Blockchain Application in Food Supply Information Security

Daniel Tse, Bowen Zhang, Yuchen Yang, Chenli Cheng, Haoran Mu

Department of Information Systems, City University of Hong Kong, Hong Kong.

(iswktse@cityu.edu.hk)

Abstract - **With the increasingly serious problem of food safety in China, it directly or indirectly endangers people's health, quality of life and safety of life. The global economy, politics and society as a whole have a greater impact. As an effective means of product quality and safety management and control, many countries and regions have been researched, developed and operated of the traceability system. On the one hand, these technologies have not been able to achieve more accurate traceability, these results cannot be directly used in Chinese market. Therefore, the article introduces the concept of Blockchain technology, putting forward the application of Blockchain technology in information security of the food supply chain and comparing it with the traditional supply chain system.**

Keywords - **Blockchain, Supply chain, Decentralization, Food safety, Information security**

I. INTRODUCTION

As food-borne diseases continue to increase, many consumers have become less reliant on food, thus creating a need for more detailed information on food production. In last few years, China has entered a period of frequent food safety incident - Low-quality milk powder, "Sudan Red" hot sauce, "hair sauce", "toxic rice", etc., which cause serious consequences. The Chinese government attached great importance to food safety issues and adopted a variety of response measures, yet achieving significant results. This study suggested that the Blockchain provides an innovative solution for achieving these goals: Firstly, it provides a permanent record for each transaction segment which is grouped into individual blocks and cannot be tampered with. Secondly, it can replace those traditional paper tracking systems and manual monitoring system, so as to prevent the traditional way of the supply chain from suffering the inaccurate impact. In other words, the supply chain tracking is an important measure to protect food safety, promoting food safety and food certification.

This paper uses the theories of information science, management science, system science and empirical research methods, making use of reasoning, comparison, theory and demonstration of research methods to study the Blockchain in the food supply chain.

II. LITERATURE REVIEW

Nowadays, food supply chain has been extensively studied. Many scholars have long recognized the necessity of speeding up the construction of the agricultural supply chain, especially the big agricultural country like China. For example, [21] once pointed out that as China's agricultural supply chain construction is still in its infancy that there are many problems. To completely solve these problems, we should seize the source of supply chain agriculture. [6] From the logistics supply chain management theory, analysis of how to improve the level of supply chain management of agricultural products and logistics enterprises, not only have advanced supply chain management technology but also improve the market service system and quality management system, and actively play a government function. To further explore the concept of traceability for safe and sustainable agriculture and Agri-food supply chains, traceability is a preventive strategy for food quality and safety management that contributes to increasing consumer confidence in the food system. [11]

In this paper, Blockchain technology was used to solve the problem of agricultural food supply chain traceability, further addressing the food safety issues, and to demonstrate its link in each supply chain in the implementation process details. Aiming at national conditions of China and Chinese market analysis, a set of theoretical methods were used to adapt to China's current situation in order to make agricultural product supply chain management more efficient and reliable, as well as the quality and safety of agricultural products.

III. PRINCIPAL CONSTRUCTS AND DEFINITIONS

Blockchain is originated from the bitcoin, a technology which is a distributed database and with the continuously increasing records regarded as blocks. Moreover, it is constantly growing as miners add new blocks to it (every 10 minutes) to record the most recent transactions. Reference [12] was coming up by [16], and applied it to the bitcoin transactions. On top of that, the blockchain has four basic characteristics which called Decentralization, Openness, Security and Privacy.

IV. HYPOTHESES

A. Blockchain insure the traceability and reliability of each transaction in the food supply chain

There is still no perfect solution for achieving the traceability and reliability in food supply chain information system. Building an Agri-food supply chain traceability system can be treated as an imperative mission when traditional logic of management and

traceability cannot fulfill the requirements of supervision and the adaptation of fast-growing food market [8]. However, the application of Blockchain in the supply chain may have been the optimal choice till now. Verifying authenticity of the document can be done by using Blockchain and eliminates the need for centralized authority. Reference [13], every transaction requires verifying the last transaction, thus guaranteeing the traceability of each transaction.

B. Blockchain can fulfill the demand of governments, enterprises and consumers

If the first hypothesis is established, applying the technology of Blockchain can meet with the demand of governments, enterprises and consumers. The technical advantages of the Blockchain bring new regulatory ideas to the government, improving the existing management flaws of the government. For enterprises, the application of the Blockchain can insure merchandise quality and giving quick response to the changing market. In fact, the application of the Blockchain can protect the rights of consumers.

V. RESEARCH METHOD

In this paper, we use the methods of information science, management science, system science and other theories and empirical research methods, mainly using the PEST analysis to analyze, contrast and demonstrate studying the application of Blockchain in the food supply chain. PEST is an analytical model which analyzes the macro-environment location of the industry. All parts of the PEST are the external environment of the industry which cannot be controlled by themselves.

The paper also carries on the demand analysis of the Blockchain system platform of the food supply chain. Firstly, this paper qualitatively analyzes the current situation of food security. The second is the demand analysis of the food supply chain traceability system platform, analyzing the food supply chain can be traced back to the root causes and the need for development. Thirdly, it analyzes the traditional traceability system of food supply chain. Fourthly, aiming at the problems existing in the food supply chain system, applying the block chain technology to build a supply chain system platform for production processors, brokers and consumers.

A. PEST Analysis

1. Political Factors

Food safety is a major responsibility of the government and regulatory authorities. Therefore, the government needs to create a cross-industry or the interdepartmental professional system in order to effectively regulate food supply chain. It is of great significance to innovate the government regulation of the food supply chain, to improve the government's management level and efficiency, to prevent rent-seeking and breed corruption.

i. _Growing government regulatory requirements_

The use of blockchain technology to achieve multi-faceted management of the food market is the government's demand, through the system of regulatory records of the food market transaction information. This can effectively solve the problem of food regulatory process. According to the understanding of the relevant government departments, there are some requirements of government regulatory authorities on the food supply chain:

(a) Precisely collect the information on all aspects of the food supply chain.

(b) Information gathering and storage of the food supply chain from planting (breeding) to the whole process of consumption.

(c) Can be transferred to the government regulatory platform through the block chain technology.

These requirements match with the technological characteristics of the blockchain which stores information on each transaction. Though each private key is produced and released by Information department of the Chinese Government, Ministry of Agriculture is given the access to the record of the data. This information would provide the basis for supervision, food recall and prior warning [22]. Therefore, we can see that the application of blockchain technology meets with the government's demand for food supply chain system.

ii. _Statistical Analysis and Information Release Requirements_

Through the information recorded by the block chain, the government can use the integrated function of the traceability system to collect statistics on various kinds of food. Through the information, statistics, analysis and processing, and generating warning information, the generated warning information is sent to the relevant departments or a node in the supply chain [22]. According to the security risks exist in the food supply chain, the government would concentrate on the management of these business activities. Therefore, through the blockchain technology to build the food supply chain traceability system, the government can release information to the public and the media correctly and timely.

2. Economic Factors

With the rapid development of the food industry, markets have become more dynamic and more complex. Food and agribusiness firms are confronted with fast changing markets as well as worldwide competition. Changes in the market affect all levels in the supply chain [9]. In case of any supply changes resulting from climate

change and market demand changes, agribusiness firms not only need to have the rapid response ability but also are in demand for marketing and production prediction. The key restriction in acquiring this ability lies in the data acquiring and data mining techniques. Armed with these techniques, agribusiness firms can reduce their risk in climate or market change, thus increasing the efficiency, taking full advantage of the agriculture foods. No wasting would happen. Once equipped with blockchain technology, the supply chain system would enable the agribusiness firms to check the authenticated source area, production date and previous transactions, thus insuring the quality of the raw material.

3. Society Analysis

i. <u>*Trust in Government is Falling Down*</u>

Food safety is a growing main problem for Chinese consumers although the government has promised to fix it again and again. Tainted baby formula, fake fruits and even seafood pumped with gelatin continuously showed up in the market these years. It was reported that 71 percent of Chinese people considered food safety a big problem in 2015.

ii. <u>*Purchase Behavior is Changing*</u>

According to the asymmetric information theory, consumers are the ignorant party who lacks information. Consumers are demanding more food quality and safety information. When people buy food, they are eager to know more information about the place of production, raw material production and dealer's information.

With the prevalence of the Internet and smart phones, the days when consumers knew little about one product except news in television have gone. Nowadays, consumers are encouraged to and able to access any information they want about one product though it is not that convenient. It is essential to increase transparency and traceability of food production along with the supply chain. It would be much more effective if consumers can easily acquire any information related to the agri-food before they want to buy. A convenient method for information checking is desired.

4. Technology Factor

i. <u>*Government Support Blockchian Technology Research in Supply Chain*</u>

In the traditional food supply chain, technologies are hard to be used in it due to many different reasons. However, with the development of the blockchain technology, the blockchain not only applied to the "Bitcoin" but also can be applied to the various areas. Thus, the Chinese Government has launched the blockchain technology research project, and published "About organizing and developing the research of blockchain technology's application and development tendency" and "China Blockchain Technology and Application White Book" to support the blockchain

research in order to adapt the China's national conditions. Therefore, the Chinese Government has already paid much attention and resources for the blockchain research in order to develop the next generation of supply chain.

ii. <u>*The Blockchain is Suitable for Supply Chain*</u>

As White Book pointed out, the supply chain is a combination with the logistics, information flow, capital flow, suppliers, manufacturers, distributers, dealers and customers are put in a supply chain series. Blockchain technology acts as a large-scale collaboration tools, it is naturally applied in the management of the supply chain. The reasons are listed as follows.

Firstly, the blockchain technology can create a complete and smooth information chain which allows all the transaction information transparent among the distributers, suppliers or other relevant parts in the supply chain. Once unsafety operating incidents happen, the mistakes or errors coming from any part of the supply chain can be found easily. It also helps the participants to find out the solution in a short time and improve the efficiency of the supply chain.

Secondly, the characteristic of the blockchain which includes the modification prevention allows each participant unable to deny any part of the transaction. Once "dishonest transaction" happens, any part of the supply chain can prove the authenticity due to each participant has got a complete book which includes all the transaction from the very beginning.

Thirdly, still because of the modification prevention, once fake or perishable food flow into the market causing the food safety incidents, it can be much easier to find the original source of the food or material for accountability.

VI. RESULTS ANALYSIS

A. Traditional Food Management Model

In China, the quality and safety of food is managed by a number of government departments. Some phenomena of cross management and blank management exist in the functions of those government departments. There are still a number of problems with such a fragmented management system. On the other hand, some manufacturers need to contact third-party (agent) to get the materials, not obtaining from the other providers directly, which can be regarded as multi-centralized market and have the credit risks. The solid dot represent them. (Fig 6)

B. The Blockchain Application Theory

The blockchain can be transferred into the food circulation information storage with the category, quantity, quality, origin, etc. The main chain is like the distributed book that all the node has the copy. All the transactions recorded on blockchain is transparent and open, everyone can search and view with the encrypted

transaction subjects. Meanwhile, all nodes are allowed to trace foods information where it was transported to or where it came from, it helps all the institutions improving the traceability management for food safety.

Due to the characteristic of the blockchain, all the transactions will be packed in one or several blocks. All the nodes also update the book on native when a new block is verified and recorded on the main chain, which means all the nodes have the same account book which records all the transactions. If someone want to change one of the transaction record, an attacker who has a high fake credibility score can possibly succeed in a 51% attack [10]. However, such process may vastly consume computing power to modify over half of the node's chain and calculate the eligible hash to repack the block. According to the statistics by the 2016.02, the eligible hash has seventeen '0' at the beginning of the hash value, it needs 1617 times of random search to calculate [23]. Therefore, modifying a blockchain needs much cost and time. The blockchain can keep the information safe without manipulation.

C. Decentralized Food Supply Chain Authentication Model

As the picture shows (Fig 7), all of the oval inside the part A, B and C dotted boxes act as the "node" of the blockchain main chuck which includes the food's raw materials suppliers, food manufacturers, food's materials processors, food's sellers and any other relevant food's industry enterprises. The full line among these ovals represents the transactions between these nodes directly, not through agents or brokers any more. When a transaction happened between two nodes, the rest of the nodes will act as the authentication institutes to verify this transaction's authenticity and finding the previous transaction record using the copy of blockchain updated from the main blockchain.

What needs to pay attention is that the ovals inside the part A. Dotted box also acts as the initial books creator, which means all the resources flowing into blockchain network are recorded by the suppliers first. The reason is that they are the source of the whole supply chain which gathered and bought the raw materials from the farmers or the individuals, and records the basic information of these materials to create the initial blocks for further transaction and use. (Fig 5). Part E represents the Information Department, which allocates the private and public key to A, B, and C. The rest of the institutions, part D, can search the information on the blockchain platform like an information sharing platform. The solid arrows mean institutions are one-way connection with part A, B and C. Their responsibility is aiming at pursuing all transport records and monitoring the food flow if necessary. On top of that, they have no authority to modify any part of the record in blockchain.

Another responsibility for the food safety institution is an agency between the blockchain network and customer. If the customer wants to search the food basic flow information, the institution is allowed to admit part of the authority for customers' requests due to the fact that they are the owner of blockchain key pairs. The ovals in part E is customer; the solid arrows represent the fact that they can pursue the food information and transportation data through the part D, the food safety institution. To some extent, they can learn the food safety information through the blockchain remotely.
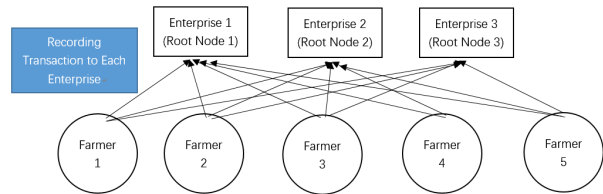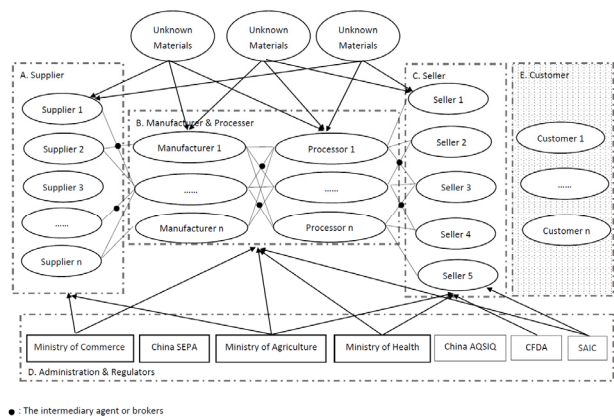
Fig 5. Initial Recording

● : The intermediary agent or brokers
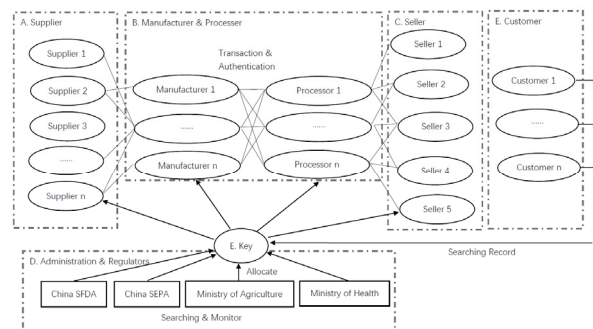
Fig 6. Traditional Food Management Model

Fig 7. Decentralized Food Supply Chain Authentication Model

VII. CONCLUSION

As above mentioned, although there still have some disadvantages, promoting the blockchain is a well worth technology for helping government track, monitor and audit the food supply chain and helping manufacturers to record the transactions in authenticity. Not only this technology can benefit the customers, manufacturers and the supervision departments but also improving the efficiency of food supply chain's processing and circulation. However, these technologies still stay in a concept, not putting into practice. Based on the above

reasons, some suggestions can be borrowed from the US implementations and then propounded for building up the system in China.

REFERENCES

[1] Amendment to the Criminal Law of the People 's Republic of China (8), Article 24, May 1, 2011

[2] Brito, Jerry & Castillo, Andrea (2013). "Bitcoin: A Primer for Policymakers" (PDF). Fairfax, VA: Mercatus Center, George Mason University. Retrieved 22 October 2013.

[3] CHEN Yaoting, LAI Yonggui, 2009. 'Research on traceability and traceability system of agricultural product supply chain', Market Modernization, p.23-24.

[4] Christian Decker, Roger Wattenhofert, 2013. Information Propagation in the Bitcoin Network. 13-th IEEE International Conference on Peer-to-Peer Computing, p.2.

[5] DENG Xunfei, WANG Kairong, Lv Xiaonan, ZHENG Suying, CHEN Xiaojia, 2009. Design and application of coding method for crop production places based on GIS technology', Journal of Zhejiang University, p.93-97.

[6] DING Hua, 2004. 'On the Application of Supply Chain Theory in Enterprises Distributing Farm Produce', China Business and Market, p.17-21.

[7] Elise Golan, Barry Krissoff, Fred Kuchler, Linda Calvin, Kenneth Nelson, and Gregory Price, 2004. Traceability in the U.S. Food Supply: Economic Theory and Industry Studies

[8] FENG Tian, 2016, An Agri-food Supply Chain Traceability System for China Based on RFID & Blockchain Technology

[9] Gerrit Willem Ziggers, Jacques Trienekens, 1999. Quality assurance in food and agribusiness supply chains: Developing successful partnerships

[10] Hiroki Watanabe, Shigeru Fujimura, Atsushi Nakadaira, Yasuhiko Miyazaki, Akihito Akutsu, and Jay Kishigami, 2016. Blockchain Contract: Securing a Blockchain Applied to Smart Contracts Hiroki. 2016 IEEE International Conference on Consumer Electronics (ICCE), p.468.

[11] KONG Hongliang, LI Jianhui, 2004. 'Application of Global Uniform Marking System in Food Safety Tracking and Traceability System', Food Science, p.188-194.

[12] Melanie. S (2015), Blockchain: Blueprint for a New Economy. O'Reilly Media, Inc. 2015. Preface x.

[13] Michael Crosby, Nachiappan, Pradan Pattanayak, Sanjeev Verma, Vignesh Kalyanaraman, BlockChain Technology: Beyond Bitcoin, 2016

[14] QI Fangzhong, ZHAO Wenbo, ZHOU Gengui, 2009. 'Architecture for Farm Produce Logistics System Based on Product Life-cycle Management', System Sciences and Comprehensive Studies in Agriculture, 25, 3, p.329-332.

[15] Robbert van Renesse (2016), A Blockchain Based on Gossip? – a Position Paper [Online]. Cornell University. Available at: https://www.zurich.ibm.com/dccl/papers/renesse_dccl.pdf

[16] Satoshi Nakamoto (2008), Bitcoin: A Peer-to-Peer Electronic Cash System [Online]. www.cryptovest.co.uk. Available at: http://www.cryptovest.co.uk/resources/Bitcoin%20paper%20Original.pdf

[17] SU Pin, 2012, ''Research on Quality Safety Traceability System of Agricultural Products Based on Multi - Agent', Science & Technology Information, p.24.

[18] Trillo, M, 2013. Stress test prepares VisaNet for the most wonderful time of the year.

[19] Vitalik Buterin (2016). A NEXT GENERATION SMART CONTRACT & DECENTRALIZED APPLICATION PLATFORM [Online]. www.weusecoins.com. Available at: https://www.weusecoins.com/assets/pdf/library/Ethereum_white_paper-a_next_generation_smart_contract_and_decentralized_application_platform-vitalik-buterin.pdf

[20] XU Demin, 2010. The Application of RFID Technology in Supply Chain Management', The Light & Textile Industries of Fujian, p.43-46.

[21] XU Jin, 2005. 'Supply Chain of Agricultural Products - Safeguard of Food Safety', China Logistics & Purchasing, p.68-68.

[22] Xu Sun, 2016. Value Analysis of NFC Technology in Traceability of Fresh Agricultural Product Supply Chain

[23] YUAN Yong, WANG Fei-Yue, 2016. Blockchain: The State of the Art and Future Trends. ACTA AUTOMATICA SINICA. Vol. 42, No. 4, p.487.

[24] ZHU Jianming, FU Yonggui, 2016. Supply chain dynamic multi-center coordination authentication model based on blockchain', Chinese Journal of Network and Information Security, .2,1, p.27-33.