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Application of Blockchain in Agri-Food Supply Chain

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Abstract:

Supply chain traceability is one of the most important problems faced by all organizations globally. Tracking any commodity is a tedious job and requires a lot of manual attention. The existing system uses a centralised database system to track a commodity. Blockchain is a decentralised, immutable ledger managed by a cluster of computers. The very nature of blockchain makes it suitable technology for traceability in a supply chain. Blockchain creates immutable records. Once a transaction is stored in the blockchain, it is impossible to tamper it illegally. This immutability of blockchain builds trust among the participants that conduct business in a lack of trust environment. Using consensus protocols, blockchain builds trust between the various participants. Blockchain provides traceability since immutable records are added in blockchain; it is easy to track the source of the product. This paper illustrates the Application of Blockchain in Agri-Food Supply Chain. It unfolds how blockchain technology can be integrated to an Agri Supply Chain and improves the traceability. This integration enables companies to quickly track unsafe products back to their source and see where else they have been distributed. This integration can result to prevent illness and save lives, as well as reduce the cost of product recalls.

Keywords:
Blockchain technology; digital agriculture; food supply chain; barriers; benefits; health challenges; tracking; traceability; supply chain

I. Introduction

The world is converging towards common needs and goals. But with this comes the importance of maintaining privacy, security, authenticity, quality and consistency of each entity and process. Blockchain technology is the new trust machine of the new world. Blockchain's capability of tracking ownership records and tamper-resistance can be used to solve urgent issues such as food fraud, safety recalls, supply chain inefficiency and food traceability in the current food system. In this report, we are going to take a closer look to address these concerns and how blockchain could make a positive impact on the agricultural food supply chain.

With 40% of the global workforce, agriculture sector presents 6.4% of the entire world's economic production and its total worldwide production is $5,084,800 million. If you have ever visited a farm, you would have seen that farmers have complicated ecosystems with seasonal financing structures, careful timing and a lot of moving parts.

After the food leaves the farm for the market, it becomes a part of the vast supply chain involving a lot of intermediaries. Everyone would like to know where the food has been produced before it is served on the plate.

What if you could check the quality of food before you eat it? It could become possible with the use-cases of blockchain in executing contracts and tracking information transparently.

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Blockchain agriculture is one of the compelling use cases that makes the process of growing and supplying food simpler. The agriculture supply chain can provide all involved parties with a single source of truth. Food traceability has been at the centre of recent food safety discussions, particularly with new advancements in blockchain applications. Due to the nature of perishable food, the food industry at whole is extremely vulnerable to making mistakes that would ultimately affect human lives. When foodborne diseases threaten public health, the first step to root-cause analysis is to track down the source of contamination and there is no tolerance for uncertainty.

Consequently, traceability is critical for the food supply chain. The current communication framework within the food ecosystem makes traceability a time-consuming task since some involved parties are still tracking information on paper. The structure of blockchain ensures that each player along the food value chain would generate and securely share data points to create an accountable and traceable system. Vast data points with labels that clarify ownership can be recorded promptly without any alteration. As a result, the record of a food item's journey, from farm to table, is available to monitor in real-time.

Figure 1. Simple Supply Chain

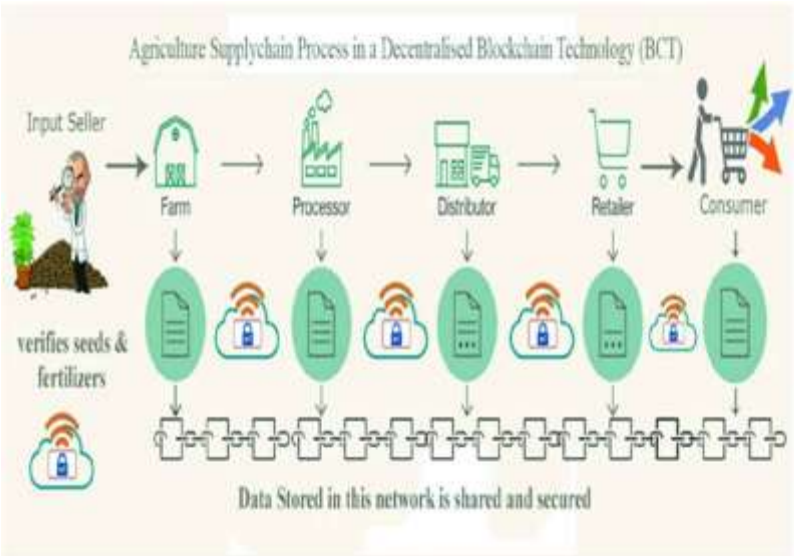

Figure 2. Blockchain integrated Agri Supply Chain

II. Review of Literatures

Food Supply Chain: The food chain worldwide is highly multi-actor based and distributed, with numerous different actors involved, such as farmers, shipping companies, wholesalers and retailers, distributors, and groceries. The main phases characterizing a generic agri-food supply chain are described below (Caro, Ali, et al. 2018):

1. Production: The production phase represents all agricultural activities implemented within the farm. The farmer uses raw and organic material (fertilizers, seeds, animal breeds and feeds) to grow crops and livestock. Throughout the year, depending on the cultivations and/or animal production cycle, we can have one or more harvest/yield.
2. Processing: This phase concerns the transformation, total or partial, of a primary product into one or more other secondary products. Subsequently a packaging phase is expected, where each package might be uniquely identified through a production batch code containing information such as the production day and the list of raw materials used.
3. Distribution: Once packaged and labelled, the product is released for the distribution phase. Depending on the product, delivery time might be set within a certain range and there might be a product storage step (Storage).
4. Retailing: At the end of the distribution, the products are delivered to retailers who perform the sale of the product (Retailers). The end-user of the chain will be the customer, who will purchase the product (Customer).
5. Consumption: The consumer is the end user of the chain, he buys the product and demands traceable information on quality standards, country origin, production methods, etc.

This current system is till date inefficient and unreliable (Tripoli and Schmid Huber 2018). Exchange of good are based on complex and paper-heavy settlement processes while these processes are not much transparent, with high risks between buyers and sellers during exchange of value. As transactions are vulnerable to fraud, intermediaries get involved, increasing the overall costs of the transfers (Lierow, Herzog and Oest 2017). It is estimated that the cost of operating supply chains makes up two thirds of the final cost of goods. Thus, there is much space for optimization of the supply chains, by effectively reducing the operating costs. Finally, when people buy products locally, they are not aware of the origins of these goods, or the environmental footprint of production.

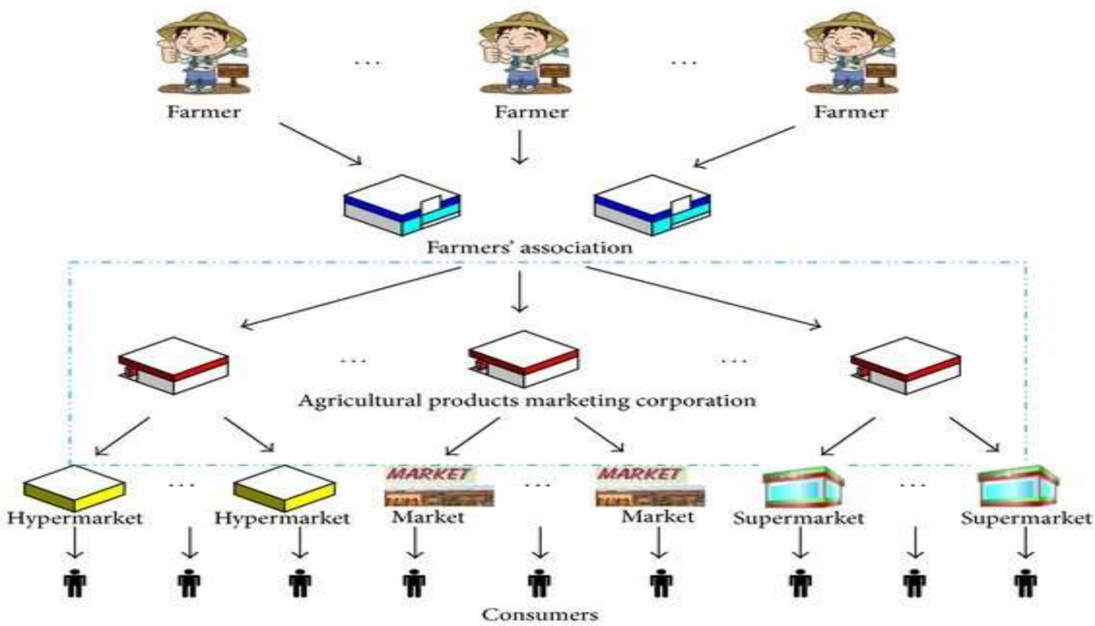

Figure 3. Agricultural Supply Chain

Blockchain in Agriculture and Food Supply Chain: While the blockchain technology gains success and proves its functionality in many cryptocurrencies, various organizations and other entities aim at harnessing its transparency and fault tolerance in order to solve problems in scenarios where numerous untrusted actors get involved in the distribution of some resource (Manski 2017), (Sharma 2017). Two important, highly relevant areas are agriculture and food supply chain (Dujak and Sajter 2019), (Tripoli and Schmid Huber 2018). Agriculture and food supply chains are well interlinked, since the products of agriculture almost always are used as inputs in some multi-actor distributed supply chain, where the consumer is usually the final client (Maslova 2017). There is evidence that blockchain applications started to become used in the supply chain management soon after the technology appeared (Tribis, El Bouchti and Bouayad 2018). Blockchain in supply chain management is expected to grow at an annual growth rate of 87% and increase from $45 million in 2018 to $3,314.6 million by 2023 (Chang, Iakovou and Shi 2019). As a successful example, in December 2016, the company Agri Digital executed the world's first settlement of the sale of 23.46 tons of grain on a blockchain (ICT4Ag 2017). Since then, over 1,300 users and more than 1.6 million tons of grain has been transacted over the cloud-based system, involving $360 million in grower payments. The success of Agri Digital served 6 as an inspiration for the potential use of this technology in the agricultural supply chain. Agri Digital is now aiming to build trusted and efficient agricultural supply chains by means of blockchain technology (Agri Digital 2017). As another recent 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 (Hoffman and Munsterman 2018). 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. Under the physical flow (top layer), there is the digital flow layer (middle layer), consisting of various digital technologies (i.e. QR codes, RFID, NFC, online certification and digital signatures, sensors and actuators, mobile phones etc.). The Internet/Web serves as the connecting infrastructure. Every action performed along the food chain, empowered by the use of the aforementioned digital technologies, is recorded to the blockchain, which serves as the immutable means to store information that is accepted by all participating parties. The information captured during each transaction is validated by the business partners of the food supply network, forming a consensus between all participants. After each block becomes validated, it is added to the chain of transactions, becoming a permanent record of the entire process. At every stage of the trajectory of food, different technologies are involved and different information is written to the blockchain, as described below for each of these stages:

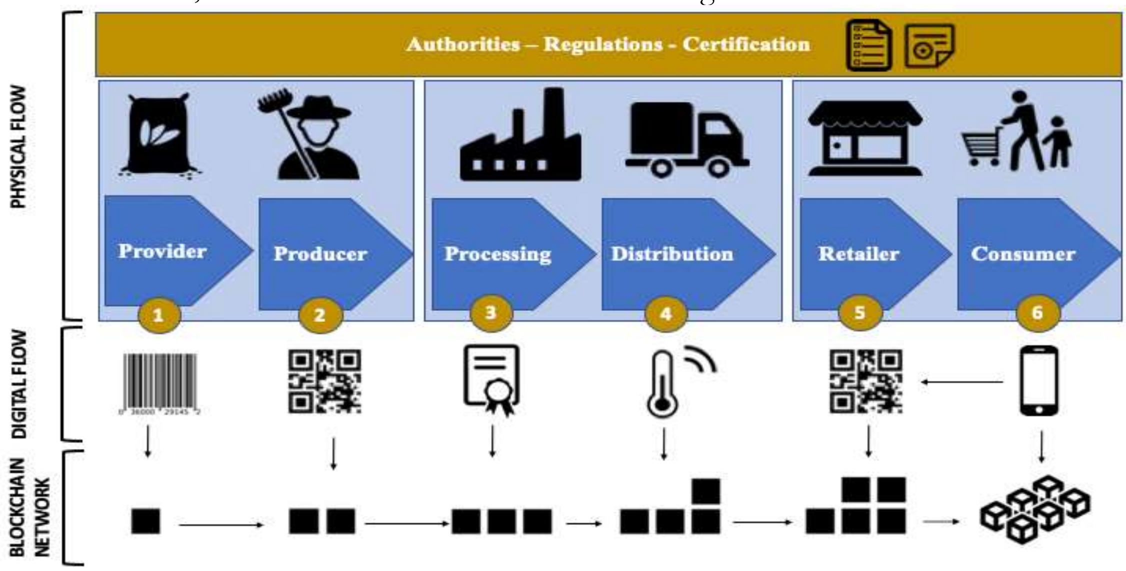

Figure 4. Blockchain integrated Agri Supply Chain

1. Provider: Information about the crops, pesticide and fertilizers used, machinery involved etc. The transactions with the producer/farmer are recorded.
2. Producer: Information about the farm and the farming practices employed. Additional info about the crop cultivation process, weather conditions, or animals and their welfare is also possible to be added.
3. Processing: Information about the factory and its equipment, the processing methods used, batch numbers etc. The financial transactions that take place with the producers and also with the distributors are recorded too.
4. Distribution: Shipping details, trajectories followed, storage conditions (e.g. temperature, humidity), time in transit at every transport method etc. All transactions 7 between the distributors and also with the final recipients (i.e. retailers) are written on the blockchain.
5. Retailer: Detailed information about each food item, its current quality and quantity, expiration dates, storage conditions and time spent on the shelf are listed on the chain.
6. Consumer: At the final stage, the consumer can use a mobile phone connected to the Internet/Web or a web application in order to scan a QR code associated with some food item, and see in detail all information associated with the product, from the producer and provider till the retail store.

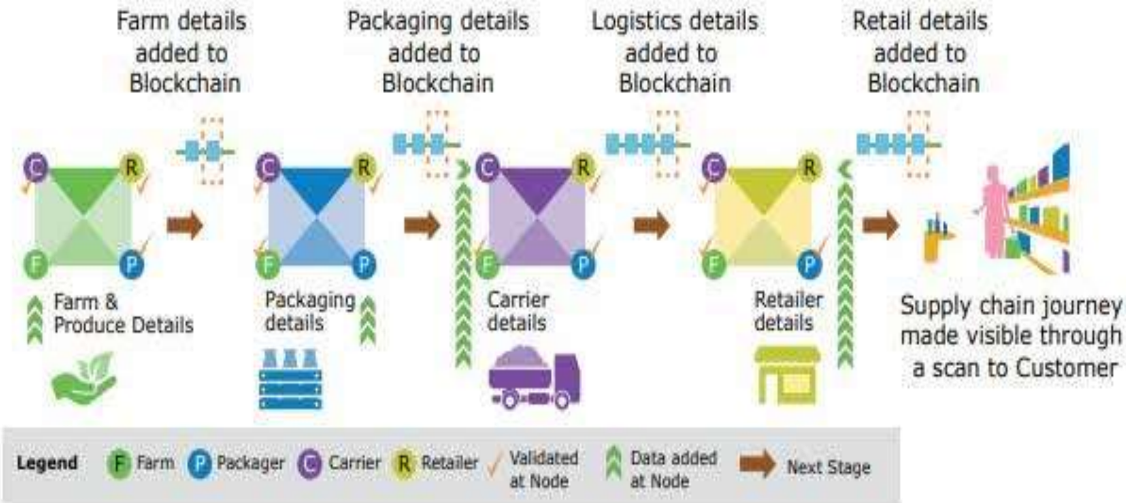

Figure 5. Blockchain Integrated Food Supply Chain

Food Safety: Food safety is the condition of processing, managing and storing food in hygienic ways, in order to prevent illnesses from occurring to human population. Food safety and quality assurance have become increasingly difficult in times of growing global flows of goods (Creydt en Fischer 2019). The Centre for Disease Control and Prevention (CDC) claims that contamination because of food causes 48M Americans to become ill and 3,000 to die every year (CDC 2018), (Tripoli and Schmidhuber 2018). In 2016, Oceana performed a research on seafood fraud, showing that 20% of seafood is labelled incorrectly (Oceana 2013). Lee et al. commented that food supply chains are characterized by reduced trust, long shipment distances, high complexity, and large processing times (Lee, et al. 2017). Blockchain could provide an efficient solution in the urgent need for an improved traceability of food regarding its safety and transparency. As Figure 2 shows, recording information about food products at every stage of the supply chain allows to ensure good hygienic conditions, identifying contaminated products, frauds and risks as early as possible. Walmart and Kroger are among the first companies to embrace blockchain and include the technology into their supply chains (CB Insights 2017), working initially on case studies that focus on Chinese pork and Mexican mangoes (Kamath 2018). Early results from the studies showed that, when tracking a package of mangoes from the supermarket to the farm where they were grown, it took 6.5 days to identify the origin and the path the fruit followed with traditional methods, whereas with blockchain this information was available in just a few seconds (Wass 2017). 9 The integration of blockchain with Internet of Things (IoT) for real-time monitoring of physical data and tracing based on the hazard analysis and critical control points system (HACCP) has recently been proposed (Tian 2017). This is particularly critical for the maintenance of the coldchain in the distribution logistics of spoilable food products. As an example, ZetoChain performs environmental monitoring at every link of the cold chain, based on IoT devices (Zeto 2018). Problems are identified in real-time and the parties involved are notified immediately for fast action taking. Smart contracts are harnessed to increase the safety of sales and deliveries of goods. Mobile apps can be used by consumers to scan Zeto labels on products in order to locate the product's history.

Food Integrity: Food integrity is about reliable exchange of food in the supply chain. Each actor should deliver complete details about the origin of the goods. This issue is of great concern in China, where the extremely fast growth has created serious transparency problems (Tian 2017), (Tse, et al. 2017). Food safety and integrity can be enhanced through higher traceability (Galvez, Mejuto and Simal-Gandara 2018), (Creydt en Fischer 2019). By means of blockchain, food companies can mitigate food fraud by quickly identifying and linking outbreaks back to their specific sources (Levitt 2016). Recent research has predicted that the food traceability market will be worth $14 billion by 2019 (MarketsandMarkets Research 2016). There are numerous examples of companies, start-ups and initiatives aiming to improve food supply chain integrity through the blockchain technology. The most important on-going projects are listed below, based on their scale, their potential impact and the significance of the partners, organizations and/or actors involved. The agricultural conglomerate Cargill Inc. aims to harness blockchain to let shoppers trace their turkeys from the store to the farm that raised them (Bunge 2017). Turkeys and animal welfare are considered at a recent pilot involving blockchain (Hendrix Genetics 2018). The European grocer Carrefour is using blockchain to verify standards and trace food origins in various categories, covering meat, fish, fruits, vegetables and dairy products (Carrefour 2018). Downstream beer (Ireland Craft Beers 2017) 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 10 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. Concerning meat production, "Paddock to plate" is a research project aiming to track beef along the chain of production-consumption, increasing the reputation of Australia for high quality (Campbell 2017). The project uses Beef Ledger as its technology platform (Beef Ledger Limited 2017). As another example, the e-commerce platform JD.com monitors the beef produced in inner Mongolia, distributed to different provinces of China (JD.com Blog 2018). By scanning QR codes, one can see details about the animals involved, their nutrition, slaughtering and meat packaging dates, as well as the results of food safety tests. To guarantee to customers that its chickens are actually free-range, the Gog chicken company uses an ankle bracelet to monitor the chickens' movements and behaviour via GPS tracking, and this information is then available through the web (Adele Peter, Fast Company 2017). The aim of the company is to build trust by documenting the origins of the food. Right now, 100,000 birds have been outfitted with GPS bracelets, but the Shanghai-based company plans to incorporate about 23 million birds into project over the next three years. The Grass Roots Farmers' Cooperative (Grass Roots Farmers' Cooperative 2017) sells a meat subscription box, which uses blockchain technology to inform consumers in a reliable way about the raising conditions of their animals. In the pilot performed, cases of chicken distributed in San Francisco are labelled with QR codes that link to the story of the meat they contain. 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 fish location and storing conditions. Hyperledger is one of the most important initiatives, based on completeness and quality of services and tools, as well as the size of the supporting community and the significance of the members that support the overall project. Hyperledger aims to offer complete solutions towards the business use of the blockchain, and it has been proposed in recent research efforts such as AgriBlockIoT (Caro, Ali, et al. 2018). Hyperledger focuses to the creation of open source frameworks based on the DLT, suitable for enterprise solutions. Two of the most mature Hyperledger frameworks are named Fabric (for permissioned blockchain networks) and Sawtooth (for both permissioned and permission less blockchain networks). These two frameworks constitute generic enterprise-grade software, offering support for various smart contract languages and they are used by a wide community of 11 companies, developers and users. In particular, Hyperledger Fabric is backed by IBM. While Hyperledger Fabric is the most well-known and widespread, Sawtooth is the most advanced and heavy-duty, allowing adequate integration with other blockchain frameworks (Suprunov 2018). 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. Traceability of tuna is also the focus of Balfegὀ (Balfegὀ Group 2017). Furthermore, ripe.io has created the Blockchain of Food (Ripe.io 2017), 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 (AgFunder News 2018). Via the services provided by the Origin Trail company, consumers can see from which orchard the ingredients they cook have grown, the origin and growing conditions of poultry etc. (Origin Trail 2018). Also, the project "blockchain for agri-food" developed a proof-of-concept blockchain-based application about table grapes from South Africa (Ge, et al. 2017). A framework for greenhouse farming with enhanced security, based on blockchain technology, is proposed in (Patil, et al. 2017). Nestle has recently entered the IBM Food Trust partnership towards food traceability (ITUNews 2018), with a pilot based on canned pumpkin and mango. Some research initiatives proposed the combination of blockchain with other technologies (i.e. IoT, RFID, NFC), in order to increase food traceability. A system based on combining RFID and blockchain technologies is discussed in (Tian 2016) while a system based on IoT devices and smart contracts is proposed in (Kim, et al. 2018). Boehm et al. proposed an updated traceability system using blockchain technology combined with Near Field Communication (NFC) and verified users (Boehm, Kim and Hong 2017). Finally, the blockchain technology is also being assessed to trace the production of non-edible crops that are also very sensitive to integrity issues because of regulation and legal aspects. Figorilli et al. (2018) experiment with an implementation of blockchain for the electronic traceability of wood from standing tree to final user, based on RFID sensors and open source technology (Figorilli, et al. 2018). Canada is currently developing a permissioned blockchain 12 network for the tracking of the cannabis supply chain (Abelseth 2018). By tracking the cannabis chain, Health Canada aims to enforce regulations more easily.

III. Research Methods

Overview of Blockchain: The most muted definition of Blockchain is that is a distributed, decentralized, public ledger. Contrary to initial understanding, blockchain is not a programming language or a cryptographic codification and is not restricted to cryptocurrency applications, although that is what brought this multi-faceted concept into limelight. It is a technology that can virtually record everything of value. It works as an immutable record of transactions that do not rely on an external authority to validate the genuineness of data. Although it is considered to be a new technology, it is interesting to note that its origins can be traced back to a 1991 dated publication called "How to Time-Stamp a Digital Document". The name of the document best explains the multiple benefits this technology holds.

Working of Blockchain: At the base level, blockchain is a chain of blocks where block represents digital information and the storage area (the public database) represents the chain. Each block is made of digital pieces of information. The process deals with 5 key concepts that include:

- Cryptographic Hash
- Immutable Ledger
- P2P Network
- Consensus Protocol
- Block Validation or 'Mining'

While we have elaborated the components involved in the blockchain process flow, the below flow table will explain the process. It is also the assumption of the paper that the reader has a basic understanding of how blockchain works. The report concentrates on the applications of blockchain in the supply chain sector.

Table 1. Blockchain Sequence of Operations

Step No.	Blockchain Operation
1	A transaction is registered by someone
2	Transaction is registered in the shared ledger
3	Block is broadcasted to all participants
4	Participants approve the valid transaction
5	Post consensus, block is added to chain
6	Actual state of blocks can be seen by all authorized participant
7	Chain is displayed to all peers in single picture

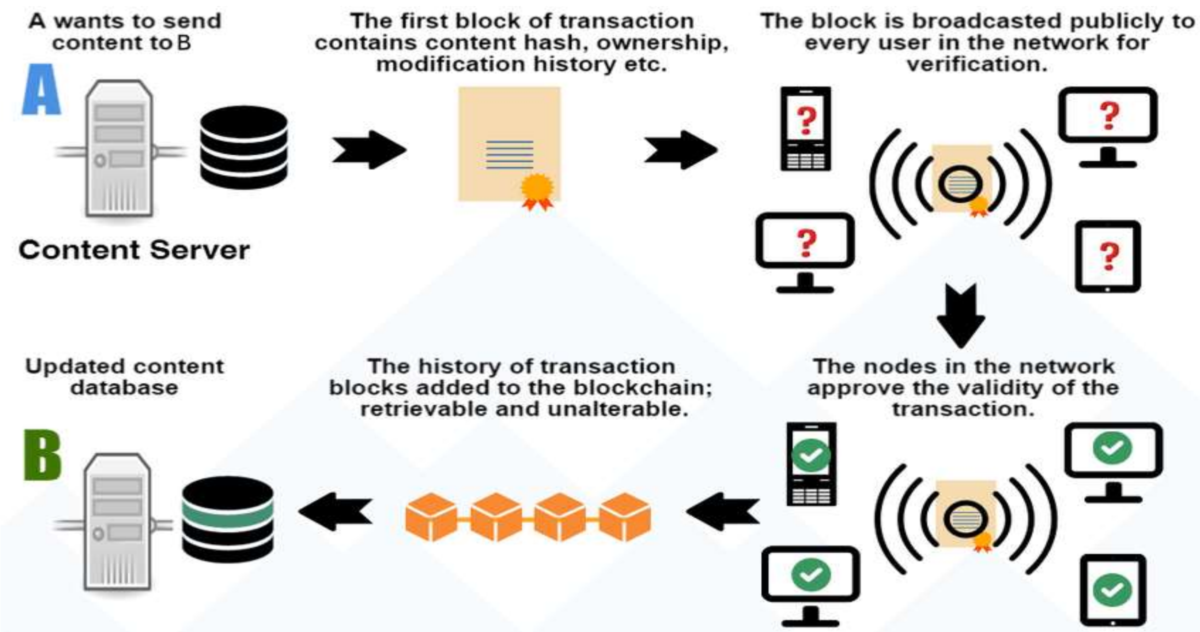

Figure 6. Blockchain working principle

3.1 Benefits

1. Enhanced Transparency:

Documenting a product's journey across the supply chain reveals its true origin and touchpoints, which increases trust and helps eliminate the bias found in today's opaque supply chains. Manufacturers can also reduce recalls by sharing logs with OEMs and regulators.

2. Greater Scalability:

Virtually any number of participants, accessing from any number of touchpoints, is possible.

3. Better Security:

A shared, indelible ledger with codified rules could potentially eliminate the audits required by internal systems and processes.

4. Increased Innovation:

Opportunities abound to create new, specialized uses for the technology as a result of the decentralized architecture.

5. Improved Quality Control:

It can help to remove ineffective processes and ensure optimal quality control conditions. For instance, crop failure is a prevalent issue faced by farmers around the globe. It usually happens because of unfavorable climatic conditions, such as poorly distributed rainfall and erratic weather. To solve this, companies like IBM are already investing millions into precision agriculture, creating IoT devices that allow farmers to monitor factors such as the soil quality, pests, and irrigation that could affect their crops.

6. Increased Traceability in the Supply Chain:

There is a dramatic rise in consumer expectations for food standards. Most notably, more and more consumers want to know where their food comes from. Using blockchain technology will solve this problem by letting consumers know exactly where their food originated, who planted it, and how fresh it is. It will only require workers to scan the product at each stage in the process to update the database with information.

7. Increased Efficiency for Farmers:

Blockchain technology would allow farmers to store all of their data in one place so that it can easily be accessed by those who need it, simplifying the entire process and saving valuable time and energy.

8. Fairer Payment for Farmers:

Blockchain based smart contracts work by triggering payments automatically as soon as a specific, previously-specified condition has been fulfilled by the buyer—and without charging extortionate transaction fees. It means that the farmer could theoretically receive payment for their goods as soon as they have been delivered, without a significant portion of their income being taken away from them in the process.

3.2 Limitations

1. SME have difficulties & lack of expertise in adopting the technology.
2. Information infrastructure might prevent access to markets for new users.
3. High uncertainties and market volatility.
4. Limited education and training platforms.
5. No regulations in place.

6. Lack of understanding among policy makers and technical experts.
7. Open technical questions and scalability issues (e.g. latency of transactions)
8. Digital divide among developed and developing world.
9. Decline of cryptocurrencies in market share and high volatility (reputation issues)
10. Cost of computing/IoT equipment required.
11. Design decisions might reduce overall flexibility.
12. Privacy issues.
13. Some quality parameters of food products cannot be monitored by objective analytical methods, especially environmental indicators.

IV. Discussion

4.1 Case Study 1: Tuna Tracking and Certification (Provenance)

a. Overview

Provenance system aims to enhance the transparency of information among the supply chain peers, by guaranteeing that certification and standards are met by all the actors of the supply chain. The system is composed of six modular programs: registering, standards, production, manufacturing, tagging, and user-facing. These six modular programs are independently compiled but registered on the same blockchain, creating a co-existence environment within the same system. Blockchain is used to record the transactions by storing the data in a public and shared ledger allowing the chain to be auditable. Moreover, it allows the activation of smart contracts that facilitate the operation of the user within the chain also for monetary or information exchange.

b. Introduction

Provenance, in collaboration with the NGO Humanity United and International Pole and Line Foundation (IPNLF), conducted a 6 months project in Indonesia, to track-and-trace yellowtail tuna. The project aimed to use a mobile application together with blockchain technology and smart tagging to track-and-trace the origin and the authenticity of the social sustainability certification. The goal was to create a solid proof of compliance via a solution applicable throughout the supply chain.

c. Problem Statement

Human rights abuses, overfishing, fraud, illegal, unreported, and unregulated (IUU) fish: a number of practices in the seafood industry are compromising the wellbeing of environments, wildlife and people all over the world. According to The Guardian, "slaves forced to work for no pay for years at a time under threat of extreme violence are being used in Asia in the production of seafood sold by major US, British and European retailers."

In Indonesia, more than 60 million people live within coastal communities and tuna fisheries are a major source of employment and foreign exchange. Particularly in the North of Indonesia, however, tuna fishing is complicated by Philippine tuna fishing vessels, with most of the fish catches by Philippine purse seiners unrecorded.

d. Solution

The whole system implemented data interoperability to track-and-trace items and certification in a secure, continuous, accessible system (Provenance, 2016). For tracking smart tags across the supply chain, a point of sale (POS) was introduced. To register the fish, the fishermen needed to send an SMS, with this SMS a new asset is created in the chain with a permanent and unique ID. The unique ID is physically attached to the fish caught using a QR Code, RFID tag, or other technologies. Afterward, the digital asset moves to the supplier along with the catch, and a digital transaction is registered on the blockchain. The identity of the fishermen is saved as well. Tracking and tracing can be verified by exploring the blockchain with public software libraries.

Figure 7. Pole and line fishermen in Ambon, Maluku equipped with cellular and smart phones illustrate an opportunity to digitise information right where fish is caught

In this case, blockchain was used for sharing information across all stakeholders of the chain, including fishermen, factories, certifier, and consumers. Blockchain was used both for the identification of both physical goods and validating certification. System integration with existing large-scale enterprise resource planning (ERP) was one of the challenges, as most of them do not follow the product throughout the whole supply chain. The unique ID in the form of an address on the blockchain was registered at the beginning of the chain, and propagated across the chain, allowing for matching data across data silos. Having data stored on the blockchain, also enabled it to operate as backend layer on the top of the existing ERP systems, and was used as an audit tool. The backend functionality of the blockchain allowed data to be shared and collected from the first mile with an end-to-end record system. Also using smart sticker and smart packing, the end consumer can use their smartphones to track the provenance of their tuna.

Figure 8. NFC-enabled smart stickers carry the Provenance mark along with item or batch IDs.

Figure 9. Touching a smartphone over the stickers shows the product's journey from sea to supermarket.

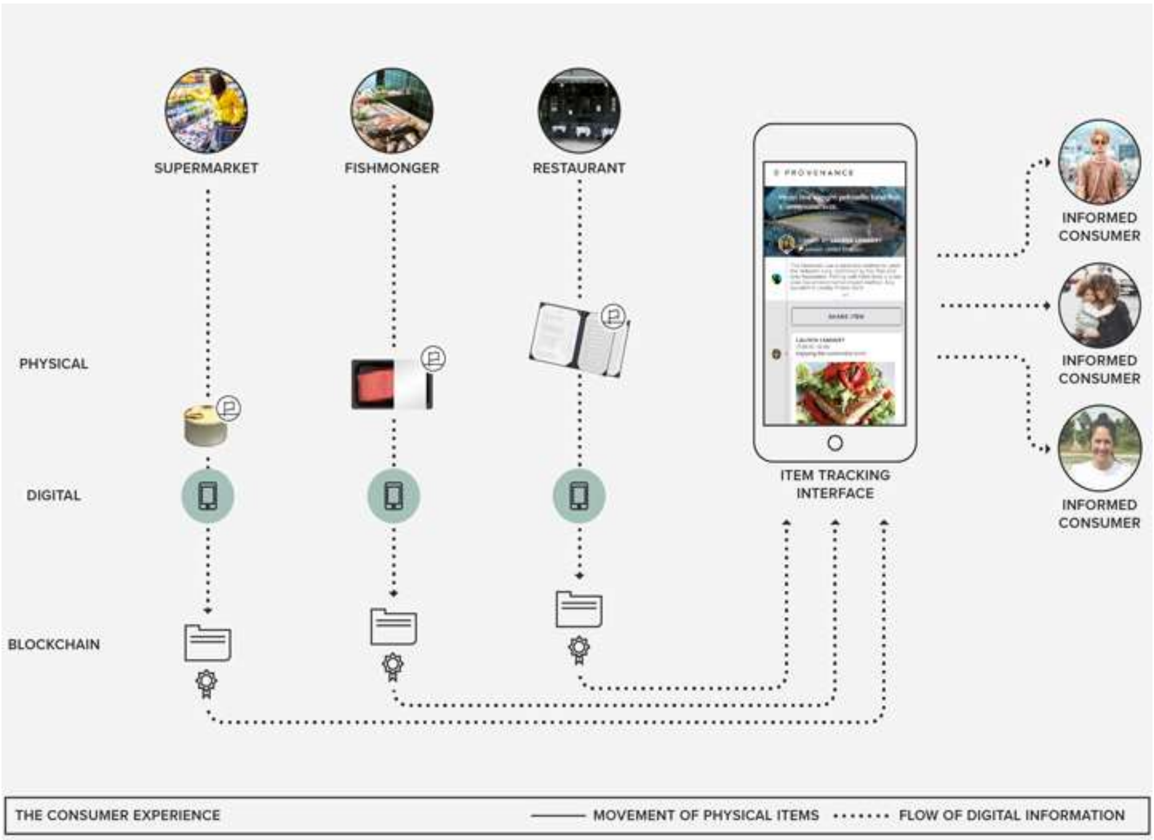

Figure 10. Blockchain providing the base layer of truth across the supply chain.

e. Result

By design, the blockchain enforces the transparency, security, authenticity, and auditability necessary to make tracing the chain of custody and attributes of products possible, which in turn allows customers to derive the high-quality information needed to make more informed choices. Implementing supply-chain transparency on the blockchain dramatically reduces the high initial cost/benefit ratio for participants, and its naturally distributed design frees a central organization from costly and error-prone operational duties. In the system we have described, the role of the anchoring core organization has been reduced to providing registration and linkage between "blockchain" and "real-world" identities.

4.2 Case Study 2: Trust to Build Transparency (IBM Food Trust)

a. Overview

Food from across the world is available to consumers today, regardless of the season, location, or environment. However, the greater options and accessibility are accompanied by increasing complexity in the food supply chain. With growing data and lengthening ecosystems within the industry, the importance of trust weighs heavier than ever before. From the farmer, processor, retailer, to the consumer, IBM Food Trust uses trust to build transparency. The blockchain solution is working to ensure that transparency enables the expanding food system. With capabilities to enable safer food, longer product shelf lives, reduced waste, faster traceability, and better access to shared information, IBM Food Trust empowers you to meet the new standard for transparency and trust. The solution provides authorized users with immediate access to actionable food supply chain data - from farm to store and ultimately the consumer. The complete history and current location of any food item along with its accompanying information (i.e. certifications, test data, temperature data) can be readily available in seconds.

Figure 11. Overview of IBM Food Trust

b. Introduction

IBM Food Trust combines supply chain modules with blockchain core functions, delivering business value to the food ecosystem from the combination of governance, standards and interoperability, and technology. In doing so, transaction partners can only access the data they are permissioned to view. Permissioned data access is an integral part of the core solution. Access controls ensure that the organization that owns the data maintains full control over who can access it on the network. All data is stored on blockchain ledgers, protected with the highest level of commercially-available, tamper resistant encryption.

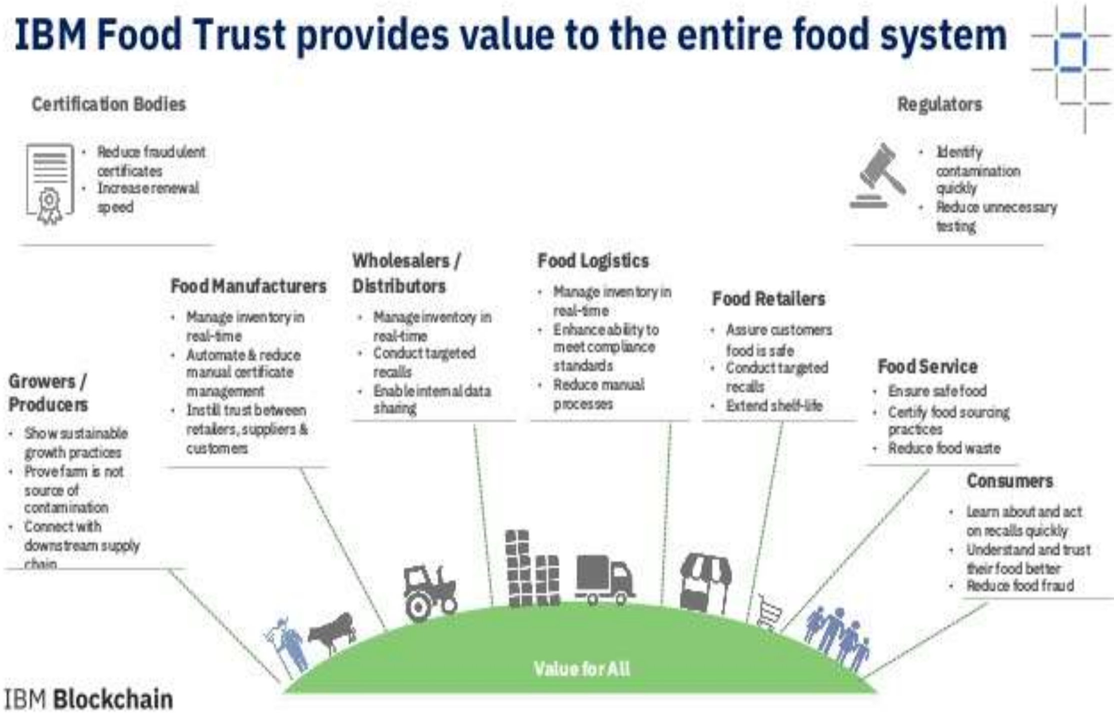

Figure 12. IBM Food Trust Value Chain

c. Problem Statement

Cases of food contamination, counterfeits and requests from consumers for more information on the origin of food are increasing the demand for solutions, both system and global, which can show all actors in the supply chain how to certify traceability and the processing of the processed, distributed and sold product. Food safety passes through platforms capable of guaranteeing transparency, traceability throughout the Agri-food chain, and which know how to give confidence to the consumer who is attentive to Made in Italy and sustainability. They must be able to check and identify fraud and avoid counterfeiting with greater ease.

d. Solution

Food Trust solution users can quickly locate items from the supply chain, in real time, by querying food product identifiers such as Global Trade Item Number (GTIN) or Universal Product Code (UPC), using the product name, and filtering on dates. It integrates set of modules addressing to various pain points and needs in the food industry. Module-based approach:

1. Trace Provide the provenance of your product through immediate access to end-to-end data. Trace also shows real-time location and status, and allow expedited product recalls.
2. Fresh Insights Connect disparate product data to draw insights and gain visibility into inventory across the supply chain, compare metrics across location, view dwell time and time since production/to expiration, and calculate at-risk inventory. You can identify inefficiencies, improve freshness, and reduce product losses.
3. Certifications Digitize business critical certificates and inspection documents to optimize efficiency for information management, certify provenance, and ensure authenticity.
4. Data entry and access Leveraging solution and global standards to share data with any network participant authorized by the data owner, you can feel confident knowing your data is shared only with need-to-know business partners in a secure and confidential environment.

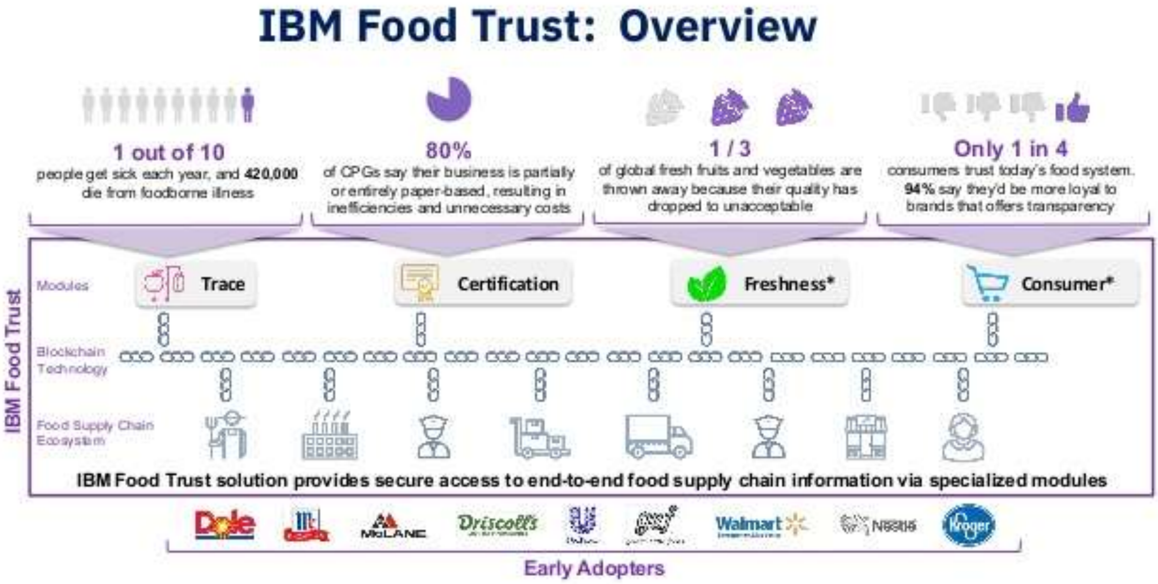

Figure 13. IBM Food Trust Solution

e. Result

IBM Food Trust designates a collaborative network that connects growers, processors, wholesalers, distributors, producers, retailers and other actors in the food industry and which, thanks to the exchange of information in safety along the entire supply chain, strengthens visibility, builds trust, provides transparency and guarantees the reliability of the entire production and commercial ecosystem, assigning a renewed value to the relationship between brands, territories and the final consumer.

Based on IBM's Blockchain technology, this solution connects participants to the network through a reliable, authorized, immutable and shared record of data concerning the origin of a food product, transaction and location data, processing details and more. A Blockchain solution does not only concern technology, but solves business problems that were previously insoluble due to the difficulties of ecosystems, the food one in this case, to share information in a transparent, unchangeable and reliable way.

V. Conclusion

This report demonstrates that blockchain technology is already being used by many projects and initiatives, aiming to establish a proven and trusted environment to build a transparent and more sustainable food production and distribution, integrating key stakeholders into the supply chain. Yet, there are still many issues and challenges that need to be solved, beyond those at technical level. To reduce barriers of use, governments must lead by example and foster the digitalization of the public administration. They should also invest more in research and innovation, as well as in education and training, in order to produce and demonstrate evidence for the potential benefits of this technology.

The blockchain is still a very recent technology, so there's a long way to go before its full set of applications can be developed and put into practice. However, it's becoming increasingly clear that there are opportunities in the agriculture industry. The global agriculture industry is now worth over 2.4 trillion dollars and has over one billion people involved worldwide. Now, more than ever, there is an opportunity for innovation.

Summing up, blockchain is a promising technology towards a transparent supply chain of food, but many barriers and challenges still exist, which hinder its wider popularity among farmers and food supply systems. The near future will show if and how these challenges could be addressed by governmental and private efforts, in order to establish blockchain technology as 27 a secure, reliable and transparent way to ensure food safety and integrity. It is very interest to see how blockchain will be combined with other emerging technologies (big data, robotics, IoT, RFID, NFC, hyperspectral imaging etc.), towards higher automation of the food supply processes, enhanced with full transparency and traceability.

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