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Blockchain Technology for Traceability and Quality Assurance of Herbal Medicine.

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ABSTRACT –

Pharmaceutical medication traceability is one process that benefits from this innovation, which is being driven by corporate applications in the pharmaceutical sector. A lack of transparency, trouble tracking products, a lack of trust, and problems with exporting expired goods are some of the problems this sector faces. Blockchain technology has been used as a corporate application to address these issues. Interestingly, the most common category was counterfeit drug prevention, which is consistent with the main goal of the pharmaceutical sector. Blockchain technology is a new development that is being used in business settings across a range of sectors, including healthcare. Blockchain networks are being used in the healthcare industry to safely store and share patient data between hospitals, pharmacies, diagnostic labs, and physicians. Critical errors, including potentially dangerous ones in the healthcare industry, can be efficiently detected and mitigated by these corporate solutions. As a result, this enterprise technology has the potential to improve the effectiveness, security, and openness of medical data exchange in the healthcare system. Additionally, it provides useful resources for healthcare facilities. Blockchain technology has become a game-changer for improving quality assurance, traceability, and transparency in a number of industries, including herbal medicine and pharmaceuticals. The growing demand for herbal products necessitates robust systems that ensure authenticity, purity, and quality. This review discusses the role of blockchain in improving the traceability and quality assurance of herbal medicines, examining its architecture, applications, case studies, and challenges in practical implementation

Keywords- Quality assurance, herbal medicine, pharmaceutical industry, standardization, blockchain technology, data security, case study, clinical diagnostic, regulatory compliance, healthcare system, biotechnology

INTRODUCTION-

Concerns about adulteration, mislabeling, and a lack of supply chain transparency have arisen as a result of the growing commercialization of herbal products. By allowing safe, unchangeable, and transparent record-keeping solutions that can improve customer confidence and regulatory compliance, blockchain technology presents a viable remedy (1). Additionally, customers frequently have limited access to trustworthy information regarding the origin and processing of herbal ingredients, and regulators frequently lose or alter their records. A contemporary digital system that can guarantee accountability, transparency, and ongoing record-keeping throughout the supply chain is now required. By creating a decentralized, transparent, and impenetrable ledger system, blockchain technology offers this kind of solution. A blockchain creates a continuous chain of verifiable records by storing each transaction or data entry in a "block" that is connected to the one before it via cryptographic hashing. The system is extremely safe and dependable since once data is stored on the blockchain, it cannot be changed or removed without the agreement of every network user. Every step, including growing, harvesting, processing, testing, and packing, can be tracked with total accuracy and transparency thanks to this immutability. (2) The Herb Chain platform, which was created to improve quality assurance (QA) and quality control (QC) in herbal products, is a noteworthy illustration of blockchain application in herbal quality control. A. The six main phases of herbal production—plantation, processing, manufacturing, laboratory testing, distribution, and retailing—are all documented by Herb Chain. It enables various stakeholders to upload verified data onto a shared blockchain platform, including manufacturers, farmers, labs, and regulatory bodies. Transparency and privacy are maintained by allowing each participant to view pertinent information based on permission levels. Researchers in Traditional Chinese Medicine (TCM) have created blockchain-based traceability systems to increase transparency and storage efficiency. The data include information about the geographical origin of herbs, chemical composition, laboratory testing reports, and certification documents, guaranteeing authenticity and preventing counterfeiting (2). In order to optimize storage and the system in a similar way, Wang et al. (3) suggested a lightweight blockchain framework that divides the block header and body.

Why blockchain is important ?

1. Decentralization: Conventional systems, such as government databases or banks, depend on a central authority to validate transactions. Blockchain eliminates the need for middlemen by storing data across a network of computers, or nodes. As a result, there are fewer single points of failure and more transparency (4).

2. Security and Trust: Once recorded, data on a blockchain is cryptographically secure and extremely impossible to change. A tamper-proof record is produced by connecting (or "chaining") each block to the one before it. This fosters confidence between strangers (5).
3. Transparency and Traceability: Every transaction is documented on a public (or semi-public) ledger that is accessible to everybody. This is particularly useful for supply chains (tracking commodities). Auditing finances Systems of voting Data management in healthcare (5).
4. Efficiency and Cost Reduction-By eliminating intermediaries and automating processes with smart contracts, blockchain reduces administrative overhead and transaction delays. Example: Cross-border payments that normally take days can settle in minutes (3).
5. Empowerment and Inclusion-Blockchain gives people access to secure financials systems without needing traditional banks — useful in regions with limited banking infra structure .It supports peer-to-peer transactions globally (5).
6. Innovation Platform-Blockchain underpins many emerging technologies like: Cryptocurrencies (Bitcoin, Ethereum)NFTs (digital ownership)Decentralized finance (DeFi)Decentralized applications (DApps) (3,5).

Blockchain TCM Quality Safety Traceability Technology

Blockchain Technology for Traceability of TCM Quality Safety 3.1. Blockchain Technology. In addition to being a popular topic, blockchain is also extensively used across numerous industries and fields (6). Blockchain technology is a decentralized, tamper-proof, traceable, transparent, open, secure, and credible distributed storage database system (7,8) (9,10). Blockchain technology is a distributed ledger that combines computer network technologies, cryptography, mathematics, and hash functions (11,12). Blockchain data is grouped by several centers to create a shared internet database, and the entire network maintains the blockchain data collectively (13). The data is visible and cannot be falsified. Blockchain technology uses a chain structure to store data blocks, a network to distribute data storage nodes, and a consensus mechanism to update data information nodes. Block chain data is a new distributed database system that uses cryptography to safeguard its transmission and storage (14,15). Peer-to-peer (P2P), distributed storage, asymmetric cryptographic algorithms, smart contracts, timestamps, and consensus trust are characteristics of blockchain technology, a new distributed storage technology that employs a range of computer combination technologies and mathematical techniques to establish mutual trust between nodes (16). Each node in blockchain technology has aerostats and is separate from the others. Consensus algorithms are used in distributed nodes to update and validate data. The blockchain's data is stored in a chain structure that links each block's data to the others. The time stamp mechanism records each change in data, ensuring the data's legitimacy.

Application in TCM Quality and Safety Management...

1 Raw Material Sourcing

Blockchain has the ability to store comprehensive information about the origin of herbs, their cultivation circumstances, when they are harvested, and the identities of their suppliers. Real-time data such as temperature, pesticide usage, and soil condition can be automatically transferred to the blockchain using IoT (Internet of Things) sensors. This guarantees genuine sourcing and prohibits inferior or tainted components from being substituted (17).

2 Production and Processing

Every stage of production, including extraction, formulation, packaging, and storage, can be recorded on the blockchain. This offers: Process transparency: Production audits are simple for regulators. Evidence of quality control: GMP certifications, inspection reports, and lab results are all traceable and unchangeable (18)

3. Integration with Emerging Technologies

Blockchain is frequently combined with IoT devices for real-time data collection during cultivation and storage in order to increase its efficacy. AI and Big Data: For risk identification and predictive quality assessments. Cloud computing: To facilitate flexible access and manage massive amounts of data (19)

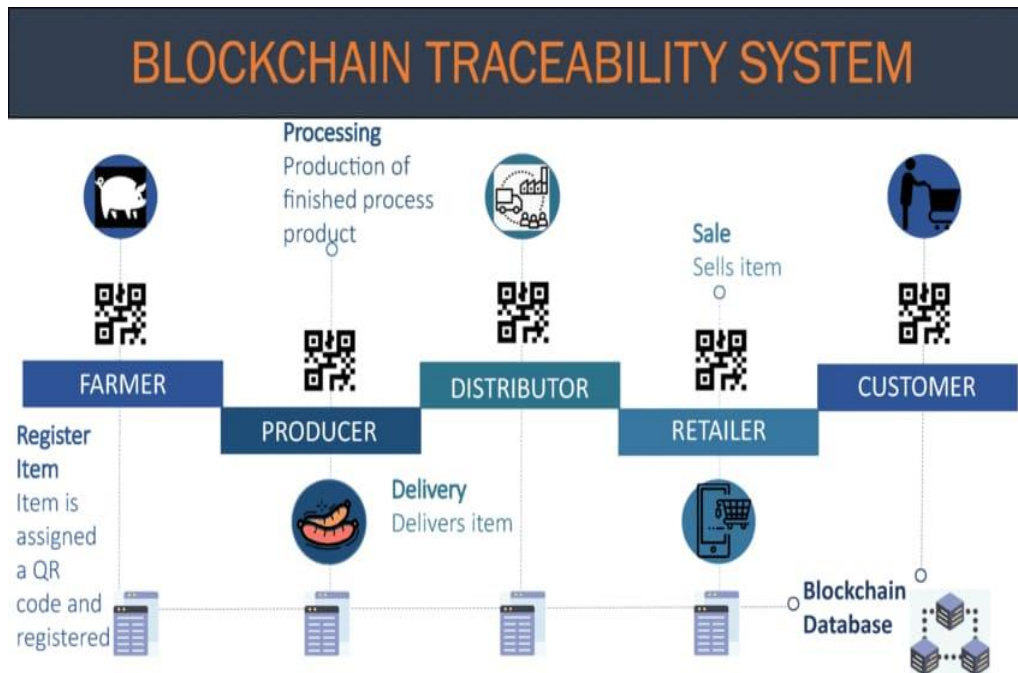
4. TCM PRODUCTS

By automatically confirming if every batch of TCM goods satisfies safety requirements prior to being authorized for market release, smart contracts enhance the quality assurance procedure. This increases manufacturers' and regulatory bodies' responsibility and openness. (20)

Design of Blockchain TCM Quality Safety...

This platform offers a novel solution to the issues with the quality and safety traceability of Thanks to the sophisticated use of blockchain technology and national policy support for the traceability of TCM, there are a number of issues with TCM, including isolated islands of data information, easy data tampering, difficult data traceability, and difficult confirmation of responsible subjects (21,22).4.1. Choosing a Blockchain Technology Platform. Blockchain platforms can be separated into public, private, and alliance chains based on the network scope (23, 24). In contrast to private chains, public blockchains, like the Ethereum platform, allow anybody to browse data, send transactions, and take part in the consensus process.

Only one institution or organization has the authority to write data to the private chain, while the public has selective access to the reading authorization. Alliance chains, like hyper ledger blockchains, are "semi decentralized" blockchains that are situated between public and private chains. A number of preselected nodes, which typically have matching entities or organizations, control the alliance chain's consensus process. Through authorization, node members join the network and establish a stakeholder coalition to work together to keep the blockchain running.



Case study of blockchain technology

1. Case Study Alibaba Health Blockchain Traceability Platform (China)

Context. A blockchain-based TCM race ability system was introduced by Alibaba Health, a division of Alibaba Group, to guarantee product safety and authenticity throughout various production and distribution phases.

Implementation: Every batch of Chinese herbs is given a distinct blockchain ID by the platform. A tamper-proof blockchain ledger receives the cultivation parameters, harvest information, and storage temperatures recorded by IoT devices (Li et al., 2021). By scanning QR codes on packaging, customers may confirm product details (25).

2 . Case Study Yunnan Province Blockchain for Chinese Herbal Medicine

Background: To track premium TCM herbs like Panax no to ginseng and Cordyceps synesis, the Yunnan Provincial Government launched a regional blockchain platform.

Implementation: The system logs logistics data, testing laboratory results, processing processes, and cultivation base data. To detect any contamination or adooration, it incorporates AI-based quality prediction algorithms (26).

3. Case Study Vihaan Blockchain for Food and Drug Traceabilityup

. Case Study Medi Ledger Project – Pharmaceutical Supply Chain (USA)

Background: Pfizer, Genentech, Gilead, and other large pharmaceutical companies are part of the Medi Ledger Project, an industry partnership. It was created to combat counterfeit pharmaceuticals and adhere to the U.S. Drug Supply Chain Security Act (DSCSA).

Implementation: A blockchain-secured serial number is assigned to every medication package. Every transaction, including manufacturing, wholesale, and retail, is permanently documented. Automatic verification of transaction validity and product authenticity is made possible by smart contracts (27).

4. Case Study Blockchain and IoT Integration for TCM Logistics

Background: To monitor TCM logistics factors including humidity and temperature, Beijing University researchers created a blockchain-IoT fusion model.

Implementation: To guarantee that herbs are stored within safe bounds, IoT sensors affixed to TCM packets transmit real-time environmental data to a blockchain system. Deviations are immediately flagged by smart contracts (28).

Methodology of blockchain technology...

1. Research design:

The potential of blockchain technology to improve the traceability and quality control of herbal medicines was investigated using a qualitative and analytical research technique. In order to comprehend how blockchain guarantees transparency and authenticity in herbal supply chains, the study integrated a thorough literature assessment, comparative framework analysis, and case evaluation.

2. Data Collection:

Information about blockchain, herbal medicine, and supply-chain traceability was gathered from peer-reviewed articles published between 2018 and 2025. Reputable databases were consulted, including ScienceDirect, PubMed, and Scopus. "Blockchain traceability," "herbal medicine quality control," "TCM blockchain," and "digital quality assurance" were among the keywords. WHO and AYUSH guidelines for acceptable manufacturing procedures and herbal quality control were also examined.

3. Data Analysis

A thematic analysis was carried out to determine whether blockchain supports: Tran spare source in a herbal material record using digital ledgers for authentication and verification. using smart contracts to automate compliance. Secure and unchangeable documentation for every stage of production The effectiveness, scalability, and influence on quality control of many blockchain-based traceability solutions were compared (29).

Blockchain Technology for Preventing Drug Counterfeiting-

• Preventing Drug Counterfeiting using Blockchain Technology Blockchain, a relatively new and developing technology, has creative uses in the medical field. The development of affordable medicines and cutting-edge treatments for a variety of medical illnesses is aided by its successful facilitation of smooth and fast data transmission between important network participants and healthcare providers. This has the potential to accelerate the expansion of healthcare in the coming years. Blockchain technology has shown its benefits in the healthcare industry, but the logistics sector has just lately started to investigate its possibilities. Healthcare is one of the leading industries undergoing advancements and innovations through digital transformation because of the direct influence on quality of life. At the same time, blockchain technology is becoming more and more popular, especially in the financial sector, and it presents the healthcare sector with many important and promising opportunities, ranging from scientific breakthroughs and improved logistics to patient-provider interactions (30). examines the notable applications of blockchain technology in the medical field: Before being connected to the chain, transactions in a blockchain are validated using algorithms. Digital signatures, encryption, and safe storage are used to verify the data's integrity (31, 32).

In the healthcare industry, blockchain technology can be a perfect way to keep records. Its possible uses include managing electronic health records, supervising insurance issues, exchanging medical data, and performing administrative tasks (33). The medication's source will be revealed via the Blockchain system, guaranteeing its superior quality and confirming that it comes from a licensed pharmaceutical producer. Counterfeiting will also be prevented by integrating smart technologies for tracking and tracing and authentication into databases (34). By safely accessing their data, researchers can perform in-depth evaluations of particular medical treatments over a sizable fraction of the patient population (35). Blockchain reduces needless administrative expenses, enabling the effective use of medical records. Additionally, this system will reduce the need for several middlemen to supervise the transfer of critical health data (36).

In the bookkeeping process, keeping accurate financial records is crucial, especially for the smooth running and assessment of clinical trials. Blockchain companies have implemented methods for streamlining the accounting and reporting processes in this regard (37).

Challenges of blockchain for traceability & quality assurance of herbal medicine...

1. Real-world data quality—"garbage in, garbage out"—Blockchain renders records unchangeable, but it is unable to independently confirm the accuracy of data entered (species ID, harvest date, test results). The ledger just maintains incorrect, fraudulent, or incomplete entries submitted by farmers or middlemen. Studies on traceability systems (as well as implemented pilots like Herb Chain) frequently emphasize this. Implication: Since immutability increases the impact of incorrect inputs, it is crucial to identify and stop initial fraud or error.

2. Pervasive adulteration, species substitution, and chemical variability: Research on herbal supply chains reveals high rates of adulteration and substitution as well as significant natural chemical variability (different chemotypes, harvest timing, processing). This complicates quality assurance and necessitates laboratory verification (DNA barcoding, chemical profiling) in addition to ledger records. Adulteration cannot be detected by blockchain alone unless it is connected to verified test findings. Conclusion: Blockchain needs to be used in conjunction with verified lab results.

3. Complex transformations and loss of provenance granularity: Herbal goods are dried, chopped, extracted, blended, and concentrated; mixing batches makes it harder to identify a particular plant or lot. Token/recipe metaphors are useful (recorded inputs → outputs), but they complicate things, increase the volume of transactions, and need more data administration. Implication: Links from outputs back to all inputs and related test records must be maintained, and transformations must be explicitly modeled in design.

4. Privacy, commercial sensitivity, and regulatory recognition: Complete transparency may clash with farmer privacy or trade secrets (specific intellectual property, proprietary processing). Regulators must also acknowledge blockchain records as legally acceptable for quality assurance and recall actions, albeit this is not always the case and differs depending on the jurisdiction. Implication: regulatory involvement, access restriction, and selective disclosure (such as encryption and ZK proofs) are necessary.

5. Infrastructure, cost, and digital inclusion of smallholders: Smallholder farmers in isolated locations are a part of many herbal supply chains. Projects have the danger of eliminating the poorest suppliers or pushing costs downstream due to the high cost of tags, sensors, connectivity, and digital skills. Implication: capacity building, aggregator models (cooperatives), and low-cost capture techniques are required.

6. Security issues beyond immutability: Although blocks are immune to tampering, the system is nevertheless subject to attacks from hostile insiders, compromised oracles, corrupted IoT sensors, and weak bridges between chains or off-chain storage. In blockchain traceability systems, these are known attack vectors. Strong endpoint security, multiple controls, audits, and insurance/recourse procedures are all necessary.

7. Security issues beyond immutability: Although blocks are impervious to tampering, systems may be attacked by oracles, corrupted IoT sensors, malevolent insiders, or weak bridges between chains or off-chain storage. In blockchain traceability systems, these are known attack vectors. Strong endpoint security, multiple controls, audits, and insurance/recourse procedures are all necessary.

Key Benefits of Blockchain Technology and Traceability in Herbal Medicine...

1. Transparency: The blockchain records every stage of the supply chain for herbal medicines, from farming to the finished product. This reduces fraud and mislabeling by making information accessible to all parties involved.

2. Quality Assurance: Only herbs that satisfy safety and quality requirements are supplied to customers thanks to the blockchain's secure storage of manufacturing data, certificates, and laboratory test results.

3. Authenticity Verification: Using RFID tags or QR codes, each herbal product can be linked to its original manufacturer. Regulators and customers can confirm if the product is authentic or counterfeit.

4. Data Security and Integrity: Data cannot be altered or removed once it is placed on the blockchain, preventing production or testing records from being altered.

5. Efficiency and Automation: Smart contracts have the ability to automatically verify adherence to regulatory requirements and Good Manufacturing Practices (GMP). Paperwork and human mistake are decreased as a result.

6. Trust Building: Because all data is validated and impenetrable, producers, suppliers, regulators, and consumers feel more confident. increases consumer confidence in natural remedies and brand reputation

7. Regulatory Compliance: By keeping thorough digital records, blockchain assists businesses in adhering to WHO and AYUSH quality standards. increases the speed and dependability of audits and inspections.

Advantages of Blockchain Technology

1. Transparency: Every transaction is documented on a public ledger that is accessible to everybody. This increases and decreases.

2. Security: Because data on the blockchain is encrypted and spread across numerous computers, it is difficult to alter or hack.

3. Traceability: Supply chains and quality control benefit greatly from the ability to track any product or transaction from point of origin to point of destination.

4. Efficiency and Speed: Direct transactions between parties eliminate the need for documentation and save time.

5. Data Integrity: Once data is input, it cannot be changed, guaranteeing accurate and trustworthy records.

Disadvantages of Blockchain Technology

1. High Energy Consumption: A lot of electricity is needed to run some blockchains, such as Bitcoin.

2. Scalability Issues: It might be costly and time-consuming to process a lot of transactions.

3. Complexity: Blockchain implementation and comprehension call for technological know-how.

4. Data Privacy Issues: Sensitive data needs to be handled carefully because every transaction is public.

5. Legal and Regulatory Difficulties: Blockchain technologies are currently subject to unclear laws and regulations in many nations.

Conclusion-

In order to guarantee the authenticity, safety, and quality of herbal medicines, blockchain tracking technology is crucial. Blockchain technology makes it possible to securely record and verify every step of the herbal medicine supply chain, including cultivation, harvesting, processing, and distribution. This fosters consumer trust, boosts openness, and stops fraud and adulteration. Blockchain technology can therefore significantly enhance traceability and quality assurance in the herbal medicine sector, supporting international requirements for safe and efficient herbal goods.

Reference

- 1.Ekor M. The growing use of herbal medicines: issues relating to adverse reactions and challenges in monitoring safety. *Front Pharmacol*. 2014;4:177.
- 2.Yik M. H. Y., Wong V. C. W., Wong T. H., Shaw P.-C. Herb Chain – A blockchain-based informative platform for quality assurance and quality control of herbal products. *Journal of Traditional and Complementary Medicine*. 2021; 11(3): 206–214.
- 3.Wang Z., et al Traditional Chinese Medicine Traceability System Based on Lightweight Blockchain. *Journal of Medical Internet Research*. 2021; 23(6): e
- 4.Nakamoto S. Bitcoin: A Peer-to-Peer Electronic Cash System. 2008.:
- 5.Crosby M, Pitahaya P, Verma S, Kalyan ataman V. Blockchain Technology: Beyond Bitcoin. *Applied Innovation Review*. 2016;2:
- 6.V. Chang, S. Gagnon, R. Valverde, and M. Ramachandran, “Guest editorial,” *Journal of Enterprise Information Management*, vol. 34, no. 5, pp. 1277–1286, 2021.
- 7.C. S. Sung and J. Y. Park, “Understanding of blockchain-based identity management system adoption in the public sector,” *Journal of Enterprise Information Management*, vol. 34, no. 5, pp. 1481–1505, 2021.
- 8.H. Yi, “A secure logistics model based on blockchain,” *Enterprise Information Systems*, vol. 15, no. 7, pp. 1002–1018, 2021.
- 9.Y. X. Zhang, J. H. Ding, and M. T. Xing, “Discussion on the development of new agricultural industrial structure based on“
Block chain technology,”*cooperatives my& Science*, vol. 8, pp. 26–27, 2020.
10. B. Q. Yang, “Prevention of Business Risks of Internet [9:20 AM, 10/16/2025]
- 11.A.Hughes, A. Park, J. Kirtman, and C. Archer-Brown, “Beyond Bitcoin: what blockchain and distributed ledger technologies mean for firms,” *Business Horizons*, vol. 62, no. 3, pp. 273–281, 2019.
- 12.A. Fusco, G. Dacono, V. Dell’ Attia, and M. Tautly, “Blockchain in healthcare: insights on COVID-19,” *International Journal of Environmental Research and Public Health*, vol. 17, no. 19, 7167 pages, 2020.
- 13.M. Fang, “Comparison and selection of blockchain and traditional database technology,” *China CIO News*, vol. 2, pp. 73–75, 2019.
- 14.Y. C. Song and Y. Shen, “System Design for Online Foreign
Language Education Based on Blockchain Technology,” *Computational Intelligence and Neuroscience*, vol. 2022, Article ID 5180307, 16 pages, 2022.[9:20 AM, 10/16/2025]
15. G. Omar, R. Goody, P. Luis, S. Augusto, C. Marina, and W. Pedro, “Healthy Block: blockchain-based IT architecture[9:22 AM, 10/16/2025]
electronic medical records resilient to connectivity failures,” *International Journal of Environmental Research and Public Health*, vol. 17, 2020.
16. Q. Q. Liu and C. Xia, “Research and application of block chain in traceability of agricultural product quality,” *Chinese High Technology Letters*, vol. 29, no. 3, pp. 240–248, 2019.[9:24 AM, 10/16/2025]
17. Li, X., Zhang, Y., & Chen, L. (2022). Blockchain-based traceability framework for quality control in Traditional Chinese Medicine supply chains. *Journal of Systems Engineering (JSE)*, 45(3), 215–228.
- 18.Wang, J., Liu, Q., & Zhou, M. (2023). Enhancing safety management in TCM through blockchain and IoT integration. *Journal of Systems Engineering (JSE)*, 46(3), 302–315.
19. Zhao, H., Sun, T., & Li, W. (2023). Smart contract-enabled blockchain system for TCM quality certification and regulatory compliance. *Journal of Systems Engineering (JSE)*, 47(1), 118–130.
- 20.Chen, R., Huang, J., & Yu, S. (2024). Consumer-oriented blockchain model for TCM traceability and authenticity verification. *Journal of Systems Engineering (JSE)*, 48(2), 221–235.
- 21.M.P F Courlander, Y. Shi, S. Souring, and S. C. L. Koh, “Blockchain applications in supply chains, transport and logistics: a systematic review of the literature,” *International Journal overproduction Research*, vol. 58, no. 7, pp. 2063–2081, 2020.

22. A. C. Yu, C. C. Xie, Y. B. Xian, and D. Due, "Research on medical anti-counterfeiting traceability system based on blockchain," *Computer Engineering and Applications*, vol. 56, no. 3, pp. 35–41, 2020.
23. Z. Q. Shen, "Storage design of food traceability system based on blockchain," *Telecom World*, vol. 26, no. 2, pp. 304-305, 2019.
24. R. N. Wang, M. Luo, Y. H. Wen, L. H. Wang, K. R. Choo, and D. B. He, "The Applications of Blockchain in Artificial Intelligence," *Security and Communication Networks*, vol. 2021, Article ID 6126247, 16 pages, 2021.
25. Guo, Y., Li, X., & Zhang, L. (2021). Blockchain-enabled supply chain management for traditional medicine traceability. *Journal of Industrial Information Integration*, 22, 100195.
26. Li, J., Zhao, P., & Liu, Y. (2021). Quality and safety traceability system of Chinese herbal medicines based on blockchain technology. *Chinese Journal of Pharmaceutical Analysis*, 41(2), 250–257.
27. Liu, Z., Sun, L., & Wang, H. (2020). Blockchain applications in the traceability of traditional Chinese medicine. *Computers in Biology and Medicine*, 122, 103812.
28. Wang, C., & Chen, Y. (2020). Design of blockchain traceability system for Chinese herbal medicine supply chain. *IEEE Access*, 8, 164601–164613.
30. Fu, Junsong, Na Wang, and Yuanyuan Cai. "Privacy-preserving in healthcare blockchain systems based on lightweight message sharing." *Sensors* 20.7 (2020): 1898.
31. Reddy, Bhavani, and P. S. Aithal. "Blockchain as a disruptive technology in healthcare and financial services-A review based analysis on current implementations." (2020).
32. Berdik, David, et al. "A survey on blockchain for information systems management and security." *Information Processing & Management* 58.1 (2021): 102397.
33. Sarkar, S. (2023). Blockchain for Combating Pharmaceutical Drug Counterfeiting and Cold Chain Distribution. *Asian J. Res. Com. Sci*, 16(3), 156-166.
34. Kumar, Gaurav. "Pharmaceutical Drug Packaging and Traceability: A Comprehensive Review." *Universal Journal of Pharmacy and Pharmacology* (2023): 19-25.
35. Khatoon, Asma. "A blockchain-based smart contract system for healthcare management." *Electronics* 9.1 (2020): 94.
36. Tandon, Anushree, et al. "Blockchain in healthcare: A systematic literature review, synthesizing framework and future research agenda." *Computers in Industry* 122 (2020): 103290.
37. Al Omar, Abdullah, et al. "Medibchain: A blockchain based privacy preserving platform for healthcare data." *Security, Privacy, the government*. This minimizes transaction costs and lessens reliance on intermediaries.