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BLOCKCHAIN AND THE FOOD SUPPLY CHAIN: THE FUTURE OF FOOD TRACEABILITY

PAMELA LATTANZI – SERENA MARIANI*

SUMMARY: 1. Introduction. – 2. "Blockchainizing" Food Supply Chains: Potential Applications. – 2.1. Traceability in the EU Food Legislation. – 2.1.1. Blockchain-Based Traceability in Practice. – 3. Future Challenges.

1. *Introduction*

The ability to trace foodstuffs backwards and forwards along all the stages of the supply chain is of crucial importance for assuring food safety because it empowers the competent national authorities and businesses to facilitate outbreak responses and food fraud deterrence. Accordingly, in setting out the general principles and requirements for the food safety regulation in the European Union, Regulation (EC) No 178/2002 (also known as the General Food Law, GFL) requires that food and food ingredients be traceable "from farm to fork", and therefore it imposes on food business operators (FBOs) a general obligation to ensure food traceability.

Current traceability systems face several challenges due to multiple factors such as the globalization and complication of agri-food supply chains, which are increasingly composed of many players of all sizes and abilities; the information asymmetry in the market, as well as the great reliance upon paper-based record keeping, susceptible to mistakes and vulnerable to fraud, or upon internal computer systems, which make data unusable for other companies and cause difficulties for stakeholder integration.[1]

Many technological innovations are in place for tackling such challenges, among them blockchain technology which is gaining substantial attention because it is not only "a way to efficiently pass down along the supply chain the traceability information" (like QR-codes and RFDI), but it also "helps to endorse the credibility of the information", in doing so it "provides the agri-food market with a trustworthy framework in which to store every passage of the production and distribution chain".[2]

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[1] S. Pearson and others, 'Are Distributed Ledger Technologies the Panacea for Food Traceability?' (2019) 20 Global Food Security 145; Ching-Fu Lin, 'Blockchainizing Food Law: Promises and Perils of Incorporating Distributed Ledger Technologies to Food Safety, Traceability, and Sustainability Governance' (2020) 74 Food and Drug Law Journal 586; G. Mirabella and V. Solina, 'Blockchain and Agricultural Supply Chains Traceability: Research Trends and Future Challenges' (2020) 42 Procedia Manufacturing 414.

[2] R. Berti and M. Semprebon, 'Food Traceability in China' (2018) 13 European Food and Feed Law Review 529.

Blockchain is a subset of distributed ledger technologies (DLTs)[3] "employing cryptographic techniques to record and synchronise data in chains of blocks".[4]

In short, it "is a distributed ledger based on a peer-to-peer (P2P) network, in which participants, called nodes, agree on a unique version of the distributed data storage through a shared consensus mechanism. All information stored inside the ledger is digitally signed employing cryptographic primitives and data-authenticity is guaranteed by the use of asymmetric key-pairs".[5]

There are many different blockchain technologies with distinct technical and functional configurations as well as internal governance structures.[6] Moreover, blockchain technology may be combined with other innovative technologies, such as the Internet of Things (IoT) and Artificial Intelligence (AI), and it can also be used as a programmable platform that enables new applications such as smart contracts (i.e. self-executing software code).[7]

The main blockchain features – decentralization, tamper-resistance, transparency, and security[8] – make it one of the best promising solution to food traceability issues and, more in general, to food supply chain management issues. However, it is still in its early stage of development and several open challenges need to be addressed before it can be widely used.

This paper, therefore, aims to investigate the potential of blockchain technologies in revolutionizing food supply chains. It will analyse the benefits and challenges of blockchain adoption in food supply chains, especially for traceability purposes.

2. *"Blockchainizing"[9] Food Supply Chains: Potential Applications*

Food chains are complex and vulnerable systems. They are composed of multiple stages and made up of different operators and processes, covering food production, transport, distribution, marketing, and consumption,[10] which have become even more

[3] 'DLTs are particular types of databases in which data is recorded, shared and synchronised across a distributed network of computers or participants', S. Nascimento and A. Polvora (eds), *Blockchain Now and Tomorrow: Assessing Multidimensional Impacts of Distributed Ledger Technologies* (Publications Office of the European Union 2019) 13.

[4] Ibid.

[5] J. Grecuccio and others, 'Combining Blockchain and IoT: Food-Chain Traceability and Beyond' (2020) 15 Energies 2.

[6] "They can be distinguished depending on who can read, execute and validate transactions. When anyone can read and access a blockchain it is categorised as "public" or "open" which means that anyone can access a whole blockchain and read its contents. When only authorised entities have access, a blockchain is considered closed or private. Blockchains can be further categorised as 'permissionless' or 'permissioned' depending on who can send transactions and who can validate them. If anyone can send and validate transactions, the blockchain is called permissionless. If entities need to be authorised to execute or validate transactions, or both, the blockchain is called permissioned'. Moreover, hybrid blockchains may combine different aspects. Nascimento (n 3) 14.

[7] Spark Legal Network and others, *Study on Blockchains: Legal, Governance and Interoperability Aspects. A Study Prepared for the European Commission DG Communications Networks, Content & Technology* (Publications Office of the European Union 2020).

[8] Nascimento (n 3) 16.

[9] Lin (n 1).

[10] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions, Farm to Fork Strategy. For a Fair, Healthy and Environmentally-friendly Food System, COM(2020) 381 final, 20 May 2020, para. 2.

complex with globalisation and outsourcing.[11] The vulnerability of the value-added chain of agricultural and food products requires great attention and remarkable efficiency in order to ensure high safety and quality standards at the lowest possible cost.[12]

Currently, the management of food supply chains is associated with numerous challenges such as information disclosure, risk assessment and management, product tracing, food fraud, consumers' trust and stakeholders' reputation.

In this context, blockchain can help simplify these challenging tasks. Blockchain is designed to be decentralized and irreversibly store data, thus it represents an interesting solution to classic and often outdated databases based on centralized systems, which lack trustworthiness due to the higher risk of data tampering.[13]

More specifically, blockchain-based food chains have the potential to improve transparency, efficiency, and safety.

Transparency is highly valued by public and political agendas and demanded by civil society. Information disclosure in the food chain is particularly crucial for companies in order to maintain consumers' trust.[14]

The advantages of applying blockchain for transparency purposes rest on the irreversibility of information along the chain: once data have been stored and verified, they are immutable. In fact, companies cannot modify or select data that are beneficial to their own reputation without altering the entire blockchain history.[15] These data are equally and instantly available to all the operators involved, creating a direct link among them along the supply chain.

The information captured in a blockchain can be used to establish many food attributes, such as provenance, ingredients, allergens, safety, quality, and consumers can depend on smart labels to access information, increasing the trustworthiness of the brands.[16]

Transparency is also important in the field of the environment and sustainability: a blockchain-based supply chain enables a circular economy since it gives consumers confidence about the origin of the food or whether the packaging is recycled or first-use.[17]

The rise in efficiency due to the adoption of blockchain is achieved through the use of smart contracts and the combination with the latest IoT technologies.

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[11] J. Duan and others, 'A Content-Analysis Based Literature Review in Blockchain Adoption within Food Supply Chain' (2020) 17 International Journal of Environmental Research and Public Health 1784.

[12] H. Folkerts and H. Koehorst, 'Challenges in International Food Supply Chains: Vertical Co-ordination in the European Agribusiness and Food Industries' (1998) 100 British Food Journal 385.

[13] G. Baralla, A. Pinna and G. Corrias, 'Ensure Traceability in European Food Supply Chain by Using a Blockchain System', in *2019 IEEE/ACM 2nd International Workshop on Emerging Trends in Software Engineering for Blockchain* (IEEE 2019).

[14] A. Mol, 'Transparency and Value Chain Sustainability' (2015) 107 Journal of Cleaner Production 154.

[15] J. Galvez, J. Mejuto and J. Simal-Gandara, 'Future Challenges on the Use of Blockchain for Food Traceability Analysis' (2018) 107 Trends in Analytical Chemistry 222.

[16] G. Spoto, 'Gli Utilizzi della Blockchain e dell'Internet of Things nel Settore degli Alimenti' (2019) 13 Rivista di diritto alimentare 25.

[17] R. Casado-Vara and others, 'How Blockchain Improves the Supply Chain: Case Study Alimentary Supply Chain' (2018) 134 Procedia Computer Science 393.

The use of smart contracts can increase efficiency because of their self-executing nature. In particular, smart contracts remove intermediaries, rapidly evaluating, certifying, and allowing trusted transactions among operators without the need for a central authority.[18]

In addition, the combination with IoT devices creates an efficient and high-speed network along the supply chain: sensors reduce manual errors by automatically capturing and storing real-time information about a product (e.g. quantity, temperature, humidity). Reliable and real-time data flows are very important especially for frozen and fresh food since their quality is easily affected by outer environments.[19]

With respect to safety, during the past decades many food scandals and foodborne disease outbreaks have been reported and this is the reason why consumers are extremely concerned about food safety.[20]

Public health and food safety issues can be more easily addressed by blockchain technology:[21] the efficient collection of critical data along the chain allows quality checks during all the different stages of food production, transport, distribution, and marketing. By way of illustration, blockchain offers a solution to the problem of checking the maintenance of adequate cold chain conditions during production, transport and storage of frozen and perishable foods, conditions that are critical to food safety.

Moreover, the use of blockchain protocols facilitates and speeds up the complicated food recall process through traceability mechanisms.

2.1. *Traceability in the EU Food Legislation*

According to the General Food Law, the fundamental goal of food traceability is the removal of unsafe food from the market. In addition, traceability could help to ensure fair trading amongst operators as well as the reliability of information supplied to consumers in terms of substantiating claims made by manufacturers. To these ends, mandatory requirements for traceability are set out in Art. 18 GFL, which applies to all food and ingredients placed on the EU market.[22]

In line with the principles of food traceability laid out in international standards provided for the Codex Alimentarius, Art. 18 GFL embraces the "one step back-one step forward" approach. Therefore, it requires that FBOs are able to identify any person from whom they have been supplied with a food/raw material and to whom their products have been supplied (excluding final consumers). "The burden of reconstructing the whole food chain when an incident occurs is on the authorities and to that end traceability information has to be made available to those authorities on demand".[23] Consumers are not necessarily provided with traceability information,

[18] Baralla (n 13).

[19] Duan (n 11).

[20] K. Demestichas and others, 'Blockchain in Agriculture Traceability Systems: A Review' (2020) 10 Applied Sciences 4113.

[21] Q. Lin and others, 'Food Safety Traceability System Based on Blockchain and EPCIS' (2019) 7 IEEE Access 20698.

[22] Art. 18 also applies to feed traceability. Additional requirements are laid down in other normative acts for specific food categories.

[23] B. Van Der Meulen (ed.), *EU Food Law Handbook* (Wageningen Academic Publisher 2014) 360.

since "traceability is conceived as a step-by-step process: information is not required to follow the entire production process and distribution chain through to the market, but is rather confined to the specific stage of the production concerned".[24]

It is important to note, that "article 18 is worded in terms of its goal and intended result, rather than in terms of prescribing how that result is to be achieved".[25] The design of the traceability system is up to FBOs and it is also left to their discretion to put in place internal traceability (aimed at establishing a link between incoming and outgoing products) and the level of detail of the adopted traceability system.[26]

Recently, the Commission has concluded the Fitness Check on the General Food Law Regulation, which also covers the implementation of mandatory traceability requirements.[27]

The results of the analysis point out that the EU-wide traceability has significantly contributed to assuring food safety. The superiority of the EU traceability system vis-à-vis other non-EU countries is also underlined.

Nevertheless, the assessment reveals that there are some aspects that could be improved, since "it still occurs that the traceability chain is interrupted because of errors or incomplete documentation at a particular stage".[28] Moreover, it is reported that the EU-wide traceability does not always result in targeted withdrawals when the risk involved with suspected products is considerable.

Even if the EU-wide traceability is not perceived as burdensome by the majority of FBOs, who believe that the benefits of mandatory traceability outweigh the corresponding costs, a significant part of consulted businesses (in particular SMEs) ranked the cost of traceability compliance (together with labelling, authorisations, registration, and certification) as one of the most costly of all EU food law requirements. This high cost could depend on the fact that the majority of SME respondents have in place more extensive traceability systems than what is required by the GFL Regulation, with a direct impact on the increased administrative burden.[29]

Many studies underline that blockchain technology may help in overcoming such limitations and improving the benefits of traceability.

2.1.1. *Blockchain-Based Traceability in Practice*

Blockchain can efficiently satisfy all traceability requirements in all stages of the food supply chain. By using blockchain technology, the system can establish a collaborative network of trustworthy information from farmer to consumer. The movements of products are recorded by each operator along the chain and the network contains all the data flow about a final product and its origin. Moreover, the adoption of blockchain protocols could quickly trace single ingredients along the

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[24] L. Salvi, 'Traceability and Hygiene Package' in L. Costato and F. Albisinni (eds) *European and Global Food Law* (Wolters Kluwer 2016) 285.
[25] Guidance on the Implementation of Articles 11, 12, 14, 17, 18, 19 and 20 of Regulation (EC) N° 178/2002 on General Food Law, Conclusions of the Standing Committee on the Food Chain and Animal Health, 26 January 2010, 17.
[26] Ibid.
[27] European Commission, Commission Staff Working Document the Refit Evaluation of the General Food Law (Regulation (EC) No 178/2002), SWD (2018) 38 final, 15 January 2018.
[28] Ibid.
[29] Ibid.

chain and verify the compliance of foods with their labels (i.e. food authentication), saving time and unnecessary costs.

One of the most well-known applications of blockchain in the food chain for traceability purposes is IBM Food Trust. In 2016 a pilot study was conducted in collaboration with Walmart to trace mangoes and Chinese pork from the final product to its origin. The study has shown that IBM Food Trust can significantly reduce the traceability time: the identification of the provenance of mangoes was reduced from approximately 7 days to 2.2 seconds. Currently, IBM is collaborating with many big food companies, such as Nestlé and Driscoll's, to identify new fields that can benefit from blockchain application.

In the past years, other pilot studies have been carried out by AgriDigital in the Australian grain industry, Provenance in the fish industry and AgriOpenData for biological food.

Following these leading studies, nowadays many startups, companies, and universities are creating solutions in the field of food traceability by using blockchain.

For example, Moyee Coffee is developing a system from Ethiopia to Europe to track coffee in a transparent manner. Seville University is testing a project named Olivacoin in order to minimize abuses and frauds in the olive oil sector. In China, ZhongAn is using blockchain to monitor the life of chickens on organic farms to address consumers' concerns. In Europe, Carrefour launched a blockchain information network for fresh products, such as oranges and lemons, to ensure greater traceability. In the area of frozen food, Bofrost has started to use blockchain to trace cod fillets and artichoke along the cold chain.

3. *Future Challenges*

In the European Union, food should be traced and tracked in all production, processing, and sales stages: an efficient traceability system provides an exact recording of product movements. However, the existing systems make it impossible to easily find out the entire product's movements along the chain.[30]

In this framework, executing food traceability by using blockchain has numerous benefits in terms of time saved, reduced costs and risks as well as increased trust[31]. The immutable and real-time data flow improves the visibility of the movement of products across the entire supply chain, thus speeding up the tracing process in an efficient, reliable, and transparent manner, allowing food authentication and targeted food recall for the benefits of operators and consumers. The adoption of blockchain could increase the trust of consumers and civil society in a brand and could be used as a tool for building strategic partnerships among stakeholders.

However, blockchain is not a panacea for all problems. It should be considered that there are a number of technical and regulatory challenges.

First of all, the food supply chain is made up of a large number of stakeholders from different and distant geographical areas, whose technological knowledge may be

[30] R. Scharff, 'State Estimates for the Annual Cost of Foodborne Illness' (2015) 78 Journal of Food Protection 1064.
[31] Galvez (n 15).

significantly diverse and who may be reluctant to adopt costly and not well-understood technologies.[32]

Moreover, blockchain has low scalability and cannot store an indefinite amount of data: the recording of a great number of data can slow down the network and the speed of validation. Furthermore, blockchain technology may not offer an added value to the existing food chains, especially to short food supply chains.[33]

In this challenging context, the legal framework has to be updated in order to safeguard consumers' rights and protect companies' intellectual property (IP), especially trade secrets. In fact, the adoption of blockchain technology cannot eliminate the risk of raw data manipulation by operators before their upload into the system, to the detriment of consumers: the authenticity of the initial data is not guaranteed by the use of blockchain. Also, the uploading of confidential information in the blockchain could lead to misappropriation of trade secrets by other operators, thus undermining the company's assets. Therefore, the law has to provide effective tools to protect IP in the blockchain era.

Furthermore, compliance between agreements and smart contracts needs to be ensured: the consequences of errors in smart contract design have to be addressed in order to avoid damage to business relations among stakeholders.[34]

Considering the remarkable investments required to develop a blockchain-based supply chain, another great challenge is to identify who owns each blockchain infrastructure, who owns the collected data, and to establish privacy mechanisms[35]. The law also needs to determine data standardisation in the food domain and to set a legal minimum for how long blockchain-based traceability records must be kept and by whom so that data are correctly archived.[36] Lastly, the legal framework needs to set common standards that can facilitate data collection in blockchain-based food supply chains across international borders and jurisdictions.[37]

In conclusion, the food sector is in a key position for exploring the potential of blockchain but it is necessary to design a strong digitalisation strategy for agrifood businesses, to develop common standards for the blockchain implementation, and to design a clear regulation for blockchain-based food chains: the creation of a better regulatory environment is fundamental for "blockchainizing" food law.[38]

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[32] Demestichas (n 20).
[33] Lan Ge and others, *Blockchain for Agriculture and Food. Findings from the Pilot Study* (Wageningen Economic Research 2017).
[34] Ibid.
[35] Pearson (n 1) 148.
[36] Ibid.
[37] M. Tripoli and Joseph Schmidhuber, *Emerging Opportunities for the Application of Blockchain in the Agri-food Industry* (FAO and ICTSD 2018) 21.
[38] Lin (n 1).