Eng Int Syst (2024) 1: 19–23

Engineering
Intelligent Systems

Blockchain Ecosystem Meets Supply Chain Ecosystem and an Application to Dairy Product Provenance

Pengdi Zhao[1], Ashley Jensen[2], Tim Jensen[3] and Elizabeth Chang[1]

[1] *Griffith University, Gold Coast, Queensland, Australia*
[2] *SmartaIndustrial Pty Ltd, Brisbane, Queensland*
[3] *7R Logistics Pty Ltd, Queensland*

The demand from consumers about information transparency in raw materials, production, and manufacturing processes of the products they purchase is currently increasing in particular markets. The traceability and provenance of information across all stakeholders on the supply chain is becoming an essential requirement. In this paper, the design of a model for a blockchain ecosystem to meet the supply chain ecosystem with application for dairy farms' product provenance is presented. This model aims to provide a reliable provenance of dairy products for consumers based on the requirements and regulations. By adopting this model, consumers can receive all information from the public blockchain by scanning the QR code on the package of products. The overall benefits of this proposed model are discussed along with further applications in the Australian Dairy exportation trade.

Keywords: Supply Chain Ecosystem, Blockchain Ecosystem, Dairy Product, Provenance, Traceability

1. INTRODUCTION

The establishment of a reliable and traceable system for agricultural products is of great importance since it can collect, store, and transmit the full information related to raw materials, processing methods, and production. The provision of transparent information throughout the supply chain can guarantee the quality and safety of Agri-products [1], and consumers can track the information, when necessary, to improve their trust and expand the sales market. To expand the market share of Australian agricultural exports [2] and improve the safety of agri-food. This work aims to build up a conceptual model of a data-led traceability ecosystem using blockchain. The provision of such information can achieve full tracking and traceability regarding the provenance of agricultural food products.

2. PROVENANCE IN SUPPLY CHAIN

The traditional tracing system for agricultural products focused on the construction of a centralised database [3]. Once it got attacked or distorted, the information may be released and, therefore, lack credibility. Also, the supply chain of agri-food generally involves different stakeholders such as farmers, logistics, processing companies, retailers, and customers [4]. The adaption of different platforms led to difficulty in sharing information among different shareholders and the lack of uniform standards and formats for data exchange [5]. Therefore, the promotion and application of the agri-food tracing system are hindered. To address this problem, this work adapts the blockchain technology, which has the properties of traceability, decentralisation, and unchangeability [6], thus sharing full data and improving

Figure 1 Traditional Supply Chain Ecosystems.

the trust level among different parties in the supply chain. For example, Bumblauskas, Mann, Dugan, and Rittmer [7] applied the blockchain technique to construct the tracing system of eggs with the "farm to table" production mode, to solve the fraud issue in the traditional agricultural industry. Hao, Mao, Zhang, Zuo, and Zhao [8] proposed a quantitative method to estimate the safety risk level of agri-food based on the data management in the supply chain with an embedded blockchain technique.

The identification of provenance of agricultural products in the European Union commenced in 2000, by combining the Hazard Analysis Critical Control Points (HACCP) along with tracing and tracking technology together to control the food safety issues such as the spread of Bovino Spongiform Encephalopathy (BCE) [1]. In 2011, the Food and Drug Administration (FDA) published the Food Safety Modernization Act (FSMA) to reinforce the control of traceability within the food supply chain [9]. Food Standards Australia New Zealand (FSANZ) is a statutory authority in the Australian Government's health portfolio, and it develops food standards and regulatory frames for Australia and New Zealand [10]. In 2001, the FSANZ established a National Livestock Identification System (NLIS) to track the whole process of domestic cattle from birth to death. In addition, Meat Standards Australia (MSA) was implemented to strengthen the supervision of the intermediate links of the supply chain [11].

Considering the type and growth cycle of certain agricultural products (such as Australian exports: milk), this work aims to develop a blockchain-based supply chain ecosystem for tracing the information on milk production, properties (protein concentration, sterilisation methods, storage temperature, processing procedures: lactose-free, low fat or full fat, cows living environment: free-range or pasture-raised), logistics, retailers and so on. This provenance of a dairy product ecosystem enables export target countries and customers to obtain access to information related to food sources, thus improving the quality of agri-food and potentially increasing the sales market.

3. SUPPLY CHAIN ECOSYSTEM

3.1 The Supply Chain Ecosystem

Supply chain ecosystem gradually evolved by business ecosystems. In the development of the supply chain ecosystem, Papert and Pflaum [12] considered stakeholders, business, government regulations, research institutions, and consumers as main elements in ecosystem. Gupta, Modgil, Gunasekaran, and Bag [13] mentioned that the supply chain ecosystem can be regarded as the greater connectivity and information flow enabled through information technology, for example IoT. It can generally be shown in Figure 1.

The advanced blockchain integrated supply chain ecosystem aims to achieve information traceability and improve data transparency, thus, enhancing the public recognition and trust confidence for customers towards dairy products. Compared with the traditional paper certificate and labelling system or the separated databases for different users, the introduction of blockchain technology enables the decentralised processing of data, therefore, achieving the governance and management of data from each link in the system.

While the dairy agri-food traceability and supply chain operations part can upload all the information of raw materials and manufacturing and transporting processes onto the blockchain database, consumers and international trade have the right to access and trace the information. The standards and regulators will get into this chain and investigate information if issues arise. The supply chain operation history, including the production, storage, transportation, and distribution steps within the system can be recorded and uploaded to each blockchain node, and generate a traceable and untampered record of dairy products for which customers can refer. The immutable data stored in the blockchain enables consumers or international trade partners to track the records and relevant food safety information within the supply chain system in the dairy industry. This can improve the confidence and trust from customers and further increase the international trade parties, due to authentic and trustworthy data sharing. Furthermore, the standards and regulators play an important role in monitoring the authenticity of the data and information.

The scheme of a typical dairy supply chain with tracible information sources is proposed and illustrated in Figure 2. Before reaching the consumers part, the dairy related information is well-recorded and stored, to be generated into a QR-code so customers can access the dairy data and report at both the production and processing stages. Starting from the first node of this supply chain – Dairy Farm, each cow comes with a RFID tag and NLIS accredited tag which monitors the health condition, including the age, vaccination history, body temperature, meadow locations and the related farmer ID. This information is uploaded frequently to monitor the well-being of cows while being stored into the local database and running out a report as a reference, for data traceability and to reduce

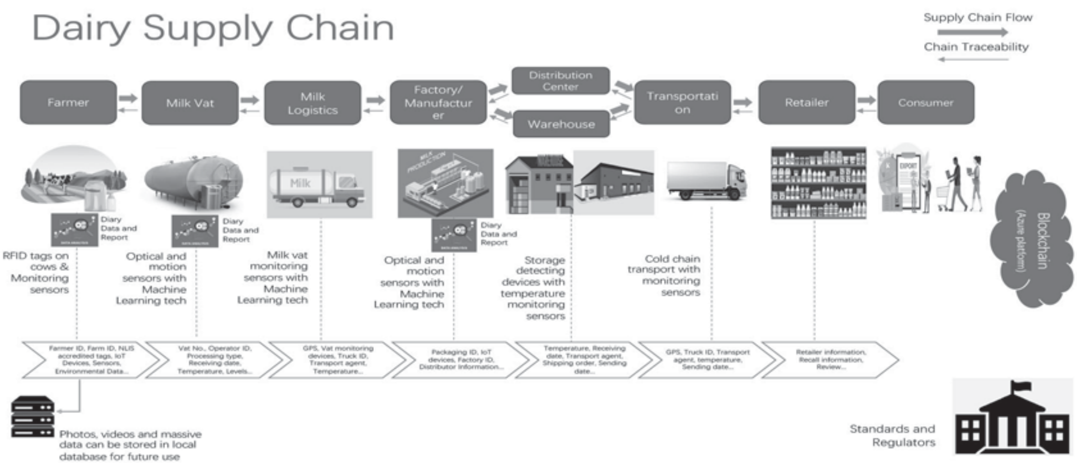

Figure 2 Dairy Supply Chain Ecosystem and Flow Map.

the congestion in the supply chain database. Then, the fresh milk is stored in the milk vat before being sent for processing. The dairy data and reports should be uploaded to the database with the quantity, storage temperature, and time periods.

In the dairy processing stage, the dairy production factories (such as milk or cheese industries) are responsible for documenting the process and quality parameters (sanitation temperature, processing methods and nutrition concentrations) of dairy products. To ensure the authenticity of information, optical and motion sensors with the machine learning technology are implemented to automatically upload the monitored processing methods and product quality, where the industry only has the right to read the data without altering rights.

In order to provide additional evidence to trace the quality of the raw milk and products, samples will be collected and analysed by stakeholders (farmer, milk vat, and manufacturers) at their own stage, and then upload the reports to the database. Also, the regulators have the right to check the reports and records that are uploaded from any step of the supply chain. When there is a quality issue, the regulators have the privilege to take samples from the processing factories to conduct quality checks to compare with the dairy quality report from the factories. The certificate from the regulators can further improve the data reliability of dairy qualities. Finally, the distribution centre or warehouses stage apply the cold chain transportation to ensure the freshness of dairy products and data including GPS positions, vehicle ID, freezer temperatures, and delivery periods which are automatically uploaded to the system to achieve data traceability along the process. When it comes to the retailer part, they can recall the information uploaded to the database and review the quality of products.

3.2 Blockchain Ecosystem Meets Supply Chain Ecosystem

The smart contract can authorise the access of users in each step and offers information interaction among different layers [14]. For example, it can either achieve the backward tracing of customer orders or the forward tracing of different batches of agri-products [15]. Therefore, the products can be labelled at each stage in this supply chain to simplify the inquiry procedures for information [16].

Due to the complexity of stakeholders and participants (farmers, logistic companies, food production companies, retailers, customers, governments, and so on) in this blockchain database, the management of authority and access to different parties will be undertaken by the blockchain ecosystem. In particular, a consortium blockchain, which constitutes the channels that reflect the operation dynamics, can be introduced in this system to enable flexibility for data management [17]. Each participant in this channel will be responsible to maintain the sharing database that guarantees the transparency of shared data.

The structure of the blockchain integrated into the dairy supply chain system is demonstrated in Figure 3. The private chain within the blockchain layer includes the text information uploaded from the business layer which corresponds to the supply chain users as illustrated in Figure 2. The end users in the business layer represent the key steps within the supply chain of dairy products, starting from cows to the final retailers. The information, such as the details of farmers/breeders, milk vat, logistics companies, dairy processing factories and manufacturers, product distribution systems and retailers, will be firstly stored in the local database of the business layer users. When it comes to the confidential commercial information, the dairy report and essential text information can be uploaded to the database in the private chain, as requested by the smart contract. That is to say, the local database of the supply chain users works together with the private chain to store the source information from each link of the business layer. Due to the supreme independency of this job and the followed connection with the public chain, Azure Authenticator (Microsoft) is recommended for uploading data into the local database, and private chain layer, and connecting with the web page for integrating information. It should be noted that each link only has the right in accessing the private chain to upload and traceable data rather than altering the uploaded information, thus realising data authenticity. The introduction of regulators in the system can further increase the data reliability of the public chain. The connection

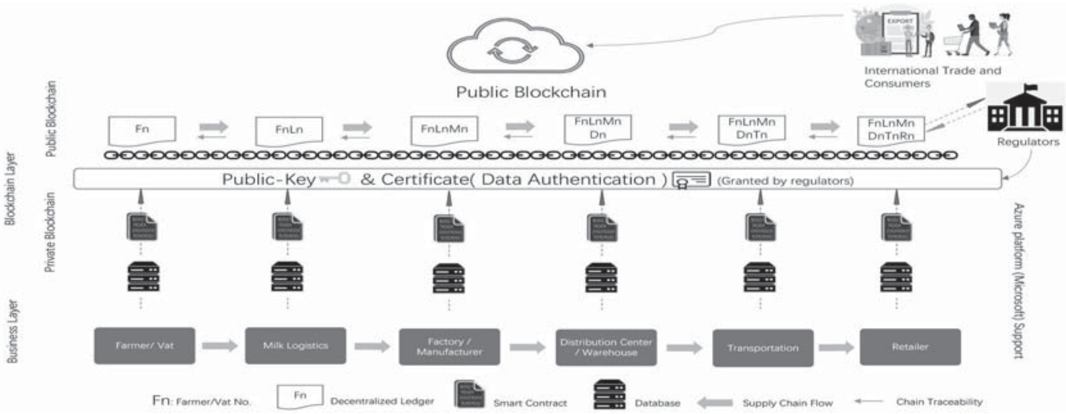

Figure 3 Blockchain Ecosystems Design for Supply Chain (Model design on Microsoft Azure).

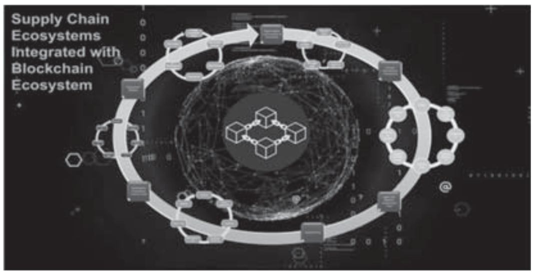

Figure 4 Proposed Supply Chain Ecosystems Integrated with Blockchain Ecosystem.

between the public chain and private chain is achieved by the public key and certificates which are granted by the regulators, and this system can be treated as a consortium. Regarding the issue that many small or medium sized farms, manufacturing, and logistics companies may experience in the supply chain system, this scheme only allows each link within the business layer to access and upload information towards the public chain when they are granted permission from external regulators. The authentication of the public key can significantly improve the data capacity in the public chain and achieve the data traceability once receiving the access request from end users in the public chain. Within the public chain, the uploaded information is stored by the decentralised ledger from the authorised node in the private chain. When customers and international trade customs scan the QR code from the product packages, the request for accessing the public chain is initialised and sent to the system. A web page including the information of dairy products, such as farm location, processing methods, production dates and so forth will be shown on the smart devices that they have used for scanning.

4. CONCLUSIONS

An advanced agri-food supply chain ecosystem has been proposed and designed in this work (Figure 4.). The realisation methods of whole process recording and traceability management of quality information in the links of grazing, warehousing, transportation, consumption, and supervision are expounded. This ecosystem achieves the feasibility of visibility and traceability by introducing blockchain platform and a set of smart contracts across agricultural industries, supply chains, and commodities. Use of smart contracts and Azure Authenticator highly increased the security and protection of all information recorded and uploaded on blockchain.

However, there are still some future works that can be explored to optimise this proposed ecosystem including undertaking a review of the regulations and policies of Australian and international Agri-product logistics and transportations, import and export. To optimise the regulator part of the framework and the relationship between supply chain and regulators. We can undertake real-world experiments or demonstrations in an industrial complex. Also, we can test and design the consumer interface from front and back end to complete the whole ecosystem.

REFERENCES

1. European Union Legislation, 'Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety'.
2. Australian Government Department of Foreign Affairs and Trade, 'World Trade Organization-Agricultural Trade'. Available: https://www.dfat.gov.au/trade/organisations/wto/Pages/agricultural-trade
3. J. Hu, X. Zhang, L. M. Moga, and M. Neculita, 'Modeling and implementation of the vegetable supply chain traceability system', Food Control, vol. 30, no. 1, pp.341–353,2013.
4. N. K. Tsolakis, C. A. Keramydas, A. K. Toka, D. A. Aidonis, and E. T. Iakovou, 'Agrifood supply chain management: A comprehensive hierarchical decision-making framework and

a critical taxonomy', Biosystems Engineering, vol. 120, pp. 47–64, Apr. 2014.

5. M. Thakur, B. J. Martens, and C. R. Hurburgh, 'Data modeling to facilitate internal traceability at a grain elevator', Computers and Electronics in Agriculture, vol. 75, no. 2, pp. 327–336, Feb. 2011.
6. N. Patelli and M. Mandrioli, 'Blockchain technology and traceability in the agrifood industry', Journal of Food Science, vol. 85, no. 11, pp. 3670–3678, Nov. 2020.
7. D. Bumblauskas, A. Mann, B. Dugan, and J. Rittmer, 'A blockchain use case in food distribution: Do you know where your food has been?', International Journal of Information Management, vol. 52, p. 102008, Jun. 2020.
8. Z. Hao, D. Mao, B. Zhang, M. Zuo, and Z. Zhao, 'A Novel Visual Analysis Method of Food Safety Risk Traceability Based on Blockchain', International Journal of Environmental Research and Public Health, vol. 17, no. 7, 2020.
9. U.S. Food & Drug Administration, Guidance & Regulation (Food and Dietary Supplement), 'Food Safety Modernization Act (FSMA)'. Available: https://www.fda.gov/food/guidance-regulation-food-and-dietary-supplements/food-safety-modernization-act-fsma
10. Food Standards Australia New Zealand, 'Food Standards Code'. [Online]. Available: https://www.foodstandards.gov.au/code/Pages/default
11. Rod J. Polkinghorne, Jm Thompson, Jean-François J.-F. Hocquette, Dw Pethick., 'Overview of Meat Standards Australia (MSA) and cuts-based grading schemes.', Meat Research, vol. 2015, 29 (2), pp. 43–48.
12. Papert, M. and Pflaum, A. (2017), "Development of an ecosystem model for the realization of internet of things (IoT) services in supply chain management", Electronic Markets, Electronic Markets, Vol. 27 No. 2, pp. 175–189.
13. Gupta, S., Modgil, S., Gunasekaran, A. and Bag, S. (2020), "Dynamic capabilities and institutional theories for Industry 4.0 and digital supply chain", Supply Chain Forum, Taylor & Francis, Vol. 21 No. 3, pp. 139–157.
14. M. Degieter, X. Gellynck, S. Goyal, D. Ott, and H. De Steur, 'Life cycle cost analysis of agri-food products: A systematic review', Science of The Total Environment, vol. 850, p. 158012, Dec. 2022.
15. T. Agrawal, J. Angelis, W. Khilji, R. Kalaiarasan, and M. Wiktorsson, 'Demonstration of a blockchain-based framework using smart contracts for supply chain collaboration', International Journal of Production Research, pp. 1–20, Mar. 2022.
16. Casino, F., Dasaklis, T.K. and Patsakis, C., 2019. A systematic literature review of blockchain-based applications: Current status, classification and open issues. Telematics and informatics, 36, pp.55–81.
17. I. Eluubek kyzy, H. Song, A Y. Wang, and J. Zhou, 'Blockchain for consortium: A practical paradigm in agricultural supply chain system', Expert Systems with Applications, vol. 184, p. 115425, Dec. 2021.