Blockchain Optimizes the Food Industry

Implementation of Blockchain into the Food Industry would enhance the transparency, traceability, and reduce costs

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Abstract

Nowadays food contamination scandals and the effects of viruses on fruits, vegetables, and animals lead to severe erosion of consumer trust, which is caused by lacking transparency and traceability. This paper used secondary and qualitative data pulled from literatures, white papers, and case studies to mention some examples of food contamination scandals and how firms applied blockchain in resolving and avoiding them in the future. In response to those issues, blockchain technology would become a feasible solution by improving transparency and traceability in the food industry. This research highlights the opportunities for implementing blockchain in this field to enhance food safety and reduce waste, as well as the challenges of this technology in the deploying process.

Keywords: *Blockchain, food safety, food fraud, cost reduction, transparency, traceability, supply chain*

Introduction

It has been years that the consumers did not have access to food quality information or the state of outbreaks and frauds. "As consumers rarely saw any news on food frauds and outbreaks in the media, they had the (false) assumption that lack of information means everything is OK", Ven stated (2019). This was the internal matter of food companies and food safety authorities. However, in recent years, the development of better-quality inspection methods and technologies reveal more contamination cases than earlier, especially in many developing countries like Vietnam, African and so forth. Consumers start losing trust in the products they are consuming and doubting the information which is displayed on the food labels. This has put growing pressure on food firms in particular and the food industry in general. Consumers nowadays are very smart and careful in choosing the food they consume. For example, they wonder if it is organic or non-GMO, originates from a certain country, even whether it is processed in compliance with HACCP guidelines, according to TE-Food International. Food companies now have to meet the consumers' requirements since food quality and freshness perception currently drive product value for end customers. Therefore, they must figure out a way to not only meet the demand quantity but also increase customers' satisfaction without wasting food.

To address these issues, new technologies have been invented to help companies prove that their products' information is true as well as to help consumers have wise choices. This means food traceability and control is needed; for instance, it will protect companies and customers against adulterated food, or reduce the scale and effect of epidemics and food frauds in emerging countries. Health and sustainability-cognizant customers need high-value food and its provenance. Blockchain is one of the viable solutions because its capabilities provide product data aggregation and disaggregation, an association of labeling data with blockchain, end to end permissiioned visibility, or even information retrieval in simpler and real-time manner (Phadke and Parwekar, 2019). Additionally, blockchain technology enables access to food provenance and information as a common property for all consumers (TE-Food, p. 6). In other words, it would reduce food waste since the provenance and its condition is clear and classified at each stage. This paper will point out the benefits when applying blockchain into the food industry such as increasing food safety and protection, anti-counterfeiting solutions by enhancing traceability and transparency, and food waste reduction.

In order to fulfil the aim of this paper, there are three research questions conducted. These questions are linked to each other for an unambiguous explanation for implementation of blockchain in the food industry. The first question points out the issues/reasons leading to the erosion in consumer trust and food waste. The second question is the solution to those problems mentioned in the first question while the last question explains some roadblocks/challenges when executing blockchain technology to tackle those mentioned subjects.

Research Question 1: *What issues/scandals are going along with the food industry?*

Research Question 2: *How could blockchain be applied in the food supply chain to solve those issues as well as improve traceability and transparency?*

Research Question 3: *What are the challenges and possibilities with an implementation of blockchain for food industry?*

Research Design

This research used secondary data and qualitative approaches such as works of literature, case studies, and white papers to prove the crucial role of blockchain in the food industry. Since there are many companies have created blockchain platform for this field such as IBM and Accenture, which have implemented this technology into various cases, the process and results in the use cases were gathered in order to demonstrate the vital role of blockchain. On the other hand, in order to see the changes in the result when implementing blockchain to the food industry, some scandals, issues and the "healing process" in this field will be pointed out as well.

Table 1. Case Studies Used

Title	Author	Year	Address Research Question
Blockchain Demystified End-to-end food traceability and control solution	Amit Phadke, Aniruddha Parwekar	2019	Research question 2 & 3
A Case Study for Grain Quality Assurance Tracking based on a Blockchain Business Network	Percival Lucena, Alecio P. D. Binotto, Fernanda da Silva Momo, Henry Kim	2018	Research question 1 & 2
Blockchain use cases for food traceability and control	Published by Kairos Future	2017	Research question 1 & 2
Food Traceability on Blockchain: Walmart's Pork and Mango Pilots with IBM	Reshma Kamath	2018	Research question 1 & 2
Tracing the Supply Chain	Christine Leong, Tal Viskin, Robyn Stewart	2018	Research question 1 & 2

Analysis

This section performs an analysis of the sources identified in the Research Design Section. Qualitative analysis was done by picking out common themes following issues within the food industry, implementation of blockchain in addressing those problems, and some roadblocks along with this technology application.

1. Social Problems and Scandals in the Food and Agriculture Industry

1.1. Outbreak of Salmonella Infections

According to the U.S Food and Drug Administration, CDC, numerous states and local officials reported that Salmonella illnesses from a variety of serotypes linked to papayas from Mexico, which caused 173 cases of salmonellosis, 58 hospitalizations, and one death across 21 states (Center for Food Safety and Applied Nutrition, 2017). It took the health officials around three weeks to trace the source to a supplier in Mexico, as indicated. Additionally, from January 2019 to July 2019, CDC reported that papayas in the US market once again linked to a multistate outbreak of Salmonella Uganda, which were products from Cavi brand whole, fresh papayas distributed Agroson's LLC. Based on the final report on September 12, 2019, a total of 81 people infected with the outbreak strain of Salmonella from nine states with the hospitalization rate of 66% and no death. The inability to immediately track the provenance of food products resulted in economic losses for papayas farmers (Kamath, 2018).

Recently, CDC and the U.S. Department of Agriculture's Food Safety and Inspection Service (USDA-FSIS) had to roll their sleeves up and investigate another multistate outbreak of Salmonella Dublin infection linked to ground beef and has not identified the common supplier of ground beef, published on November 1, 2019. Up to now, there are 10 cases from 6 states, which includes 8 hospitalizations and 1 death ("Outbreak of Salmonella Infections Linked to Ground Beef", 2019). For instance, Great Value frozen meat, Walmart's private-label product, have been recalled for possible salmonella contamination (Andrew, 2019). This would have raised consumers worrisome about food safety and eroded their trust day by day.

1.2. Fox-Tainted Donkey Meat

Jourdan from Reuters stated that Wal-Mart had to recall donkey meat included fox meat after the DNA test and traced back to its Chinese supplier “Five Spice”. This scandal did not only dent Wal-Mart’s reputation for quality in the food and grocery market which led to a significant loss of trust from consumers, but also its market share fell from 7.5 percent to 5.2 percent, China Market Research estimated at that time (Reuters, 2014). Wal-Mart’s China president and CEO, Greg Foran, said, “It is a deep lesson (for us) that we need to continue to increase investment in supplier management.” It was obvious that the inability to track the record at every stage in the food supply chain would cause many serious consequences.

1.3. Food Fraud in Horse Meat Scandal

In 2013, the European Union countries found most of the beef products containing horse DNA while most traces of a painkiller banned from the human food chain detected from Britain (Castle, 2013). The European Commission reported there were 193 tested revealed traces of horse DNA, and 16 cases positive with the painkiller. Noticeably, the Humane Society mentioned, “The European Union has failed to seek tests for a whole host of other banned veterinary drugs which are commonly administered to horses and is thereby failing the public by allowing meat from those animals to be sold in the European Union in contravention of its own food safety and consumer protection regulations”, which was an issue of lacking transparency in product provenance led to a delay in handling this food fraud scandal. Turning to Tonio Borg, the European commissioner for health and consumer policy, emphasizing this scandal was “a matter of food fraud and not of food safety.”

1.4. African Swine Fever Outbreak

African swine fever (AFS) is considered as one of the most dangerous diseases of swine. At the beginning of this year, the first outbreak of this disease was reported to have been found at a family-owned backyard pig farm in Hung Yen Province, Vietnam. After the first detection, the disease spread to every province in Vietnam, which forced the cull of over 5 million pigs (accounting for 18% of the total hog herd) and drove up prices almost 70% (Vu and Singh, 2019). The outbreak was confirmed in the northern part of Vietnam, limitrophe Chinese border, where many instances of illegal movement of animals and meat products across the two countries border have been reported, according to the Food and Agriculture Organization of the United Nations (2018). Although the AFS virus merely impacts pigs, not people, and it is not a public health threat that could be transmitted from pigs to humans, or a food safety issue, USDA mentioned, it has corroded consumer trust in pork products and shifted the market demand from pork to other types of meats. This disease and the inability to control the movement of pigs or pork products (transparent provenance) have resulted in an economic loss for Vietnam in general and farmers in particular.

2. Blockchain and Its Application in the Food and Agriculture Industry

2.1. Blockchain Fundamentals

The birth of blockchain was built on the platform of Bitcoin; however, they are not the same. Beyond the first use case of Bitcoin – recording Bitcoin transactions – blockchain also has many other potential uses (Gupta, 2019, p. 6). In general, "blockchain is a decentralized software mechanism that enables a shared distributed ledger system. It allows the tracking and recording of transactions and assets without the presence of a central trust authority or regulatory" (Phadke and Parwekar, 2019, p.4). Furthermore, blockchain makes the transactions difficult to be hacked and minimizes other cybercriminals to manipulate data, since it uses consensus protocol and cryptography linked to every added transaction. This enhances transparency when exchanging data, assets and currencies based on rule-based smart contracts (Phadke and Parwekar, 2019, p.4).

A series of data blocks are organized in a "chain" and strung together across the network called blockchain. Each data block is securely hashed and typically contains four pieces of information: a reference to the previous block, the list of included transactions including the transaction summary, a time stamp, and a cryptographic proof (Phadke and Parwekar, 2019, p.4). This increases trust and better data integrity regardless of a central authority. There are four types of blockchain networks, which could be built in several ways depending on user purpose: public, private, permissioned, and consortium blockchain networks. Table 2 below describes each type of blockchain based on definition from IBM Blockchain (2019).

Table 2. Types of Blockchain

Types	Description
Public Blockchain Networks	Is available for everyone to participate and decentralized without authority's control. An example is Bitcoin.
Private Blockchain Networks	Similar to a public blockchain network, it is a decentralized peer-to-peer network, with one organization governing the network making a significant difference. It governs who is allowed to participate in the network, implements a consensus protocol and manages the shared ledger. This can significantly boost confidence and trust between participants, depending on the use case. It is possible to run a private blockchain behind a corporate firewall and even be hosted on-site.
Permissioned Blockchain Networks	Can be regarded as a private blockchain or partial blockchain network. It places restrictions on who, and only in such transactions, is allowed to participate in the network. Participants must be invited or allowed to join.
Consortium Blockchains	Multiple organizations can share a blockchain's responsibilities. These organizations pre-selected determine who can submit transactions or access the data. A blockchain consortium is ideal for business when all participants must be allowed and have a shared responsibility for the blockchain.

According to Phadke and Parwekar, blockchain's characteristics provide six main benefits as mentioned in Figure 1 below. Noticeably, decentralization of data is one of the most crucial advantages of this technology due to its higher protection ability, which is usually disrupted by fire, theft, natural disaster, hacks, and corrupt file systems when using the traditional centralized data systems. Since there is no central authority control, blockchain also avoids many illegal and fraudulent actions, because changing even a single transaction record would require the alteration of all subsequent records and the agreement of the entire network. Thus, the transparency feature of blockchain makes data more accurate and reliable. Also, blockchain lines up all data and makes it always available for everyone to trace and track its provenance, quantity and so forth, thanks to its traceability trait. This proposes the information can be communicated easily and faster, especially in the response to some urgent situations needed tackled immediately. It is also stated that blockchain is more secure than other record-keeping systems as whenever a transaction is approved, it is encrypted and linked to the previous transaction.

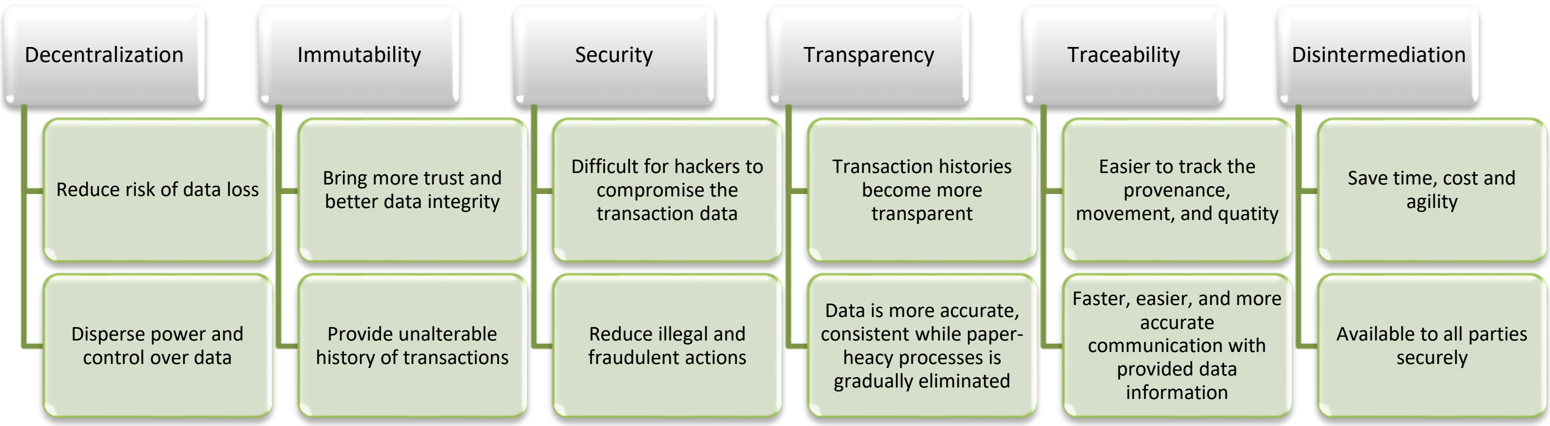


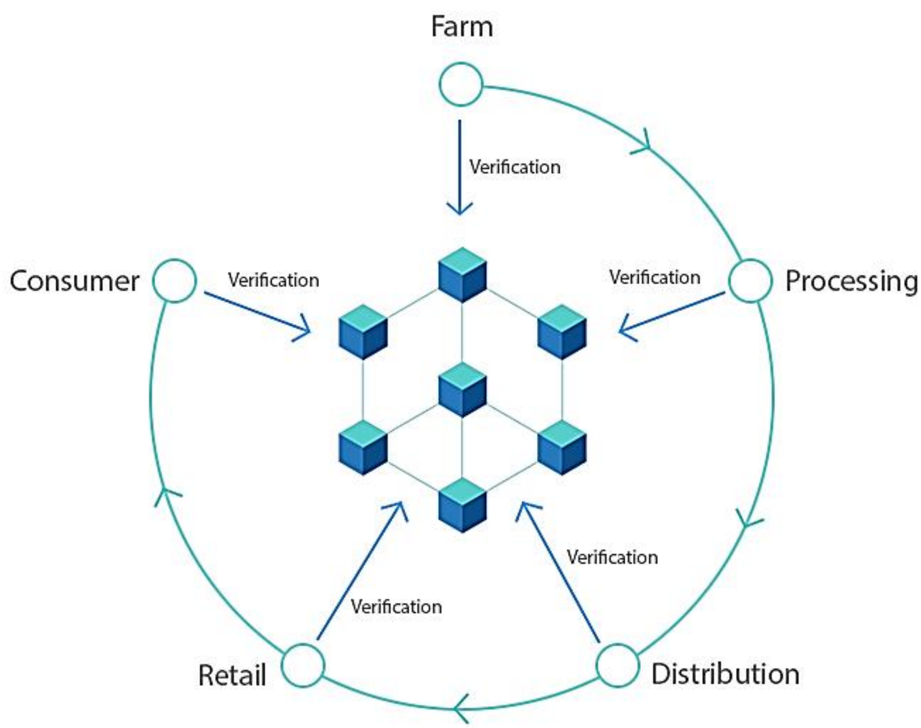
Figure 1. Six Characteristics and Benefits of Blockchain

2.2. Why does the Food Industry Need Blockchain?

"If you're buying some food or medicine, for example, you have this complex global supply chain… Ideally, you'd want to have some kind of common shared network that you could use to get all the information about where each individual thing came from so you could trace every part of the product back to where it came from," said Buterin (2017). He emphasized the necessity of a shared network, so everyone is able to check all the information they are looking for in the fastest way. Blockchain, Buterrin recommended, is an optimal solution.

Due to various scandals about food corruption and food fraud, consumers have been curiously wondered whether the food they are consuming is safe and meets the standardized quality. In other words, significant distrust and suspiciousness among consumers, supply chain firms, and authorities, data in this supply chain field must be unmodifiable and stored in a shared, distributed ledger to provide transparency, according to TE-Food. Moreover, food safety-related data and its accessibility must be public and democratic since this is considered as a common property for the whole food supply chain, from the upstream throughout the downstream. TE-Food also pointed out that blockchain would solve the corruptible food history information leading to enhancement in transparency, which can improve public health and save lives.

Adding to this concept, blockchain could as well reduce food waste and costs associated within the supply chain, because everyone, from farmers to the end-consumers, can track the record and check the quality of each product at every stage. This helps any participant in this supply chain easily figure out issues in time and traces back the source of each food product to tackle them immediately and at the early stage. Thus, suppliers and producers will not have to wait until contaminated or fraudulent food reach to the end consumers, then recall and scrap all of them. Those blocks contain verified data and stored in shared distributed ledgers, so everyone can access it. By implementing this technology, the food industry would solve the phenomenon of consumers' trust erosion at the same time.



Source: TE-Food

Figure 2. How blockchain is used for food supply chain

Turning to further investigation and pilot development from Kairos Future (2017), blockchain can be used in three areas which are conditions at the production facility, tracking of food items, and tracking of food volumes in the supply chain. First of all, self-reporting capability is made with any digital records such as a photo, video or a digital file stored at the production facility, which is verified and cannot be manipulated in the blockchain. Therefore, quality inspectors can then verify those digital files corresponding to the actual conditions at the facility, the workforce, which avoids mismatch information and fraudulence at any stage in the production process. With continuous automatic tracking of changes in the environment and production, product's current conditions will not be misrepresented, and producer can ensure their product is still in a good state for further processing and delivery to end consumers. Secondly, blockchain technology enables an extremely high control of food items in the supply chain with cost-efficiency, since information is always available and secured, as well as manual work in tracking and tracing back the product is too pricey and time-consuming. Lastly, this technology also increases trust in the supply chain by handling situations where food is processed, cut, repackaged in terms of volume incentive, which eliminates food fraud. All of these capabilities ensure the food value chain partners with better transparency on how the food flows through the chain to optimize their processes.

From Phadke and Parwekar's (2019) point of view, blockchain technology has seven core competencies to enable better traceability, transparency and control over the food supply chain. Since blockchain contains various secured blocks, each block storing certain data will be labeled with a unique identifier such as a barcode, an ID, or a QR-code. Product data aggregation and disaggregation, and basic analytics are abilities mentioned by the authors as well. Furthermore, with permissioned visibility and genuine traceability through immutability, every participant with permission will have access to all the information stored in that "chain". If any problems are coming up with the product at any stage, information can be retrieved easily and in a real-time manner. Phadke and Parkewar also mentioned about blockchain audit capabilities which can handle altering parameter through smart contracts. All of these traits once again eliminate food fraud and raise consumer trust as well as reduce costs associated with this supply chain.

The following Figure 3 below is retrieved from *"Blockchain Demystified End-to-end food traceability and control solution"* by Phadke and Parwekar, which indicates how the blockchain will be activated for food supply chain:

Parameters	Farmer/ Producer	Logistics Provider	Warehouse/ Distributors	Retailers
Process	• Grows produce • Breeds poultry and farm animals	• Transports meat and produce • Provides transit schedules	• Intermediate storage • Product consolidation and repackaging services	• Verify the product for traceability • Storage before final consumption • Product unbundling
Technology	• Sensors • RFID Tags	• Temperature, humidity and pressure sensors • RFID Tags and Bar codes	• Temperature, humidity and pressure sensors • RFID tags and Bar codes	• Temperature, humidity and pressure sensors • RFID tags and Bar codes
Input Data	• Information from ID Tags for animals • Feeding logs • Antibiotic usage • Fertilizer and pesticide usage • Temperature controls • Certifications	• Dates (scheduled and actual arrival and departure dates) • Temperature control by food type • Humidity • Pressure • Certifications • Other Quality control information	• Dates (scheduled and actual arrival and departure dates) • Temperature control by food type • Humidity • Pressure • Light • Certifications • Other Quality control information	• Temperature control by food type • Humidity • Pressure • Light • Other Quality control information
Blockchain Interactivity	• Web applications (for data upload and reporting) • Open data interfaces for data load (for more sophisticated producers)	• IOT enabled APIs for blockchain (to integrate data from sensors) • Open interfaces for the data loads • APIs to connect to ERP and other supply chain management systems • Web applications for track and trace	• IOT enabled APIs for blockchain (to integrate data from sensors) • Open interfaces for the data loads • APIs to connect to ERP and other supply chain management systems • Web applications for track and trace	• IOT enabled APIs for blockchain (to integrate data from sensors) • Open interfaces for the data loads • APIs to connect to ERP and other supply chain management systems • Web applications for track and trace
Blockchain Framework	• Parameters registry • Repository for the traceability documentation • Architecture / Solution framework for Blockchain • Interfacing technologies for data ingestion and delivery into and from blockchain			
Blockchain Data Enablement	• Reporting interfaces • Mobile Apps for consumers • Analytical applications			

Source: Phadka and Parwekar – Blockchain Demystified End-to-end food traceability and control solution

Figure 3. How the blockchain will be activated for food supply chain

2.3. Use Cases of Implementation of Blockchain in the Food Supply Chain

According to Lucena, Momo, Kim and Binotto, Brazilian grains including soybeans were applied Internet of Things (IoT) and blockchain to track grains stored in warehouses for quality assurance with the purpose of optimizing grain grading with global exporters based on Hyperledger Fabric and smart contracts (IBM Agritech) platform. This would lead to an added valuation of around 15% for GM-free soy in the scope of a Grain Exporter Business Network in Brazil.

Going back to 2017, Walmart ran two blockchain experiments in partnership with IBM which is known as IBM Food Trust. The first involvement of blockchain was used to track Chinese pork while the second experiment was to trace Mexican mangoes provenance as well as figure out the cause of Salmonella outbreak linked to papayas. Walmart used Hyperledger Fabric platform, a blockchain originally built by IBM and housed under the Linux Foundation's Hyperledger group, for their experiments, Hackett indicated. Based on the research of Leong, Viskin and Stewart from Accenture, Walmart also executed IoT and blockchain to track mangoes throughout the supply chain, from the upstream to the downstream, intending to classify provenance and improve food safety issues. The result showed that the tracing process (traceability) experiencing a significant decrease from 7 days to 2 seconds.

Last but not least, TE-Food has reported that its current traceability volume per day are 12,000 pigs, 200,000 chickens, and 2,500,000 eggs (TE-Food, p. 5). Figure 4 below summarizes numbers of use cases based on the blockchain platform from TE-Food, which enhance traceability and transparency in the food industry.

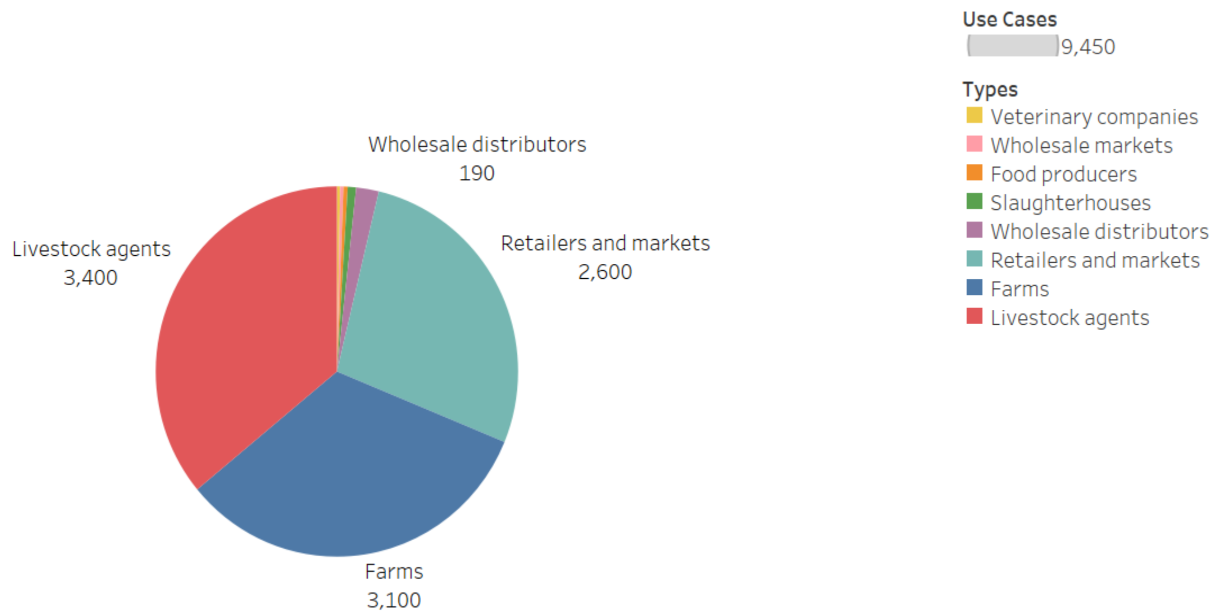


Figure 4. TE-Food Blockchain implementation

Types and sum of Use Cases. Color shows details about Types. Size shows sum of Use Cases. The marks are labeled by Types and sum of Use Cases.

Conclusion

Alongside the benefits, blockchain implementation faces some challenges that are needed to be solved along the line; otherwise, these issues would particularly pose substantial hurdles for this industry. First of all, the eco-friendly issue is one of the reasons challenging this technology these days. Because blockchain relies on encryption, which needs complicated algorithms to be run, resulting in a requirement for large amounts of computing power. This means energy consumption is as much as that of used by 159 nations around the globe, Phadke and Parwekar emphasized, driving environment cost up significantly.

Besides from that, one of the biggest potential roadblocks when implementing blockchain technology in the food supply chain is the adaptability of this industry, especially in some emerging countries or even in rural areas of developed nations in which plentiful farmers and producers are located. Since blockchain needs to be engaged across the whole supply chain for optimal improvement, every participant including farmer, producer, distributor, packager, and many others must be willing to adopt this technology into their working environment. Hence, the workforce should be trained and equipped with technological knowledge to use this advance framework.

Thus, in response to all the issues mentioned above such as food safety, food fraud, food waste and so forth, blockchain is one of the viable solutions for better traceability and transparency to handle them in the food industry. Even though some challenging possibilities aligning with this implementing process, the unstoppable evolvement of this technology in this Fourth Industrial Revolution would overcome these hurdles and bring even more benefits to this field.

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