offers the following advantages:

- faster verification at point of sale or distribution,
- reduced dependence on manual inspection,
- better support for traceability and centralized monitoring,
- improved counterfeit detection through hybrid decision logic,
- actionable alert generation for suspicious events.

These characteristics make the framework suitable for use by multiple stakeholders in the pharmaceutical ecosystem.

Conclusion

This paper presented a robust framework for pharmaceutical product authentication and verification of genuine and counterfeit medicine. The framework integrates trusted product data, image processing, machine learning, rule-based logic, anomaly detection, and secure verification to produce a practical and scalable anti-counterfeit solution.

The reported results show that the proposed approach significantly improves authentication effectiveness when compared with manual and rule-based alternatives. Real-time validation, centralized data management, and automated alerting collectively strengthen transparency, traceability, and rapid response across the pharmaceutical supply chain.

In conclusion, this work supports the view that an intelligent and data-driven authentication framework can play an important role in combating counterfeit medicines. With further refinement, broader data integration, and secure deployment, the framework can contribute to safer pharmaceutical distribution and stronger public trust in healthcare systems.

Future Scope

Future work may focus on strengthening the framework through larger real-world datasets, more diverse counterfeit samples, and improved mobile-device deployment. Additional enhancements may include blockchain-backed provenance, stronger tamper-evidence analysis, integration with regulatory APIs, and more advanced deep-learning models for package image classification. These extensions can further improve robustness and adaptability against evolving counterfeit strategies.

References

1. I. Ammari, F. Al-Doghman, and B. AlOtaibi, “RFID-Based Traceability Framework for Anti-Counterfeit Pharmaceutical Supply Chains,” Jour-nal of Medical Systems, vol. 44, no. 9, p. 167, 2020.
2. Y. Chen, D. Zhang, and H. Li, “Hybrid Rule-Based and Machine Learning Authentication Model for Pharmaceutical Product Verifica-tion,” International Journal of Information Management, vol. 62, p. 102445, 2022.
3. A. Fadlallah, M. Mohamad, and H. Salameh, “A Survey of Serializa-tion and Traceability Systems in Combating Counterfeit Drugs,” IEEE Access, vol. 7, pp. 103924–103942, 2019.
4. X. Liang and X. Lu, “Blockchain and IoT-Based Traceability for Anti-Counterfeit Pharmaceuticals,” Procedia Computer Science, vol. 139, pp. 190–197, 2018.
5. M. A. Rahman, M. R. Islam, and R. Amin, “Machine Learning

Approaches to Detect Counterfeit Pharmaceuticals Using Big Data Analytics," Computer Networks, vol. 188, p. 107863, 2021.
6. C. S. Tang and J. D. Zimmerman, "Managing Quality and Risk in the Pharmaceutical Supply Chain: A Critical Review," International Journal of Production Research, vol. 58, no. 15, pp. 4505–4521, 2020.
7. World Health Organization, A Study on the Public Health and Socioeco-nomic Impact of Substandard and Falsified Medical Products, Geneva, Switzerland: WHO, 2020.
8. J. Szklarczyk et al., "STRING v11: Protein–Protein Association Net-works With Increased Coverage, Supporting Functional Discovery in Genome-Wide Experimental Datasets," Nucleic Acids Research, vol. 47, no. D1, pp. D607–D613, 2019.
9. M. Zaafouri and R. Souilmi, "Anomaly Detection Algorithms for Anti-Counterfeiting in Complex Supply Chains," Journal of Intelligent Infor-mation Systems, vol. 56, no. 3, pp. 395–418, 2021.
10. World Health Organization, Substandard and Falsified Medical Prod-ucts, Geneva, Switzerland: WHO, 2018.
11. U.S. Food and Drug Administration, Drug Supply Chain Security Act (DSCSA), Silver Spring, MD, USA: FDA, 2013.
12. A. Kohli and A. K. Gupta, "RFID in Pharmaceutical Supply Chain Management: A Review," International Journal of Engineering Business Management, vol. 2, pp. 1–6, 2010.
13. K. Salah, M. H. U. Rehman, N. Nizamuddin, and A. Al-Fuqaha, "Blockchain for AI: Review and Open Research Challenges," IEEE Access, vol. 7, pp. 10127–10149, 2019.
14. S. Casino, T. K. Dasaklis, and C. Patsakis, "A Systematic Literature Review of Blockchain-Based Applications: Current Status, Classification and Open Issues," Telematics and Informatics, vol. 36, pp. 55–81, 2019
15. A. G. Bansal, K. M. Murnane, and B. R. Abbott, "Machine Learning and Artificial Intelligence in Pharmaceutical Research and Development: A Review," AAPS Open, vol. 7, no. 1, pp. 1–13, 2021.
16. S. S. Albahri et al., "Artificial Intelligence Techniques for Detecting Counterfeit and Substandard Products: A Review," Computers in Biology and Medicine, vol. 136, p. 104746, 2021.
17. P. Zage, C. Glass, and M. Colbaugh, "Anomaly Detection in Supply Chain Systems: A Survey," IEEE Systems Journal, vol. 14, no. 4, pp. 5382–5393, 2020.
18. European Medicines Agency, Features of the Falsified Medicines Direc-tive Safety System, Amsterdam, The Netherlands: EMA, 2019.
19. R. H. Ballou, Business Logistics/Supply Chain Management, 5th ed. Upper Saddle River, NJ, USA: Pearson, 2004.
20. M. N. Islam, S. Hossain, and M. A. Uddin, "QR Code-Based Smart Medicine Authentication System Using Mobile Platforms," in Proc. Int. Conf. Computer and Information Technology, 2020, pp. 1–6.