CHAPTER 3

Blockchain Applications in Food Supply Chain

Abstract The food supply chain faces unprecedented challenges concerning human health, food security and safety, climate change, animal welfare. In addressing these challenges, ensuring transparency and traceability in the food supply chain is becoming increasingly important issue for reducing food loss and waste and ensuring food safety. In particular, digitalization and new information technologies that are rapidly developing with Industry 4.0 and their applications to the supply chain lead to significant improvements in traceability systems. One of these new technologies is blockchain. The rise of blockchain-based initiatives find use in providing traceability in bringing more transparency and efficiency to the agricultural and food supply chain. Typical outcomes of the chapter are; (i) To list the triple bottom line food supply chain challenges. (ii) To narrate the feasible tracking and tracing solutions with the support of blockchain technology.

Keywords Traceability · Validating labour conditions · Sustainability · Delivery challenges · Framework

3.1 Introduction

Food supply chains have become global and complex with multiple suppliers of raw materials and ingredients spread across the world (Roth et al. 2008). This makes it difficult to track the flow of raw materials

N. Subramanian et al., *Blockchain and Supply Chain Logistics*,
https://doi.org/10.1007/978-3-030-47531-4_3

and the products from the farm to the fork and to ensure traceability across the supply chain. Instances of food recalls have also become quite common with multiple products being recalled everyday due to quality and health concerns. This has also resulted in high profile cases like the peanut butter recall in the US, the horsemeat scandal in the UK and the baby milk powder adulteration in China. Powdered food products, spices and high value products like olive oil are particularly susceptible to adulteration. Consumers want to become more aware of the quality of the food they are consuming and will like to have the traceability information before they purchase the product. Retailers need to ensure such traceability and also track the condition of the products that is being transported.

Technologies like RFID or wireless sensor devices can be used to track the location and condition of the product respectively. Blockchain can integrate and manage each process and transaction throughout the agricultural supply chain in real time. Each transaction that is processed on the distributed ledger can carry transaction details and specific attributes for the product which can be added by members in the supply chain (Tian 2017; Tripoli and Schmidhuber 2018). Companies can input traceability information while keeping important proprietary or business-competitive information hidden. Supply chain members can identify and examine the product's movement along every step in the supply chain from the farm to the transportation and storage conditions and details as the product moves to the retailer and consumer (Tripoli and Schmidhuber 2018). Thus, Blockchain can enable retailers to share the provenance information with the customers.

3.2 Motivation and Challenges

All stakeholders involved the food supply chain (farmers, distributors, packers, processors, grocers, restaurants, traders) are driven by a need to demonstrate to their customers the superior quality of their processes and products (Smith 2008). But, this has proved to be a very difficult task because of multiple stakeholders involved in the chain and the geographical dispersion of the chain. The use cases of blockchain in food supply chain go beyond ensuring food safety. It also adds value to the current market by creating a distributed ledger in the network and balancing market price. Some of use-cases in food supply chain are given below, but these are not limited.

3.2.1 *Sharing Information for Traceability and Transparency*

Information about an end product should be as extensive, reliable and easily accessible as possible. QR code can allow sharing such information, for example, that provides access to all available information about origins of the individual components or production conditions, transportation and packaging. In food and beverage industry, such traceable, reliable information is also important for stakeholders in the production chain, so they can make sure they comply with the necessary regulations, and document that compliance. But before the data across multiple stages of the supply chain can be incorporated into the blockchain, they have to be verified by everyone involved in the network. This will provide the consumer with an uninterrupted information chain that can be examined anytime, and will guarantee that the product has been produced and transported under optimal conditions.

For example, early adopters of blockchain in the meat industry can be very successful, especially if combined with DNA codification (Sander et al. 2018). Thus, DNA samples from an animal can be used to identify its breed, and additional information such as country of origin, exposure to toxins and unregulated medication, among other key markers, can be collected. These data can be crosschecked with the blockchain record to assure the animal's authenticity and lifecycle and shared with customers (Galvez et al. 2018). Knowing the origin of meat produce has a key influence on consumers' purchasing decision process (Vukasovič 2009). Thus, a clear record of product history will improve buyer confidence that goods being purchased are from ethical sources (Saberi et al. 2019). Another example of blockchain technology adoption with using emerging technologies in food supply chain that a Chinese company, ZhongAn Online launched a blockchain-based farming program, called "GoGo Chicken" in order to provide customers to track organically farmed chickens, they have pre-purchased by using facial-recognition technology and also to monitor the health and movement of poultry through GPS tracking bracelets attached to legs. All information is recorded on blockchain ledger immutably and customers can track their movement how they grow and what they eat.

3.2.2 *Validation of Labour Conditions Across the Supply Chain*

Food companies and retailers have a difficult task of verifying that no unfair labour practices have been used across the supply chain. Once each worker has trusted identification represented on the blockchain, farmers or suppliers can then create and record a labour contract that specifies information such as payment terms, expected work hours or output, contract length and labor conditions. Workers can then receive payment digitally, of which the receipt is automatically recorded to the blockchain and payment confirmation is shared with organizations downstream. While blockchain is capable of recording the data, the success of this use case is predicated upon its adoption and enforcement. Similar to other labor-practice certifications, farmers and cooperatives could be incentivized to adopt this solution and in turn increase the value of their produce (Widdifield 2018).

3.2.3 *Improving Quality and Avoiding Recalls*

Product recalls are increasing concern for food manufacturers and retailers with lack of adherence to good manufacturing practices (GMP) being a primary reason for such recalls (Kumar and Budin 2006). Lack of capture and real-time monitoring of process data makes tracking of individual batches of production difficult. Tracking substandard products accurately and identifying further transactions of the products can help reduce the rework and recall (Saberi et al. 2019). Capturing process data using RFID or sensors and creating systems for alerts if the process parameters coupled with blockchain ensuring no tampering of data will help in real-time monitoring. This will help in improving product and process quality in production, storage and transportation and avoid costly recalls of food products.

Some challenges include tracking of fruit and vegetables sold loose that come from different farms, resistance from farmers to sharing too much information and creating complete data inputs from different nodes along a long value chain.

3.2.4 *Improving Sustainability in Food Supply Chain*

The outcomes of blockchain application seems to be promising in terms of sustainability gains in the form of reduced environmental impact and better assurance of human rights and fair work practices (Saberi et al.

2019). An example can be given to understand the sustainability impact of blockchain. The consumer product manufacturer Unilever built a consortium with the participation of British grocery retailer Sainsbury and packaging company Sappi in conjunction with three banking companies and pursued a year-long pilot blockchain project, called Trado model to manage transactions within tea supply chain among up to 10,000 farmers in Malawi (CISL 2019). By enabling project partners to reliably track products throughout the supply chain, the blockchain-based shared data system validated the sustainability of the tea farmers' agricultural practices easily and rewarded them appropriately. Tea farmers benefited from preferential pricing by focusing on methods designed to increase harvest without using more land. This blockchain-based project incentivized sustainable farming practices such as increased sustainable sourcing and livelihoods of smallholder farmers and made sustainable agriculture mainstream.

3.2.5 Avoiding Food Delivery Challenges

In a sharing economy powered by blockchain, companies have visibility in the presence of all unused logistics assets (trucks, trailers, construction equipment, warehouse capacity). Instead of waiting for customers to own and maintain fleets of logistics equipment, businesses can scale their capacity on demand. In other words, people have access to property rather than direct ownership. All participants along food supply chain can share the available unused assets on blockchain platform and utilize them.

3.3 Food Chain Use Case

French retailer Carrefour has launched blockchain information for 20 items including chicken, eggs, raw milk, oranges, pork and cheese, and will add more in the future with a focus on areas where consumers want reassurance, like baby and organic products. Customers can scan a QR barcode on a pomelo grapefruit with their phone and find out the date of harvest, location of cultivation, the owner of the plot, when it was packed, how long it took to transport to Europe and tips on how to prepare it (Thomasson 2019). Use of Blockchain to share product information with customers has resulted in faster sales of pomelo fruits and chicken for Carrefour. Sharing such information with customers is also

helping Carrefour to obtain customer trust. The initiative has proved most popular so far in China—where it is already common for shoppers to scan QR codes, followed by Italy and France, with some people spending as long as 90s reading the provenance information. While Carrefour is focusing the project on its own brands, it has also worked with Nestle on giving consumers access to blockchain data for its Mousline potato puree, allowing them to see it is only made from French potatoes (Thomasson 2019).

3.4 Framework with Future Directions

There are several adoption barriers to implement blockchain technology in food chain. As per Kayikci and Subramanian (2018), nine of them are explained below with a conceptual model shown in Fig. 3.1 is developed with Technology Acceptance Model (TAM) as a theoretical reference.

Interoperability: Interoperability is the ability of different digital data to acknowledge and communicate with each another. It is a crucial for connecting business process data and humans. Process data are captured

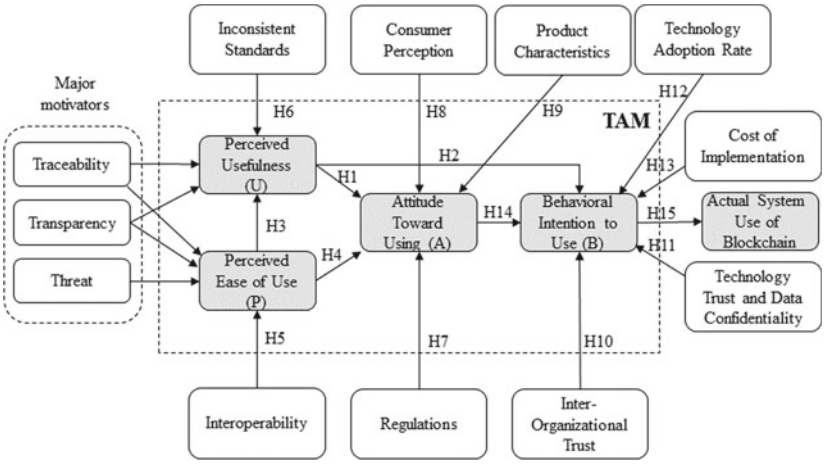

Fig. 3.1 Blockchain adoption model (*Source* Author)

from hashing, EDI, RFID, wireless sensor networks, ERP and data warehouses (Deloitte 2017; Francisco and Swanson 2018).

Inconsistent standards: Nonexistence of unique standard for blockchain technology is a serious issue for adoption (Casey and Wong 2017). There are a few initiatives to define industry standards for blockchain, one among them is the Blockchain in Transport Alliance (BiTA, https://bita.studio/) which involves thousands of companies in the transportation and logistics industry.

Regulations: There is no regulations set by industry or policy makers regarding blockchain implementation which poses a serious challenge to supply chains (Hackius and Petersen 2017).

Consumer perception: Customer preferences toward tracking food in the supply chain gains attention. If consumers are not sure about food safety and authenticity then it profoundly impacts company's bottom line (Pant et al. 2015).

Product characteristics: At the moment product characteristics such as provenance of components, material, and specifications are needed to verify by supply chain parties (Francisco and Swanson 2018). Public availability of blockchain database would reveal the characteristics to the people without any verifications.

Inter-Organizational Trust: Right now, consortium with big partners dictates the rules, which causes inter-organizational trust problems among small and medium enterprises (Hofman et al. 2017). Trust is regarded as an emergent property for honest interactions of different participants in the system (Christidis and Devetsikiotis 2016), therefore future blockchain consortium should inclusive and think about developing acceptable procedures for all partners in the supply chain.

Technology trust and data confidentiality: The data confidentiality and technology trust are important separately to verify every transaction on the distributed database before the data becomes the "undeniable truth" (Francisco and Swanson 2018).

Technology Adoption rate: As we know the acceptance and implementation depends on the higher rate of successful technology adoption of emerging technologies (Hackius and Petersen 2017).

Cost of Implementation: Cost-saving is the ultimate driver for companies to go for technology adoption (Crosby 2017). As all new technologies right now the capital cost of blockchain technology is very high because of the proof-of-work algorithm used requires significant computing power to process transactions (ESC 2017).

3.5 Key Takeaways

The chapter summarises few process and people related challenges to adopt blockchain technologies in food supply chain. The proposed research model sets out several hypotheses that would hinder various attributes of technology adoption model. These needs empirical verification from different economies.

References

Casey, M. J., & Wong, P. (2017). Global supply chains are about to get better, thanks to blockchain. *Harvard Business Review*.

Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the Internet of Things. *IEEE Access, 4,* 2292–2303.

CISL. (2019). *Trado: New technologies to fund fairer, more transparent supply chains*. University of Cambridge Institute for Sustainability Leadership. Available at: https://www.cisl.cam.ac.uk/resources/sustainable-finance-publications/trado-new-technologies-to-fund-fairer-more-transparent-supply-chains. Accessed 27 October 2019.

Crosby, M., Pattanayak, P., Verma, S., & Kalyanaraman, V. (2017). Blockchain technology: Beyond bitcoin. *Applied Innovation Review, 2,* 6–10.

Deloitte. (2017). *Global Dairy Sector: Trends and opportunities* (White Paper). Deloitte. Available at: https://www2.deloitte.com/content/dam/Deloitte/ie/Documents/ConsumerBusiness/ie_Dairy_Industry_Trends_and_Opportunities.pdf. Accessed 20 December 2019.

ESC. (2017). *Top five enterprise blockchain challenges that must be overcome in 2018*. ESG Intelligence. Available at: https://esg-intelligence.com/blockchain-articles/2017/11/13/blockchain-challenges-2018/. Accessed 20 December 2019.

Francisco, K., & Swanson, D. (2018). The supply chain has no clothes: Technology adoption of blockchain for supply chain transparency. *Logistics, 2*(2), 1–13. Available at: www.mdpi.com/2305-6290/2/1/2/pdf. Accessed 20 December 2019.

Galvez, J. F., Mejuto, J. C., & Simal-Gandara, J. (2018). Future challenges on the use of blockchain for food traceability analysis. *TrAC Trends in Analytical Chemistry, 107,* 222–232.

Hackius, N., & Petersen, M. (2017). Blockchain in logistics and supply chain: Trick or treat? In *Proceedings of Hamburg International Conference of Logistics* (pp. 3–18). Hamburg, Germany.

Hofman, W., Spek J., & Brewster, C. (2017). *Applying blockchain technology for hyperconnected logistics*. pievent. Available at: https://www.pi.events/

IPIC2017/sites/default/files/IPIC2017-Workshop-2.2_presentations.pdf. Accessed 20 December 2019.

Kayikci, Y., & Subramanian, N. (2018). Feasibility of food loss reduction with blockchain in the merging economy context. *Proceedings of the 23rd International Symposium on Logistics (ISL 2018)* 255:261. ISBN-13 9780853583240.

Kumar, S., & Budin, E. M. (2006). Prevention and management of product recalls in the processed food industry: A case study based on an exporter's perspective. *Technovation, 26*(5–6), 739–750.

Pant, R. R., Prakash, G., & Farooquie, J. A. (2015). A framework for traceability and transparency in the dairy supply chain networks. *Procedia—Social and Behavioral Sciences, 189*, 385–394.

Roth, A. V., Tsay, A. A., Pullman, M. E., & Gray, J. V. (2008). Unraveling the food supply chain: Strategic insights from China and the 2007 recalls. *Journal of Supply Chain Management, 44*(1), 22–39.

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research, 57*(7), 2117–2135.

Sander, F., Semeijn, J., & Mahr, D. (2018). The acceptance of blockchain technology in meat traceability and transparency. *British Food Journal, 120*(9), 2066–2079.

Smith, B. G. (2008). Developing sustainable food supply chains. *Philosophical Transactions of the Royal Society B: Biological Sciences, 363*(1492), 849–861.

Thomasson, E. (2019). *Carrefour says blockchain tracking boosting sales of some products*. Available at: https://uk.reuters.com/article/us-carrefour-blockchain-idUKKCN1T42A5. Accessed 2 August 2019.

Tian, F. (2017). A supply chain traceability system for food safety based on HACCP, Blockchain & Internet of Things. In *2017 International Conference on Service Systems and Service Management* (pp. 1–6). Dalian. https://doi.org/10.1109/icsssm.2017.7996119.

Tripoli, M., & Schmidhuber, J. (2018). *Emerging opportunities for the application of blockchain in the agri-food industry*. FAO and ICTSD: Rome and Geneva. Licence: CC BY-NC-SA, 3.

Vukasovič, T. (2009). Consumer perception of poultry meat and the importance of country of origin in a purchasing making process. *World's Poultry Science Journal, 65*(1), 65–74.

Widdifield, J. (2018). *Brewing blockchain: Tracing ethically sourced coffee*. Available at: https://www.ibm.com/blogs/blockchain/2018/08/brewing-blockchain-tracing-ethically-sourced-coffee/. Accessed 2 August 2019.