# Food Supply Chains Using Blockchain Technology

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***Abstract* -** Food holds a significant role in human beings' lives and human societies in general across the planet. The large number and heterogeneity of the stakeholders involved from different sectors, such as producers, distributors, retailers, customers, and quality checkers, render agricultural supply chain management one of the most complex and challenging tasks. Nowadays, the customers are unaware of the events happening to the supply chain items, which creates a lack of trust in their minds. So, the solution to this problem can be implemented efficiently using Blockchain technology. This paper is intended to explore transparency in the supply chain of food products by using Blockchain technology. It allows for decentralized data storage and provides immutability. The decentralized data storage makes it impossible for an unauthorized actor to tamper with the data.Our findings indicate that blockchain is a promising technology towards a transparent supply chain of food, with many ongoing initiatives in various food products and food-related issues. However, many barriers and challenges still exist, which hinder its wider popularity among farmers and systems. These challenges involve technical aspects, education, policies, and regulatory frameworks.This paper discusses relevant methodologies to replace the ongoing methods employed by the industry to trace products in the supply chain, thus leading to a massive decrease in cost and efforts for the stakeholders and making products cheaper for the customers. The blockchain could also be deployed on cloud services to increase availability and reliability. The methodologies presented in this paper can be used by any food manufacturing industry that wants to track the products better and explore transparency in the supply chain.

## I. INTRODUCTION

Food supply chains have a vast complexity, which is often the cause of a lack of transparency and traceability. On top of that, a significant issue directly affecting public health is food safety. During the past twenty years, various food epidemic incidents have been reported[1], like the foot-and-mouth Disease in Europe in 2001, the Escherichia coli outbreak in spinach in 2006 in the USA, the Sanlu milk scandal in China in 2008, the E. coliO104:H4 outbreak in Germany in 2011, the South African listeriosis outbreak in 2017–2018, etc. Governments and health organizations, in an attempt to prevent such dangerous outbreaks, have established relevant directives, laws as well as standards and regulations. For example, in Europe, the traceability of food products is compulsory according to the European Directive 178/2002 since 1 January 2005, together in compliance with the HACCP (Hazard Analysis and Critical ControlPoints) principles. Likewise, regulations all over the world have been established, aiming to diminish food epidemic incidents. Nowadays, consumers' concerns regarding food provenance and quality are profound, resulting in the tendency to spend more money on food products whose origin is certified. Despite the developed technologies that are already in use, in many cases, the vast majority of the traceability systems are centralized, asymmetric, and outdated in terms of data sharing and interoperability. Existing systems lack transparency and consumers' trust due to the unavailability of a fast and trustworthy way to retrieve information on the product's provenance. Considering all the above, together with the rapid technological development adopted in value chain areas, we observe a significant increase in emerging innovations that lead the way for new digital traceability systems by taking advantage of information and communication technology (ICT), Radio-Frequency Identification (RFID) sensors, Internet of Things (IoT), blockchains and more. In this context, distributed ledger technologies (DLT) such as blockchain offer a solution to many existing problems but simultaneously pose new challenges as well.

Since 2014 it has increasingly been realized that blockchain can be used for much more than cryptocurrency and financial transactions so that several new applications are being explored(Tayeb and Lago 2018): handling and storing administrative records, digital authentication and signature systems, verifying and tracking ownership of intellectual property rights and patent systems, enabling smart contracts, tracking patient health records, greater transparency in charities, frictionless real-estate transfers, electronic voting, distribution of locally produced goods and, in general, for tracking products as they pass through a supply chain from the manufacturer and distributor to the final buyer. Such changes are already revolutionizing many aspects of business, government, and society in general, but they might also pose new challenges and threats that need to be anticipated. Many of these new applications combine blockchains and distributed ledger technologies (DLTs) with smart contracts and decentralized applications, making third party tampering or censorship virtually impossible(Buterin 2015).

In this paper, the authors identify, gather, and present a thorough literature review of ongoing scientific papers, technical publications, research projects, and pilot integrated and commercial platforms using blockchain for traceability in the agriculture supply chain. We also present design and implementation for the Supply Chain for food products.

### *A. Brief Introduction to Blockchain*

Nakamoto[2][3] proposed a decentralized digital currency, Bitcoin, supported by a decentralized payment system. Decentralization refers to an operating mechanism that allows peer-to-peer (P2P) exchange or transactions with-out centralized authorities. This disruptive innovation eliminates the heavy reliance on powerful third parties. Blockchain is the technology underpinning the Bitcoin cryptocurrency, which is a consecutive growing list of blocks, wherein each block records encrypted transactional data and may have further potential for other decentralization purposes [4]. The Operating nodes in this kind of collaborative network have a duplicate record of transactional information, known as a‘‘ledger.’’ Inherently shared by participating nodes, Distributed Ledger Technology provides the opportunities for a trustless operating environment without traditional trusted authorities such as banks and clearinghouses. P2P exchange facilitates trust-building among participating nodes and the shared ledger is maintained by nodes in the network.

Computer nodes comply with an encrypted protocol to verify updated data in the shared ledger. This kind of distributed ledger system harvests the benefits of decentralized governance which may solve the issue of information expo-sure and accountability [5]. This inherent attribute favors the interactions between counterparties in the context of business operations [6]. Critical information could be maintained without checking the consistency of individual data and every single node possesses a duplicate of transactional data, thereby enhancing the transparency and visibility of business activities.

In a supply chain context, this kind of system and operational scheme may provide a better foundation of trust as well as benefits resulting from the absence of a centralized authority and intermediation [7]. Accordingly, blockchain could further be utilized to record the ownership of assets [8], permissions, and activity logs. This improves the traceability of information, cash, and process flows, and thus provides timely tracking of products and services. The different types of blockchain are public, private, and consortium (or federated) blockchains, each of which could be applied in certain scenarios to gain better advantages and for effectiveness.

## II. LITERATURE SURVEY

The food chain is highly distributed and comprises numerous actors, such as farmers, transportation companies, manufacturers, dispatchers, distributors, wholesalers, retailers, and customers. [9]

The main phases of a food supply chain are described below.

1.*Production*: The production phase represents all agricultural activities implemented within the farm. The farmer uses raw and organic material such as seeds, fertilizers, etc., to grow crops.

2.*Processing*: The processing phase concerns transforming a primary product into one or more other secondary products. It can be followed with a packaging phase where each packaged product can be identified uniquely using a QR code or product identification code, which can be used in the further phases to add/ retrieve product-related information.

3.*Quality Checks*: After the product is ready, quality checks are performed either internally or externally. The internal quality assurance team makes sure that the product is packaged according to the given specifications. In contrast, the external quality assurance team can be any food agency such as FSSAI, which checks if the product is quality compliant and also if the product is organic so that the product can be given an organic certification.

4.*Distribution*: Once the product is ready and organic quality is verified, it is released for the distribution phase. It also involves the storage of food products under a specific range of temperature and humidity for preserving the organic quality of the food products.

5.*Retailing*: After the distribution phase, the products are delivered to retailers who perform the organic product's sale. The end-user of the chain will be the customer, who will trace the product and then will decide on purchasing the product.

6.*Consumption*: The customer is the end-user of the food chain. The customer can retrieve the product information and details about product storage using the QR code or the product identification code assigned to the product in the processing phase. The customer can then decide on purchasing the product if he/she finds it to be quality compliant.

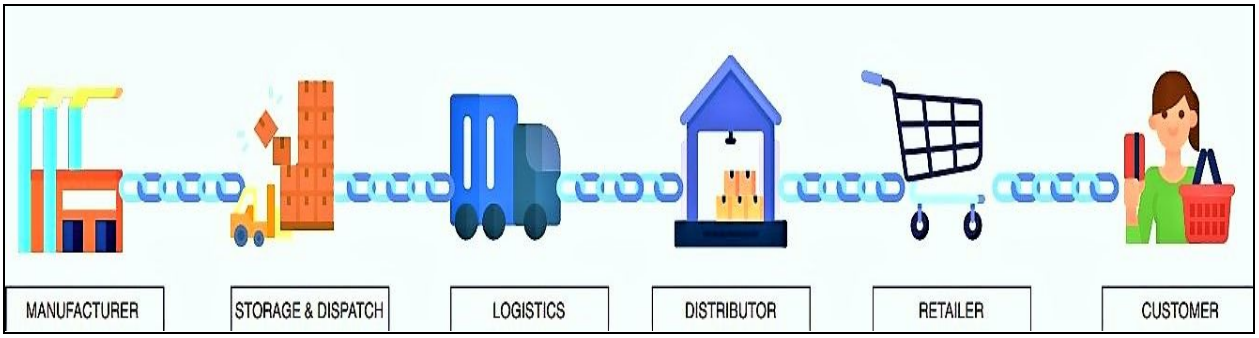


Fig 1: General food supply chain

Fig. 1 gives a pictorial view of the traditional food supply chain. This system is unreliable because it does not allow for tracing of food products, and also, it is not trustworthy. The exchange of products and goods are based on complex and paper-heavy settlement processes. In contrast, these processes are not transparent, with high risks between buyers and sellers during the exchange of value [10]. As transactions are vulnerable to fraud, intermediaries get involved, increasing the overall costs of the transfers[11]. According to an estimation, the cost of operating the supply chain contributes to two-thirds of the final product's cost.

Thus, there is a high scope of improving the supply chains' performance by effectively lowering the operating costs. Finally, when people buy products locally, they are not aware of these goods' origins or are genuinely organic and quality compliant.

The first electronic traceability systems were centralized solutions based on databases and data import conducted either manually or semiautomatic. Gandino et al. (2009)[12] propose a framework consisting of RFID tags attached to products in a fruit warehouse. The data was stored on a central database and was written using RFID tags. The data can be read from a Personal Digital Assistant(PDA) device provided to the personnel.

Another traceability system which is based on a central computing system is proposed by C. Cheng [13]. This system marks the products with unique codes and stores information about them on a centralized database in Extensible Markup Language(XML) files, made available to every stakeholder. This implementation was efficient when the amount of data was small so that the data can be processed without any additional requirements of computational resources.

These electronic traceability systems represent efforts to think differently than the traditional complex processes involved in the food supply chain.

### *A. Blockchain in Food Supply Chain:*

The research on using blockchain technology in supply chain management for food began in 2016 when the blockchain technology was maturing and becoming more mainstream in other application domains such as in real estate, in exchange for cryptocurrencies, and gaming.There is evidence that applications for supply chain management were being developed using blockchain technology soon after the technology appeared [14].Blockchain in supply chain management is projected to grow at an annual growth rate of 87% and increase from $45 million in 2018 to $3,314.6 million by 2023 [15].

While the blockchain technology is succeeding and proving its functionality in many cryptocurrencies, various organizations such as IBM and Linux Foundation aim at harnessing its transparency and fault tolerance in order to solve problems in an environment where numerous untrusted actors get involved in the distribution of some resource such as food products in a supply chain [16].Walmart and Kroger were among the first companies to work on blockchain and to include the technology into their supply chains [17], working initially on case studies that focus on Chinese pork and Mexican mangoes[18].

Moreover, in April 2017, Intel demonstrated how Hyperledger Sawtooth (Hyperledger 2018), a platform for creating and managing blockchains, could facilitate traceability at the seafood supply chain. The study used sensory equipment to record information about the fish location and storing conditions. As another example, Louis Dreyfus Co (LDC), one of the world's biggest foodstuffs traders, teamed up with Dutch and French banks for the first agricultural commodity trade (i.e. a cargo of soybeans from the US to China) based on blockchain [19]. According to LDC, by automatically matching data in real-time, avoiding duplication and manual checks, document processing was reduced to a fifth of the time.

Caro et al. propose an integrated solution of a blockchain platform named AgriBlockIoT in the agriculture supply chain. AgriBlockIoT is a fully distributed system that uses blockchain technology in combination with IoT devices in order to collect and distribute traceability data. The proposed solution was tested with two different blockchain platforms, namely Hyperledger Sawtooth and Ethereum. Trial results showed that Ethereum performed considerably better compared to Hyperledger Sawtooth, in terms of latency, CPU, and network usage.

In the same year, the World Wildlife Fund (WWF) created a project called "Bait-to-plate" focused on the traceability of tuna in New Zealand throughout the whole supply chain. WWF's project adopts RFID technologies for fish tagging and an Ethereum-based blockchain. Downstream beer is the first company in the beer sector to use blockchain technology, revealing everything one wants to know about beer, i.e. its ingredients and brewing methods. Every aspect of this craft beer is being recorded and written to the blockchain as a guarantee of transparency and authenticity. Consumers can use their smart-phones to scan the QR code on the front of the bottle and they are then taken to a website where they can find relevant information, from raw ingredients to the bottling.

In January 2018, the World Wildlife Foundation (WWF) announced the Blockchain Supply Chain Traceability Project (WWF 2018), to eliminate illegal tuna fishing by means of blockchain. Through the project, fishermen can register their catch on the blockchain through RFID e-tagging and scanning fish. The traceability of tuna is also the focus of Balfegó[20]

Furthermore, ripe.io has created the Blockchain of Food[21], which constitutes a food quality network that maps the food's journey from production to our plate. Ripe.io has recently raised $2.4 million in seed funding in a round led by the venture arm of global container logistics company Maersk.

### III. DESIGN AND IMPLEMENTATION

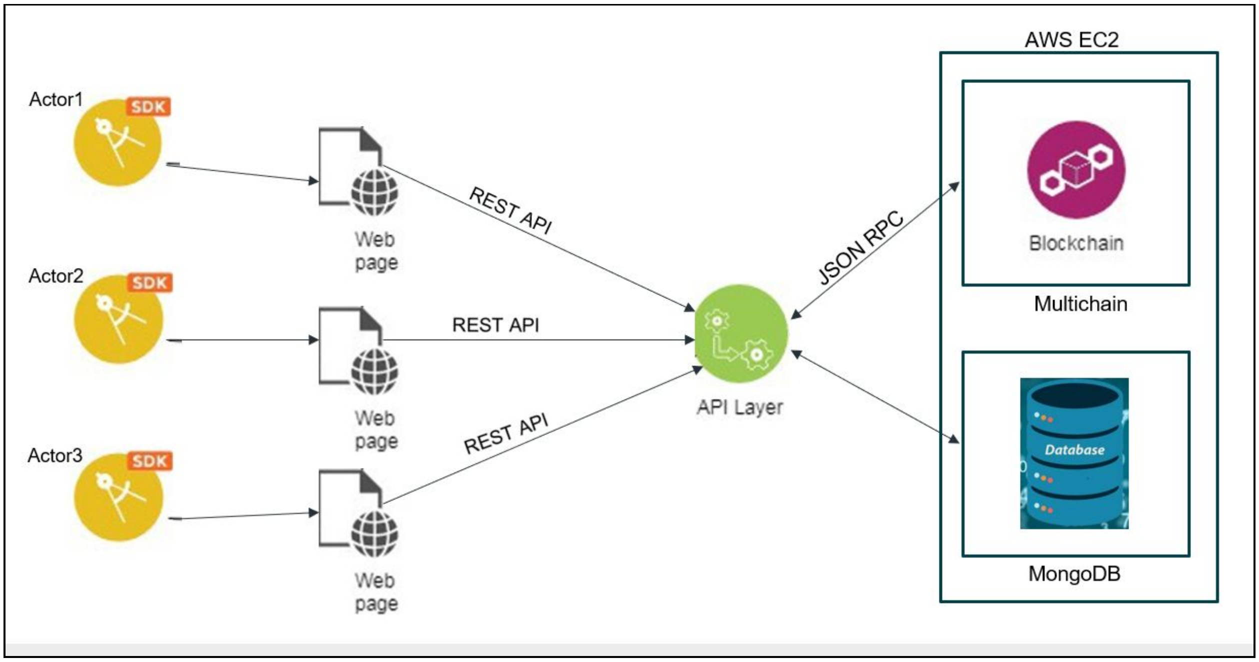


Fig 2: Architecture

Actors or systems interact with the blockchain through web pages as shown in above Fig. 2. Web pages further interact with the API Layer in order to record or retrieve transactions on the blockchain. Tokens are implemented for security purposes in the interaction between nodes and blockchain. Business logic is implemented along with the API in the middle layer. A database implementation helps in authenticating users.

Web pages are implemented using HTML, CSS and Javascript. Javascript is a dynamic computer programming language. It is a lightweight, interpreted programming language which is designed for creating network-centric applications and is most commonly used as a part of web pages, whose implementations allow client-side script to interact with the user and make dynamic pages. Ajax calls are used at multiple points in order to send and retrieve data from a server asynchronously without interfering with the display and behaviour of the existing page.

API is implemented on nodejs and expressjs (JavaScript-based platform). REST (REpresentational State Transfer) API is preferred since it is lightweight, highly scalable and maintainable. Since this web application has to handle more than one pair of request-response to complete, session management is implemented in order to track its current status. Typically, a session is started when a user authenticates their identity using login credentials. API plays an important role in interacting with the multichain server in order to send and retrieve data. Multichain-node library is used for building native Javascript clients in this web application.

Permissioned blockchain is built on the Multichain platform. Multichain is an extended open-source fork of Bitcoin which can be used to launch custom blockchains, both private and public. It offers a well-selected set of features and enhancements targeted at enterprise and business users [22]. MongoDB is implemented for authenticating users. It includes various actors' details, login credentials and sessions. MongoDB is a cross-platform, document oriented database that provides, high performance, high availability, and easy scalability.

Blockchain with multichain is deployed on Amazon Web Services (AWS) cloud. JSON-RPC is a stateless, light-weight remote procedure call (RPC) protocol which helps in interaction between API and multichain . Primarily this specification defines several data structures and the rules around their processing. It is transport agnostic in that the concepts can be used within the same process, over sockets, over HTTP, or in many various message passing environments. It uses JSON (RFC 4627) as data format.

A MultiChain blockchain can contain any number of streams, where the data published in every stream is stored in full or referenced by a hash inside transactions. MultiChain streams enable a blockchain to be used as a general purpose append-only database [22]. It provides a natural abstraction for blockchain use cases which focus on general data retrieval, timestamping and archiving. Each stream is an ordered list of items, with the following characteristics:

- One or more publishers.
- One or more keys.
- Some data in JSON, text or binary format.
- Information about the item's transaction and block.

One stream called product-data is created to store data. Data can be queried from streams using JSON-RPC calls. Three major functionalities implemented using streams such as add product, update product status and trace product. In add product the data is added to the streams in JSON format by providing the product code as key. In Update Product status functionality, product data can be updated only by the authorized actor i.e., the actor possessing the product and a new JSON object is published to the product-data stream with the same key as that of add-product functionality. While tracing products, the customer can enter the unique product code to fetch all the details related to the product. While tracing, the array of objects with product code as key is retrieved from the product-data stream and these objects are combined to create a summarized object containing all the details of the product and this JSON object is sent to the Front-End using REST API .

# IV. RESULT

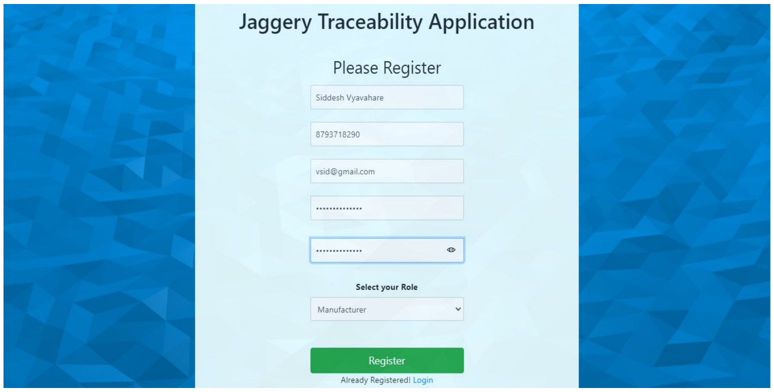


Fig 3: Register Page

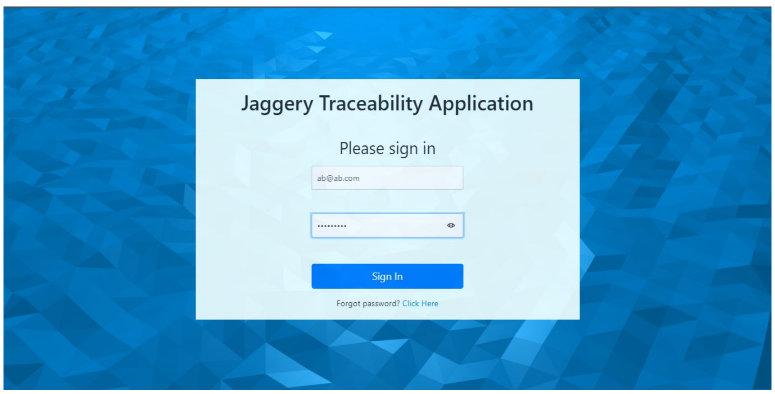


Fig 4: Login Page

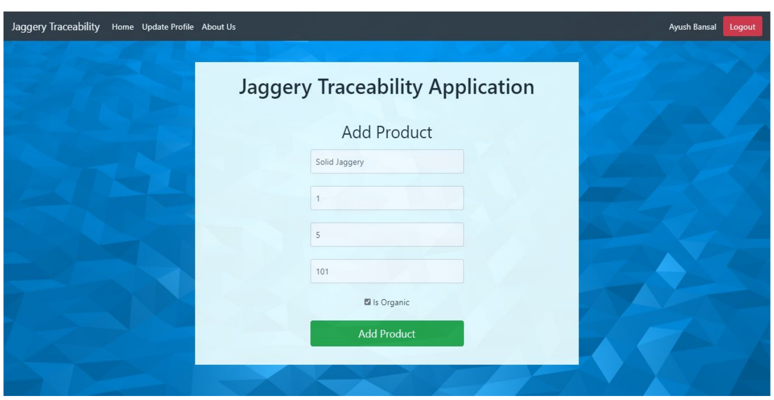


Fig 5: Add Product by Manufacturer

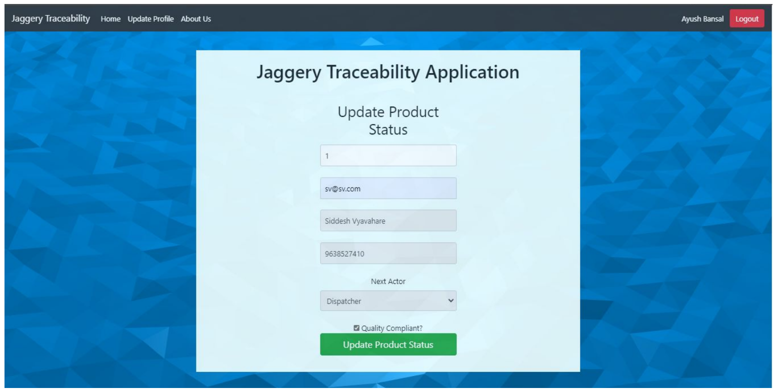


Fig 6: Update Product Status by Actor 1

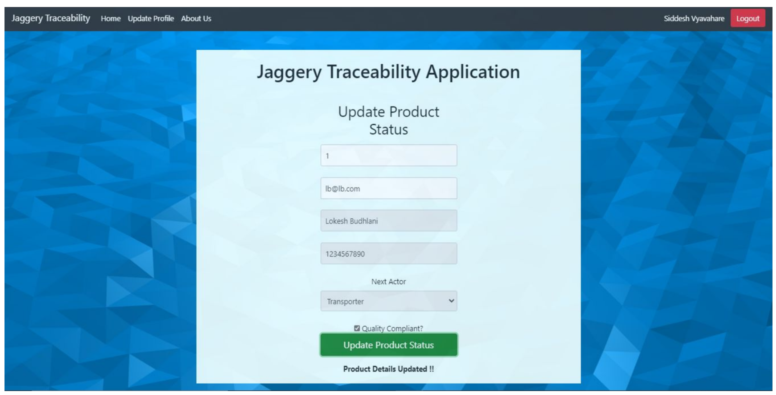


Fig 7: Update Product Status by Actor 2

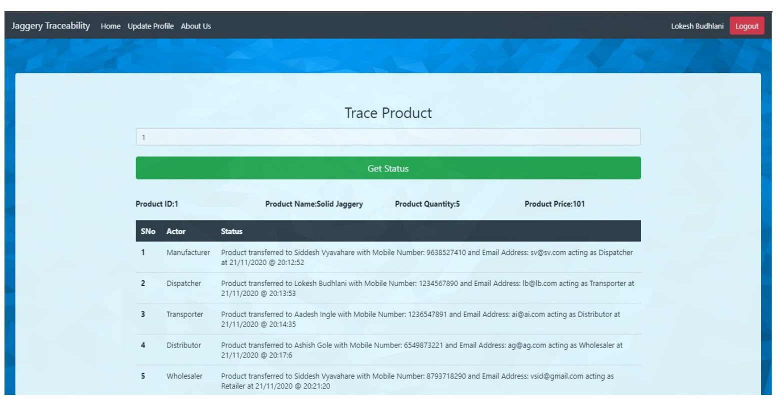


Fig 8: Trace Product

## V. CONCLUSION

Implementing the Food supply chain using blockchain makes it possible for a system of independent actors to share and trust a record of digital assets, transactions, and information as well as it offers the potential to disrupt and transform existing business models [24]. There are several contributions of this paper to the knowledge of supply chain management evaluation for organic food products. In general terms, this article can help to replace the ongoing methods employed by the industry to trace organic food products in the supply chain, thus leading to an immense decrease in cost and efforts for the producers and making the products cheaper for the customers [24].

Future supply chains are likely to be more dynamic in nature, and consist of collaborative value networks in which productivity and efficiency are constantly maximised. These future supply chains will be beneficial to organic foods in terms of preservation of quality. In Future of this research, implementation of IoT smart sensors will be included in the supply chain commodities to verify constraints used for quality preservation [25].

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