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Pharma Trace : Enhancing Drug Packaging System Using Blockchain Technology and Enhanced QR Code Scanning

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***Abstract*:** Scanning a QR code on medicine packages reveals crucial information like the medicine's name, batch number, expiry date, and manufacturing date. This integration, coupled with blockchain technology, ensures both accessibility and security of the data. The aim is to create a user-friendly system that offers easy access to medication details, empowering informed decision-making in healthcare. Implementing a comprehensive system for medication information, the integration of QR codes on medicine packages serves as a gateway to vital details such as the medicine's name, batch number, expiry date, and manufacturing date. This innovative approach not only enhances accessibility but also fortifies the security of data. The inclusion of blockchain technology further elevates the system's integrity, employing the hashing concept to ensure data tamper resistance. With this enhanced security measure, users can confidently trace the journey of a tablet sheet, from its initial manufacturing state to the final distribution state. This holistic solution not only provides a user-friendly platform for obtaining medication details but also empowers individuals to make informed decisions in healthcare, promoting transparency and accountability in the pharmaceutical supply chain.

Keywords: *Blockchain, IoT, Supply Chain, Pharmaceutical, Information Security, Counterfeiting, Traceability, Transparency, Smart Contracts, Digital Health Platforms, Authentication, Drug Traceability, Pharmaceutical Fraud, Technology Solutions.*

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I. INTRODUCTION

The global pharmaceutical industry faces critical challenges related to the authenticity and safety of medicines, especially in regions like Africa where improper dosing from counterfeit drugs results in over 100,000 deaths annually. The existing pharmaceutical supply chain struggles to ensure drug authenticity due to continuous ownership changes and the lack of connection between physical and information flows, making real-time traceability a costly practice for regulatory authorities. Consequently, patients often fall victim to the circulation of counterfeit drugs. Addressing these issues, this research explores the transformative potential of Blockchain technology in the pharmaceutical supply chain. The Information and Communication Technology (ICT) landscape is undergoing significant advancements, and Blockchain, in particular, stands out for its potential to enhance end-to-end visibility, security, trust, and traceability in the pharmaceutical supply chain. The conventional challenges associated with the lack of visibility and traceability can be mitigated through the integration of Blockchain and IoT.

In response to vulnerabilities in current pharmaceutical packaging practices, concerted efforts are being made to establish robust rules and standards. The aim is to enhance the safety and clarity of medicine packaging, reducing the infiltration of counterfeit drugs. This becomes especially crucial during times of crisis, such as the COVID-19 pandemic, where the demand for medicines increases, creating a higher risk of encountering substandard or fake products. The pharmaceutical industry plays a pivotal role in global health, providing life-saving medications. However, the current lack of stringent rules and standards for medicine packaging poses a significant challenge. This research aims to contribute to the creation of a safer pharmaceutical supply chain by leveraging Blockchain and IoT technologies. Through the implementation of comprehensive guidelines and technological solutions, the objective is to uphold the quality of medicines, ensuring they are safe and genuine for patients worldwide. In the pharmaceutical industry, ensuring the authenticity and safety of medications remains a top concern. However, the widespread circulation of counterfeit drugs, particularly common in regions such as Africa, poses significant challenges and puts public health at risk. The current state of the pharmaceutical supply chain is characterized by vulnerabilities and inefficiencies, leading to an increase in counterfeit products. Real-time traceability, crucial for ensuring drug authenticity, remains difficult to achieve, exacerbating these issues.

Taking inspiration from the tuna fish concept, where each tuna can be traced back to its source through a comprehensive tracking system, exploration is made into the potential of Blockchain technology to address the challenges faced by the pharmaceutical supply chain. Similar to the tuna fish industry's ability to trace individual fish back to their origins, Blockchain offers a promising solution for enhancing transparency, security, and traceability throughout the pharmaceutical supply chain. By leveraging Blockchain technology, the goal is to establish a robust system that enables the tracking of pharmaceutical products from their manufacturing origin to their distribution endpoints. This comprehensive tracking system will strengthen medication authenticity, reduce the risks associated with counterfeit drugs, and ultimately improve patient safety. Recognizing the pivotal role of the pharmaceutical industry in global health, efforts are made to contribute to the establishment of a safer pharmaceutical supply chain. Through the implementation of Blockchain technology and the adoption of principles akin to the tuna fish concept, this seeks to provide a framework for ensuring medication authenticity and promoting public health on a global scale.

II. LITERATURE SURVEY

The World Health Organisation (WHO) found that incorrect dosage from fake medications purchased from unidentified or unreliable suppliers causes more than 100,000 fatalities annually in Africa [1], [2]. The actors in the pharmaceutical supply chain are unable to fully ensure the authenticity of drugs due to two reasons: first, the supply chain does not link the physical and information flows of drugs, making it difficult to track where a product or drug is at any given time. Blockchain has the potential to improve supply chain visibility, tracing, tracking, and trust through smart contracts. As a result, it will improve how the pharmaceutical sector operates. Our concept is to utilise the benefits offered by blockchain and IoT to bring all these aspects to the supply chain [3, [4], [5].

Due to the significant quantity of information exchange required, blockchain solutions for non-financial applications and their integration into company strategy are encountering opposition. When deploying blockchain, it is imperative that all users/actors be involved, according to Perboli, G. et al. [6]. Mettler M. [7] spoke about Hyperledger, a cross-industry research network that includes Accenture, Cisco, Intel, IBM, Block Stream, and Bloomberg. The project, Counterfeit Medicines, was just established. The author of paper [8] outlines the difficulties and upcoming demands for product tracing in the pharmaceutical sector. The author also explains how blockchain technology provides the greatest and most efficient means of securely and effectively exchanging data throughout the whole product life cycle and supply chain. According to A. Jabbari et al. [9], blockchain must do away with the need for reliable third parties and be tailored to the unique requirements of supply chains in terms of data requirements and potentially complicated supply chain structures in order to have a major impact on supply chain management. According to a Deloitte analysis [10], as electronic chips and sensors continue to advance in technology, they become more portable. This presents an opportunity for an organisation to connect sensors to real items in order to improve monitoring and, ultimately, detect fraud. Rebuilding Medicine Supply Chain Architecture using Blockchain Technology: Ensuring Authenticity and Privacy of Traceability Data" (Clark, 2021)

Clark's research investigates the application of blockchain technology to reshape the medicine supply chain, with a particular emphasis on ensuring authenticity and privacy of traceability data. The study establishes a robust foundation for blockchain data storage, incorporating smart contracts, Electronic Product Codes (EPCs), and algorithms. These components play a crucial role in creating and verifying contracts, ensuring the secure and private handling of traceability data within the medicine supply chain. "Blockchain Technology in the Pharmaceutical Supply Chain: Benefits, Challenges, and Limitations" (Flannigan & McBride, 2020)

Flannigan and McBride's study explores the advantages of implementing blockchain technology in the pharmaceutical supply chain. Highlighting transparency, security, and data immutability, the research offers valuable insights into the benefits associated with blockchain adoption. Additionally, the study addresses challenges and limitations, providing a comprehensive perspective on the considerations involved in integrating blockchain into the pharmaceutical industry. "Blockchain Technology for Ensuring Authenticity and Traceability in the Pharmaceutical Supply Chain: A Conceptual Framework" (Sawyer, Jimmerson, Bradley, Connors, & Ramirez, 2019)

Sawyer et al. present a conceptual framework designed to incorporate blockchain technology into the pharmaceutical supply chain. The primary objective of this framework is to ensure the authenticity and traceability of pharmaceutical products. Addressing concerns related to data integrity and supply chain transparency, the study outlines a structured approach to leveraging blockchain for enhancing the reliability and security of pharmaceutical supply chains.

"Design and Fabrication of Manufacturable Optical Filters based on Serial Ring Resonators" (Martinez, Fuentes, et al., 2019) Martinez and colleagues focus on the design and fabrication of optical filters using serial ring resonators. The study treats these resonators as systems with both computationally expensive and cost-effective components. It involves constructing inexpensive mathematical models for directional coupler sections, comparing the performance of robust bandpass filters against designs that don't account for uncertainties in optical filter fabrication.

III. REVIEW FINDING

The pharmaceutical industry faces multifaceted challenges that significantly impact its operational landscape and success. This review identifies critical areas that warrant attention for regulatory compliance, intellectual property protection, drug development costs, and market access and pricing.

1. Regulatory Compliance:

Meeting stringent regulations poses a substantial hurdle for pharmaceutical companies. Non-compliance not only invites hefty fines but also jeopardizes a company's reputation. Navigating through evolving regulations introduces complexity into daily operations, necessitating a

proactive approach to stay abreast of and adhere to regulatory requirements.

2. **Intellectual Property Protection: The protection of ideas and inventions within the pharmaceutical industry is a formidable task. Complex legal frameworks and heightened generic competition create challenges in safeguarding intellectual property. Companies must employ astute strategies to defend their innovations amidst evolving legal landscapes and dynamic market conditions**

3. Drug Development Costs:

The exorbitant cost associated with developing new drugs, ranging from hundreds of millions to billions of dollars, poses a significant financial risk for pharmaceutical companies. Given the relatively low success rate in drug development, there is an urgent need to explore and implement cost-effective approaches to mitigate financial risks and enhance overall efficiency in the drug development process.

4. Market Access and Pricing:

Entering the market and determining optimal drug prices are intricate tasks influenced by reimbursement policies, healthcare regulations, and competitive forces. Striking a balance between affordability, profitability, and compliance is an ongoing challenge. Pharmaceutical companies must navigate this complex landscape to ensure the availability and viability of their drugs in the market.

IV. PROPOSED SYSTEM

Blockchain-Based Track and Trace System: This system would involve the creation of a blockchain network specifically tailored for the pharmaceutical supply chain. Each transaction, from the manufacturing of drugs to their distribution to various points of sale, would be recorded as a block on the blockchain. These blocks would be linked together in a chronological and immutable chain, providing a transparent and auditable record of every step in the supply chain. By implementing this system, stakeholders can easily track the journey of pharmaceutical products, verify their authenticity, and identify any anomalies or discrepancies in the supply chain.

QR Code Integration: QR codes would be embedded on pharmaceutical packaging, containing encrypted information such as the drug's name, batch number, expiry date, and manufacturing details. These QR codes can be scanned using smartphones or dedicated scanning devices at each stage of the supply chain. This integration allows for quick and easy access to essential product information, enabling stakeholders to verify the authenticity of medications and ensure compliance with regulatory requirements as shown in fig 1.

Fig 1: QR code for easy access

Blockchain Authentication Protocol: A blockchain-based authentication protocol would be developed to verify the authenticity of pharmaceutical products in real-time. This protocol would leverage cryptographic techniques to create unique digital signatures for each drug batch, which can be securely stored and verified on the blockchain. By integrating this protocol into existing supply chain management systems, stakeholders can instantly authenticate pharmaceutical products and detect any counterfeit or tampered items.

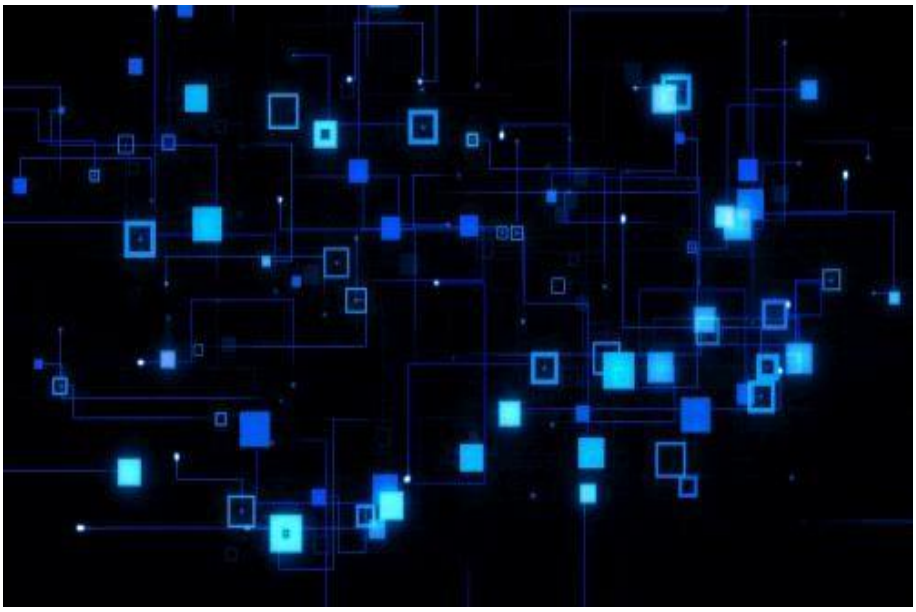

Fig 2: Blockchain Technology

Smart Contracts for Supply Chain Transactions: Smart contracts, self-executing contracts with predefined terms written in code, can automate and secure transactions within the pharmaceutical supply chain. These contracts can be used to enforce agreements between different parties, such as manufacturers, distributors, and retailers, streamlining processes like payment settlements, product recalls, and compliance checks. By eliminating manual intervention and reducing the risk of errors or fraud, smart contracts enhance the efficiency and reliability of supply chain operations.

Data Analytics for Supply Chain Optimization: Data analytics tools would be deployed to analyse large volumes of supply chain data and identify patterns indicative of counterfeit drug distribution. Advanced machine learning algorithms can detect anomalies and deviations from normal behaviour, enabling stakeholders to proactively address potential risks and vulnerabilities in the supply chain. By harnessing the power of data analytics, stakeholders can gain valuable insights into supply chain dynamics, improve decision-making, and enhance overall supply chain resilience.

Collaborative Supply Chain Platform: A collaborative platform would be established to facilitate communication and information sharing among all stakeholders involved in the pharmaceutical supply chain. This platform would provide a secure and centralized environment for stakeholders to exchange data, coordinate efforts, and respond to supply chain disruptions in real-time. By fostering collaboration and transparency, this platform enables stakeholders to collectively combat counterfeit drugs and ensure the integrity of pharmaceutical products throughout the supply chain.

Mobile Applications for Consumer Authentication: Mobile applications would be developed to empower consumers to verify the authenticity of pharmaceutical products directly from their smartphones. These applications would enable consumers to scan QR codes or blockchain-based digital signatures on product packaging, providing instant access to information about the product's origin, authenticity, and compliance status. By empowering consumers with this information, mobile applications enhance transparency in the pharmaceutical supply chain and enable them to make informed purchasing decisions, thereby reducing the risk of exposure to counterfeit drugs.

Implementing these proposed systems would require collaboration and cooperation among stakeholders across the pharmaceutical industry. However, the potential benefits, including enhanced transparency, improved product authenticity, and better public health outcomes, justify the investment and effort required to implement these innovative solutions.

System Architecture:

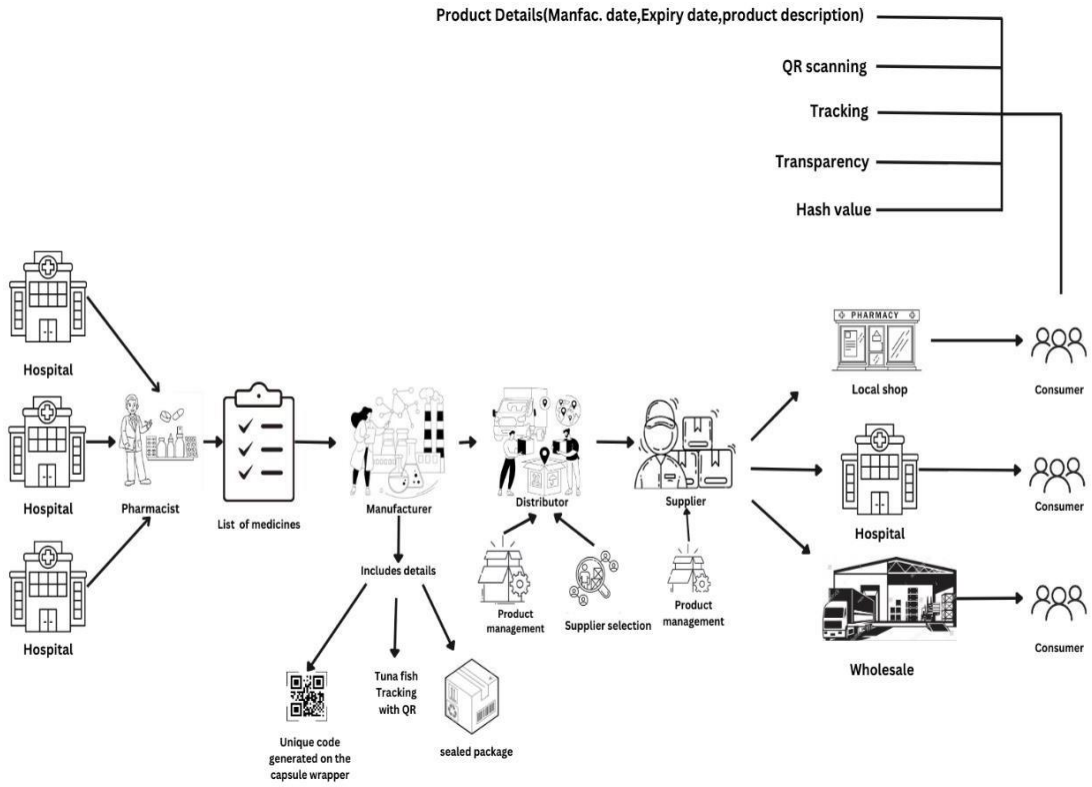

Fig: 3: Proposed System Architecture

From Fig 3 this medicine supply chain system involves various stakeholders. It commences with the manufacturer generating a unique code for each capsule wrapper, providing details like manufacturing and expiry dates. The distributor seals the medicine in a package, managing distribution and ensuring transparency through a hash value. Additionally, the tracking path is revealed to the customer through the Tuna Fish Algorithm, showcasing the product's journey to their hands. The pharmacist, the subsequent stakeholder, receives the medicine from the distributor and supplies it to the local shop or hospital, which then sells it to the consumer. At each stage, the medicine is tracked using a QR code, guaranteeing transparency and security. Consumers can scan the QR code to access product details, including the manufacturer's information, product description, and tracking information.

The system incorporates a wholesale stage, enabling multiple pharmacies or hospitals to buy medicines in bulk. Consumers can also purchase medicines directly from the manufacturer or distributor, bypassing the pharmacy or local shop. In summary, this medicine supply chain system, enhanced by the Tuna Fish Algorithm, ensures transparency, security, and tracking from the manufacturer to the consumer. The utilization of QR codes and hash values ensures transparency and security, allowing consumers to access product information with a simple scan.

V. METHODOLOGY

TUNA FISH:

The Tuna Fish Algorithm is a pioneering blockchain solution ensuring transparency in the tuna industry supply chain. Employing blockchain's decentralized nature, it addresses issues like illegal fishing and promotes sustainability.

Blockchain Integration: Utilizes blockchain for secure and tamper-proof recording of tuna's journey.

Smart Contracts: Automated contracts enforce sustainability measures, fostering ethical fishing practices.

Real-time Tracking: IoT devices provide real-time data, ensuring accurate traceability and transparency.

Application in Tablet Supply Chain:

1. Manufacturing:

Integration of Tuna Fish Algorithm: Ensures authenticity and sustainability from the point of tablet production.

Blockchain Recording: Records manufacturing details securely, enhancing transparency in the supply chain.

2. Distributor to Supplier:

Smart Contracts Implementation: Enforces compliance with ethical sourcing and distribution standards.

Traceability Assurance: Allows distributors to trace tablets from multiple sources, ensuring legitimacy.

3. Supplier to Local Shops:

Blockchain Verification: Local shops access blockchain, verifying tablet origin and adherence to ethical standards.

Consumer Confidence: Empowers consumers with data about tablets' journey, fostering responsible purchasing.

4. Local Shops to Consumer:

Scannable Technology: Consumers use smartphones to scan tablet packaging, retrieving blockchain-based information.

Transparent Information: Informed consumers make choices aligning with sustainability and ethical practices.

Benefits:

Illegal Activity Deterrence: Acts as a deterrent to illegal practices in the tablet supply chain.

Supply Chain Transparency: Enhances visibility and trust by providing verifiable information at each stage.

Consumer Empowerment: Empowers consumers to support ethical practices by making informed purchasing decisions.

VI. RESULTS

After completion of QR generation, user can scan the QR in the android with any scanning app or by built-in camera.

Fig: 4: QR of the Product

Fig 4 represents the QR developed or generated by the Manufacturing Company.

The following details are displayed after scanning QR or entering Product ID like below product details will be displayed：

Product ID: A unique alphanumeric code assigned to each product for identification purposes.
Product Name: A descriptive name given to the product for easy recognition by consumers.
Manufacturer Name: The name of the company or entity responsible for producing the product.
Distributor Name: The entity tasked with distributing the product to various retail outlets or suppliers.
Supplier Name: The name of the entity providing the raw materials or components used in manufacturing the product.
Manufacturing Information: This crucial section encompasses a wealth of essential details vital for transparency and safety. It includes the Manufacturing Company Name, providing accountability and traceability. The list of Ingredients offers transparency regarding what goes into the product, ensuring consumers can make informed choices. Storage Conditions outline the optimal environment for maintaining product quality and effectiveness. Pricing details aid consumers in making purchasing decisions while Warnings and Instructions promote safe usage, minimizing risks. Altogether, this comprehensive information ensures transparency and safety throughout the product's lifecycle.

User Scanning the QR in website

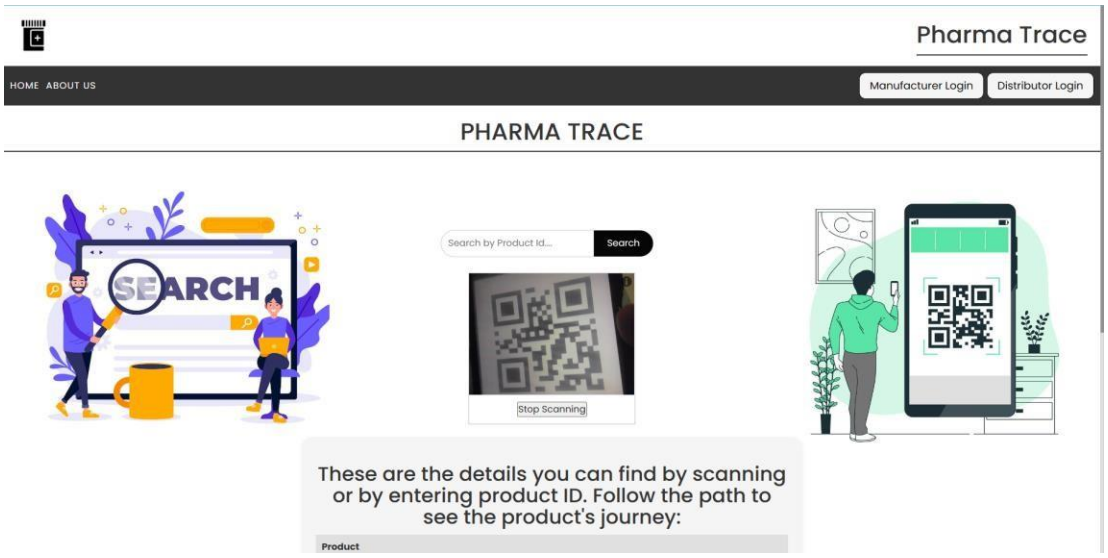

Fig:5: User scans the QR in mobile which redirects to our authorized website

After compiling all the necessary details, a QR code is created to represent the product information. This QR code is then printed onto tablet sheets by the manufacturer. These sheets are distributed among different distributors, who further disseminate them to suppliers. When a user interacts with the QR code by scanning it or manually entering the product ID displayed on the tablet sheet, they are immediately redirected to an authorized website shown in fig 5. This streamlined process ensures efficient access to accurate product information for users, enhancing transparency and trust in the supply chain.

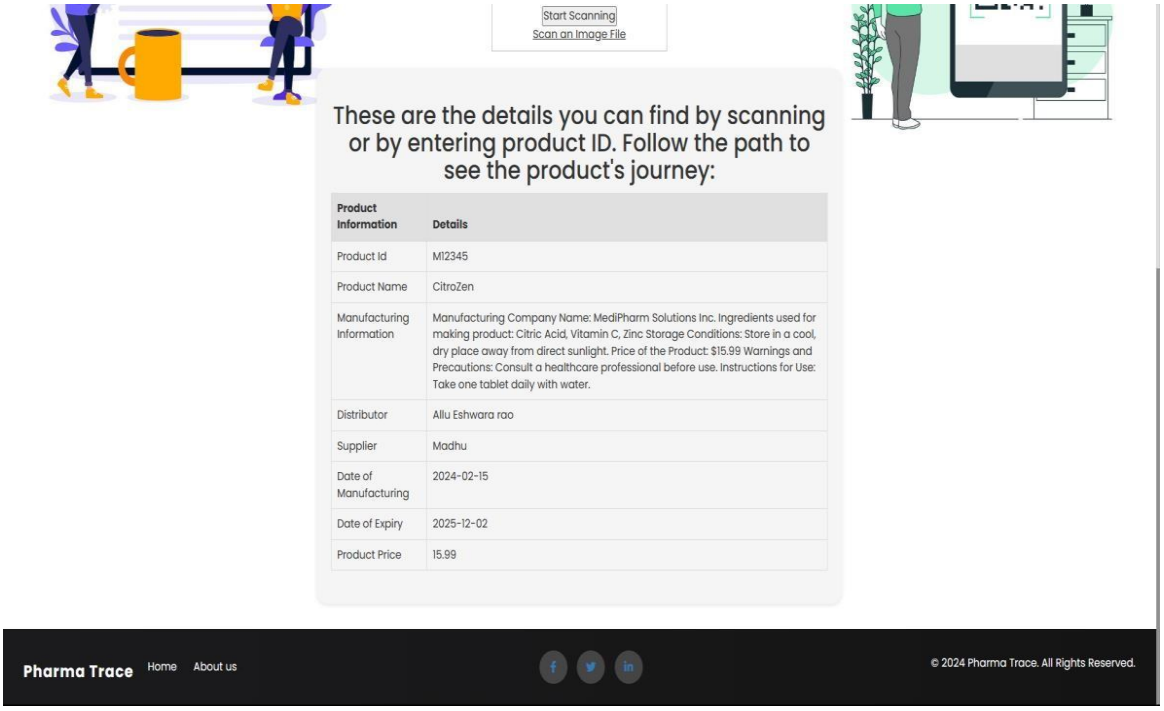

Fig: 6: Details of the Product that displayed in the authorized website.

From fig 6 Upon authenticating the QR code, consumers gain access to a many of vital product details. These encompass the product's name, manufacturer information, manufacturing and expiry dates, batch number for traceability, a complete list of ingredients, precise storage instructions, and clear usage directions. Additionally, essential safety precautions and potentially pricing information may also be provided. This comprehensive array of information ensures transparency and authenticity, enabling consumers to make well-informed decisions about the product's suitability and safety, ultimately fostering trust in the brand and its offerings.

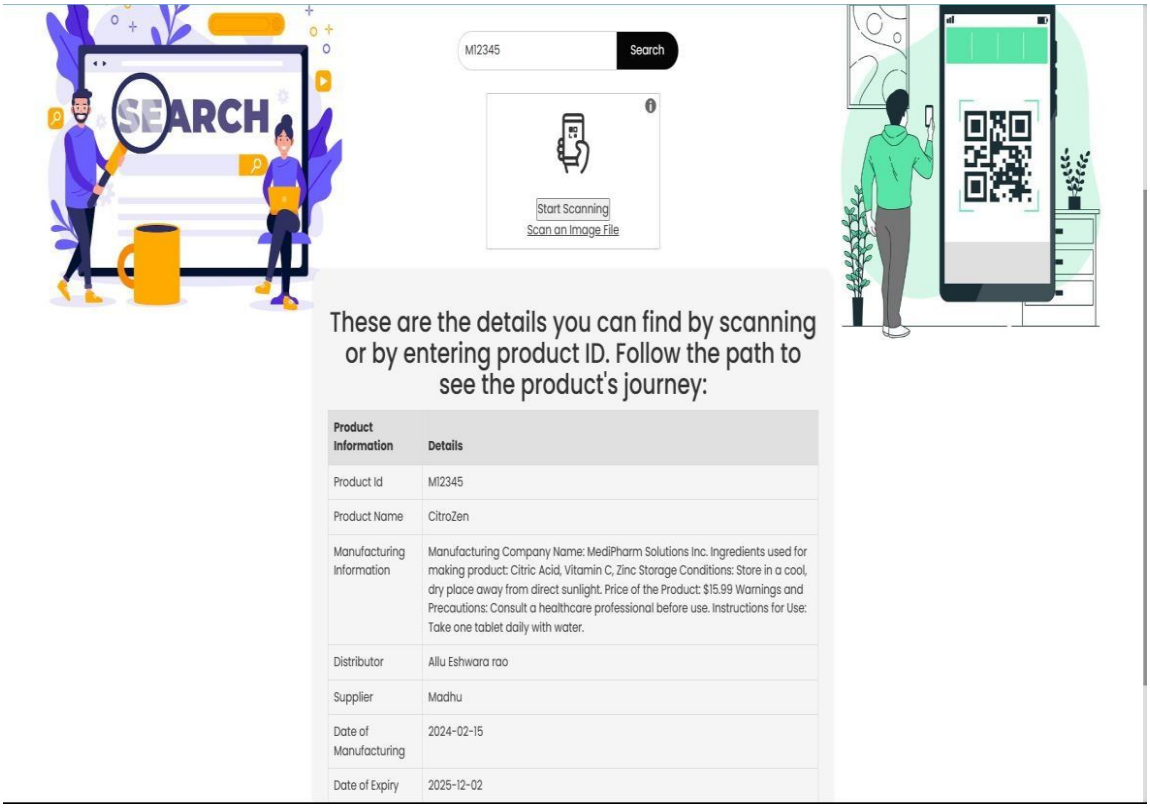

Fig: 7: We can check product details by the Product ID also.

An additional method for verifying product details, emphasizing the use of the Product ID. This means that alongside scanning the QR code, users can also input the unique Product ID to access comprehensive information about the product shown in fig 7. This redundancy in verification methods ensures flexibility and accessibility for users, accommodating various preferences and technological capabilities. Whether through scanning or manual entry, consumers can swiftly and reliably retrieve essential product details, enhancing transparency and trust in the product and its supply chain.

If Product ID or QR is not registered then the message displays like **No Products details available. Scan registered QR or enter Valid Product ID**.

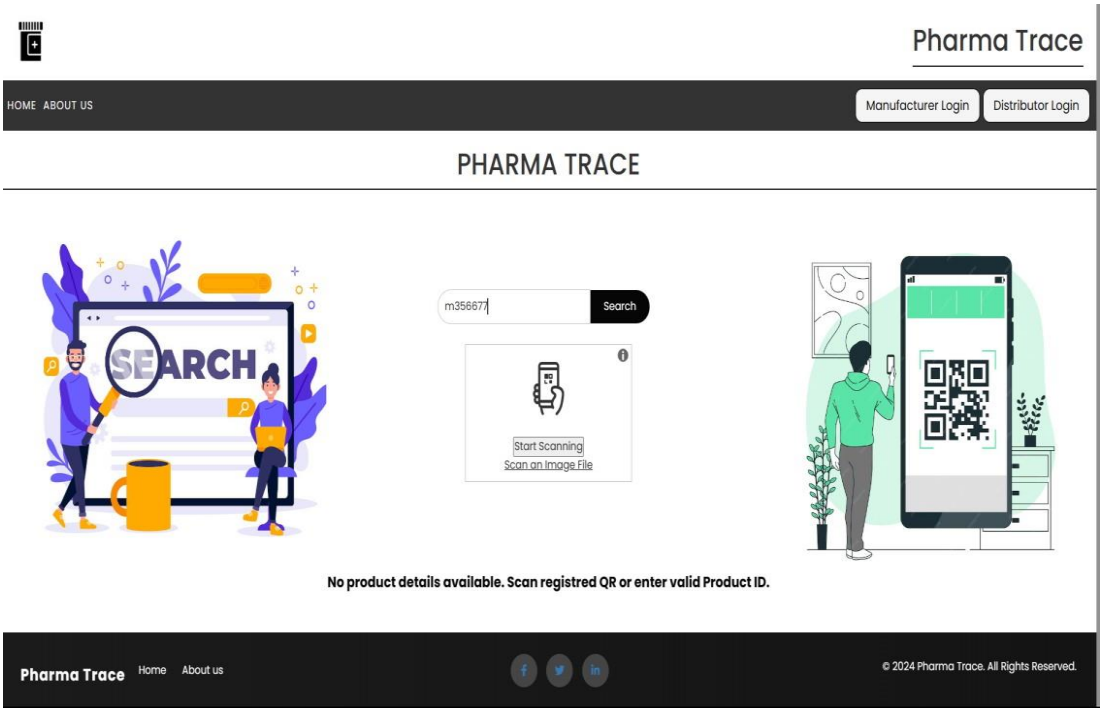

Fig: 8: Alert Message If Product ID is invalid

If the Product ID or QR code is not registered, a message will be displayed indicating "No product details available. Please scan a registered QR code or enter a valid Product ID" as shown in fig 8 This notification informs users that the provided identifier does not correspond to any registered product in the system. It prompts them to ensure they are using a recognized QR code or accurately inputting a valid Product ID to access the associated product details. This helps manage user expectations and directs them towards the correct actions for obtaining relevant information.

VI. CONCLUSION

The Pharma Trace system, inspired by the Tuna Fish Algorithm, revolutionizes pharmaceutical supply chain management with its innovative use of Blockchain, QR codes, and IoT technology. This comprehensive solution ensures the authenticity and safety of medicines from production to distribution. By applying the principles of the Tuna Fish Algorithm to tablet manufacturing, the system promotes ethical practices and transparency throughout the supply chain. The integration of Blockchain facilitates a secure and tamper-proof record-keeping system, enhancing transparency and traceability. Smart contracts enforce ethical standards, ensuring tablets are sourced and distributed responsibly. The real-time tracking provided by IoT devices adds another layer of accuracy and transparency to the entire process.

Consumers benefit significantly from this system. By simply scanning the QR codes on tablet packaging, they gain instant access to vital information about the tablet's origin, authenticity, and compliance with ethical standards. This user-friendly approach empowers consumers to make informed and responsible purchasing decisions. Overall, the Pharma Trace system, guided by the Tuna Fish Algorithm, acts as a deterrent to illegal activities in the pharmaceutical supply chain. It not only enhances supply chain transparency and consumer empowerment but also lays the foundation for a safer and more accountable pharmaceutical industry. This amalgamation of cutting-edge technologies promises a future where medicine safety is prioritized, and stakeholders have easy access to essential details through a seamless scanning process.

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