Unlocking Opportunities

Harnessing Blockchain Technology for Agricultural Supply Chain Traceability

Date of Publication
March 2024

Author
Charlie Kellaway

Reading Time
12 minutes

Introduction

Blockchain, the digital record-keeping technology behind Bitcoin and other cryptoasset networks, has emerged as a transformative force in various industries. One area in which it has potential to enhance transparency, traceability and efficiency is supply chain management. Blockchain can greatly improve supply chains by enabling faster and more cost-efficient delivery of products, enhancing products' traceability, improving coordination between partners and aiding efforts to fight counterfeit. This commentary examines the extent of this possible impact, analysing the challenges and opportunities associated with adoption. Examples of real-world application in China and Australia are presented and discussion focuses on blockchain's ability to validate each stage of a product's lifecycle.

Agriculture Traceability Solutions

The food and agriculture sector is a major employer worldwide, with stakeholders involved from diverse regions across farming, distribution and retail. A huge number of parties interact to ensure delivery to consumers, making agricultural supply chain management challenging. Current chains incur complexity at the expense of transparency and traceability which can compromise food safety, as observed in various epidemics over the last 20 years. Recent examples include *Salmonella* in Canada [1], *Listeria* in Sweden [2] and lead-tainted applesauce manufactured in Ecuador [3], but instances in the mid-2000s – such as the *Escherichia coli* outbreak in spinach in 2006 in USA [4] – demonstrate that food safety is an enduring, global problem.

Food processing has undergone significant change in the last 10 years and many procedures in the supply chain have been automated. Technology has evolved at speed, resulting in data gathering methods that rely on sensor technology for product identification, ingredient analysis, transportation and storage, as well as information capture throughout the lifecycle. Barcodes, QR codes, Radio-Frequency Identification (RFID) sensors and wireless sensor networks are the most widespread and well-known. However, traceability systems are often centralised, asymmetric and outdated in terms of data sharing and interoperability [5].

Existing systems lack transparency and trust due to the unavailability of methods to retrieve legitimate information on a product's origin. Data is often not shared between entities in a chain. Isolated data creates murkiness – a suboptimal feature if aiming for trusted supply. Given the need to ensure food safety, new solutions should aim to tackle deficiencies in transparency and traceability.

Why does traceability matter? Traceability is the ability to recall all information about the origin of a food product, including production, processing and sales [6]. It includes information about ingredients, sources, storage and transportation, covering the lifecycle of any product from its original

source to the shelves of local supermarkets. This information matters to the end customer. A study on 500 consumers of food products in Poland found that information disclosed on packaging (including the identity of the producer, ingredients, energy values, best before date and raw materials) are of equal importance for men and women, regardless of age, education or income [7]. In addition, Deloitte's survey of 5,000 people worldwide found that 51% of consumers make purchase decisions based on health, safety, social impact and experience, compared with 49% driven by price, taste and convenience [8].

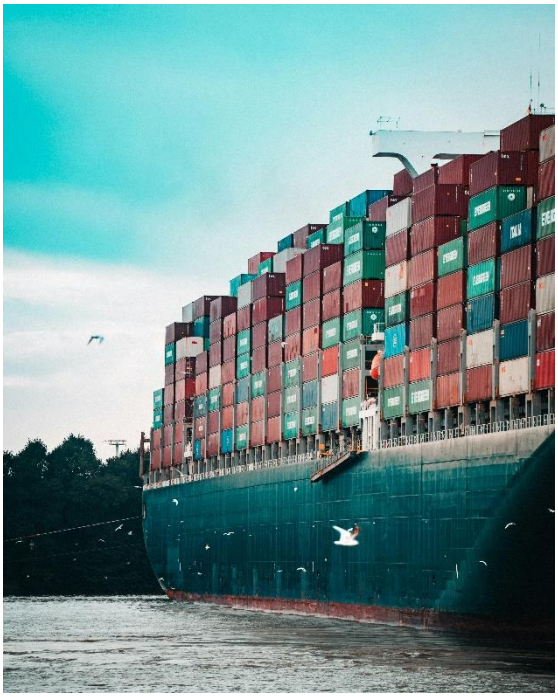
Consumers are aware about how different products affect their health, with many questioning the standards supporting widespread marketing terms such as *artisanal, multigrain, free-range and organic* [9]. Increasingly, consumers care more about the production methods used to grow food and want both accurate and precise information on its lifecycle. Consumers also want to know how many miles their food has travelled, where raw materials come from and the working conditions of people who harvest them, with environmental and social impacts motivating organic food purchases even more than personal health or quality considerations [10]. Take, for example, Tony's Chocolonely, a Dutch confectionary company committed to eliminating slavery from the cocoa industry and selling fair trade chocolate. In 2015, 8.8% of chocolate bar sales in Netherlands supermarkets were bars of Tony's Chocolonely. In 2019, this number increased to nearly 19%.

This poses a problem for companies operating within agriculture and food supply chains. The industry plays a crucial role in economies worldwide, contributing significantly to exports and domestic consumption, but every single product has its own story and metrics. Traceability demands a large volume of data to be collected across numerous business and timelines, making visibility extremely complex [11]. With demand for safe, traceable and sustainable food products increasing, there is a growing emphasis on enhancing transparency and accountability in the food supply chain. This brings distributed ledger technologies (DLT) into consideration, as blockchain can capitalise on information distribution to drive technological innovations.

Blockchain's Potential

A blockchain is a distributed ledger, meaning a digital system for recording transactions among multiple parties in a verifiable, immutable way. Its main function is to enable anonymous parties to transact securely with one another in the absence of a trusted intermediary mediating the transaction. A single block is a record with data inside it, connected cryptographically to a previous block in the chain and displays a value representing its own hash. The hash can be thought of as the digital fingerprint of data within the block, and the cryptographic link between the hash of the current block and the hash of the previous block forms an immutable chain. If someone attempts to tamper with the data in a given block, that block's hash will change and render subsequent blocks invalid [12].

This technology provides capabilities to create more secure supply chains: chains with transparent and immutable audit trails of the product lifecycle in real-time. Theoretically, a given network can exist on a global scale, spanning countries, stakeholders and industries, and establish a trusted information flow with specific agreements on data exchange. This means that traceability information regarding product origin, composition, storage and transportation can be established and shared through a collaborative blockchain network between farmers, manufacturers and distributors.



As one supply chain management executive advised: "On the visibility side, blockchain ERP (enterprise resource planning) systems could enable everyone involved to track the product's journey from the manufacturing floor to the retailer's shelf, without having to worry about records being lost or tampered with… Nowhere is this more prevalent than in the

food and drink space, where blockchain will provide transparency and product provenance that is validated from farm to fork" [13].

How It Looks in Practice

As applications of blockchain technology have diversified, research efforts have turned to applying it across agriculture traceability systems and literature reviews consolidate many of these efforts [5]. Feng (2016) put forward a system based on RFID sensors and blockchain technology to guarantee food safety and quality throughout the entire Chinese agriculture supply chain [14]. The proposition aims to apply blockchain across data collection and information management for every transaction between all stakeholders in the supply chain, promoting accessible monitoring, tracking and tracing for any given product. Kim and Laskowski (2016) proposed the use of smart contracts on Ethereum to define crucial components in the product lifecycle as different traceable categories [15]. Kumar and Iyengar (2017) offered a rice supply chain system that uses blockchain technology to assure the safety of rice during its flow through the supply chain [16], whilst frameworks to improve tuna traceability to stop illegal and unsustainable fishing practices have also been suggested [17].

Blockchain application to agricultural traceability is a burgeoning area of research. Put simply, solutions propose that at each stage of the product lifecycle, from harvest to factory to delivery, data is collected and packaged into a block. With validation by the network, each block could be chained to the former, establishing an immutable ledger of the process. For example, a blockchain network that traces tuna would contain a chain showing where a tuna was caught, its weight and breed, in what factory it was processed, additional ingredients, how many air miles it has been transported…revealing all of the information right up to the point you buy the tuna steak from your local supermarket.

But what about practical application in the real world?

In China, foodborne contamination and illness is at the forefront of public attention. Milk formula killed six infants and sickened 294,000 in 2008 when it was found to contain melamine, a compound used in plastics and resins [18]. A survey on the general population in 2010 found that food safety was considered the second greatest risk faced in daily life (after earthquakes), whilst 92% of respondents said they expected to become a victim of food poisoning at some point [19]. And, though there is no robust finding that SARS-CoV-2 was a foodborne virus, the pandemic brought to light serious questions about food origins and the responsibility of suppliers to ensure safety [20]. Solutions to rectify distrust of the industry were needed, so Alibaba stepped in.

China's e-commerce giant introduced a blockchain solution on Tmall Global (Alibaba's international marketplace) to track food products through their lifecycle, then made this information available to consumers [21]. By simply scanning a QR code, customers can use Alibaba's mobile app to access the following information on a product [22]:

- The location of the product and its temperature during the entire delivery process;
- The producer's name;
- Photos of the government permits and stamps certifying the distributors;
- Food certificates and standards; and
- Pesticides and chemicals used on crops

The solution tracks a diverse product suite including meat, seafood, rice, tofu, soy, fruits and vegetables, poultry, eggs, dairy, cooking oils and supplements. However, each product has a unique code, so information is bespoke.

The system works towards transparency by integrating the efforts of farmers, manufacturers, distributors, transportation bodies and consumers on a single chain. It builds the trust of consumers, smooths return processes, enables simpler localisation of products that need to be replaced and eases the cost of product recall. Additionally, the initiative has highlighted the possibility for small businesses to differentiate their products from lower quality copycats on the market, protecting against counterfeit and fraud. PwC revealed that food fraud costs US$40 billion globally, affecting brand reputation and consumer confidence [23]. One in three organisations are victims of fraud; a prime example being the Parmigiano Reggiano Consortium (PRC), which oversees production of parmesan but has been fighting off cheap imitations and copycats for decades [24]. Alibaba's solution makes a stand against such malpractice by creating a ledger of legitimacy.

To make blockchain effective, multiple businesses must be involved, and Alibaba recognised this. It set up the Food Trust Framework, a consortium whose members want to track food produced in China and guarantee international imports from Australia and New Zealand. Australia is the perfect candidate for collaboration, as several organisations are actively developing and deploying blockchain-based solutions for supply chain validation in agriculture. Examples include AgriDigital, which has been using blockchain for grain supply chain management [25], and AgUnity, which provides an app that permanently records all transactions by users and clients on an immutable ledger. AgUnity has provided member farmers with mobile phones and their AgUnity app supports even the most remote farmers establish efficient lines of trade. Similarly, Aglive is working to digitise the food supply chain, integrating Internet of Things (IoT) with blockchain to cover logistics from "paddock-to-plate". All three companies highlight key benefits. For farmers, the ability to bypass a paper-based

system is efficient and blockchain offers a route to legitimacy. For the end consumer, trust in the authenticity of products and a transparent understanding of lifecycle are achieved.

BeefLedger attempted to maintain, or even enhance, the reputation of Australian beef suppliers. In an industry exceeding US$13 billion per annum, risks of fraud and reputational damage are high and inferior meat can be passed off as Australian in other countries [26]. BeefLedger launched the BEEF Token to power the Blockchain and provide users with access to credentialed provenance data, sale history, consumer feedback insights and heightened food security. Unfortunately, the company fell into administration in 2022 (operating for just under six years) but was an example of how tokenisation might work in agriculture supply chains to protect against counterfeit and fraud.

Challenges Remain

Despite its potential benefits, the adoption of blockchain technology in agricultural supply chains faces several challenges. It will take time to implement and, as shown by the collapse of BeefLedger, the road to decentralisation is not easy.

Principally, to make blockchain most effective requires participation of businesses from all corners of the globe. Implementing solutions of scale will require upfront investment in technology and software, which will cost, and encouraging small-scale producers to adopt the right technology and develop the appropriate expertise presents a challenge.

Consortiums or fledgling ventures may be the start, but the long-term aim must be a new economic model that embraces decentralisation of data across every party in the supply chain. If one party takes over, the system will not work. Using blockchain in supply chains is about breaking existing monopolies and developing new ecosystems.

Consider, for example, Walmart's food-tracking blockchain [27]. To combat foodborne illness, reduce waste from the recall and disposal of associated but uncontaminated produce and protect against reputational damage, Walmart sought to track their supply chain. The business required suppliers of leafy greens to trace their products all the way back to the farm on Walmart’s blockchain - and to set up all systems by the end of 2019. Inherently, the requirement is focused on making food safer through the supply chain. However, risks for smaller stakeholders exist under this model. In

committing data to a *centralised* system (as here, on Walmart's own blockchain rather than a decentralised network), suppliers risk being locked in, required to share data about their business without appropriate compensation. Long-term, a central authority could analyse data and mould supply chains to their desire. Small businesses may find themselves pressured to reduce costs, increase quality, adapt their own production lines and accept the terms and conditions of the central authority. Ultimately, without true decentralisation, the system may simply further consolidate power in the market.

Society is adopting artificial intelligence (AI) at pace and the expansion of IoT is such that nearly every asset, environment, process and interaction will be fully programmable within a few decades [28]. Interoperability is essential for seamless integration with current supply chain logistics, and standardisation efforts and collaboration among industry players are necessary to address this challenge. Demonstrating the tangible benefits of blockchain in improving food safety is good, but a smooth transition to this state is crucial. If achieved, it will ensure future society is one of widespread access, engagement and value exchange. But it requires businesses today to collaborate and form large, dynamic and decentralised networks. Benefits will accrue to those businesses, and both the economy and society will prosper as value exchange becomes smoother, more transparent and more inclusive.

Lastly, ensuring the privacy and security of sensitive data on the blockchain will be a challenge. Early-stage networks will need to work to prevent unauthorised access and subsequent data breaches. Regulation will contribute to this, but frameworks need development to provide more certainty in appropriate innovation. Start-ups cannot be suddenly undermined by regulation or will be discouraged. Investment, scale, security and supervision are required to ensure trust in the new system.

Naturally, these considerations encourage further development. To realise blockchain's full potential, research efforts should focus on optimising blockchain protocols and infrastructure to support large-scale supply chain networks. Enhancing the scalability of blockchain solutions to accommodate the diverse needs of agricultural operations is critical for widespread adoption. In addition, as can be observed across DLT more generally, clear regulatory guidelines and standards for blockchain implementation are essential to protect consumer interests, build trust and safely promote innovation. Collaboration between government agencies, industry associations and technology providers is necessary to establish a conducive regulatory environment. Success in this area could also foster integration with existing technologies, such as IoT and AI, which may further enhance the effectiveness and value of supply chain validation solutions. Leveraging these synergies could enable

real-time monitoring, predictive analytics and automated decision-making, but are beyond the scope of this commentary.

Concluding Remarks

Blockchain technology holds immense promise for transforming the agriculture industry by enhancing transparency, traceability and efficiency in supply chain validation. While challenges remain, investment, innovation and experimentation are driving the adoption of blockchain, as observed in real-world ventures across China and Australia. A more transparent, resilient and consumer-centric agricultural ecosystem is necessary and blockchain is paving the way for this to exist. By addressing the challenges and seizing the opportunities presented by blockchain, stakeholders can unlock new possibilities for sustainable growth and competitiveness. Businesses that consider how raw material is sourced and publish a transparent lifecycle of their products will better meet the demands of customers, protect themselves against fraud and flourish.

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