Wine Traceability and Counterfeit Reduction: Blockchain-Based Application for a Wine Supply Chain

Ulpan Tokkozhina[1,2], Joao C Ferreira[1,3,4], and Ana Lúcia Martins[1,2(✉)]

[1] Iscte - Instituto Universitário de Lisboa, 1649-026 Lisbon, Portugal
{ulpan_tokkozhina,jcafa,almartins}@iscte-iul.pt
[2] Business Research Unit (BRU-IUL), Lisbon, Portugal
[3] ISTAR-IUL, Lisbon, Portugal
[4] Inov Inesc Inovação—Instituto de Novas Tecnologias, 1000-029 Lisbon, Portugal

Abstract. With the growing number of counterfeits in food supplier chains, one of the most important subjects to a final consumer is the assurance of product legitimacy and safety to consume. In this paper, we develop an approach towards wine traceability, with main objectives on combating counterfeit and increasing brand reputation by assuring the origin of wine to the final consumer. We build an architecture for a blockchain-based system to track and record all the main transactions between the supply chain participants from the moment the grapes are harvested until the moment when the final consumer is making a decision to purchase the wine. This application shows the enormous potential of blockchain technology to reduce counterfeiting levels and assure the final consumer with the origin of the wine, potentially avoiding health risks that counterfeit wine can cause, and thus increasing the wine brand reputation.

Keywords: Blockchain · Supply chain · Wine counterfeiting

1 Introduction

In recent years, major organizations such as technology firms and financial entities have made significant investments in blockchain-based technologies with the goal of fundamentally transforming business applications and move towards decentralization of processes. Blockchain technology (BCT) can be characterized as a distributed ledger, where all the historical transactions are tamper-proof and transparent to all the network participants; at the same time all the information within the ledger is immutable, which makes it secure [1]. BCT is based on a decentralized nature, which implies a high level of transparency [2], and can be implemented to facilitate the execution of safe corporate procedures and the automation of inter-company transactions.

Additionally, BCT represents a significant potential for small and medium-sized businesses who lack the resources necessary to engage in new technologies and are often left behind when a technological leap happens. Various sectors were studied as

A. L. Martins et al. (Eds.): INTSYS 2021, LNICST 426, pp. 59–70, 2022.
https://doi.org/10.1007/978-3-030-97603-3_5

possible examples for BCT implementation starting from healthcare [3, 4], e-government [5, 6] and food traceability [7, 8], to fashionable products [9], diamond authentication [10, 11] and property rights tokenization [12].

Unique features of BCT bring an enormous potential to modern supply chains (SCs), allowing to build well established business processes that bring innovativeness in terms of transparency and enhanced trust between stakeholders [13]. Small and medium businesses may innovate and gain an advantage via blockchain transformation by using BCT-based services and developing their own applications, such as decentralized applications, or DApps. Some examples of application cases may include marketplaces for renting or selling properties on BCT-based peer-to-peer platforms (real estate); managing claims (insurance); monitoring and tracking freight movement (logistics); addressing security (IoT); and ensuring food safety via IBM's Food Trust Network, which connects distributors, retailers, producers, and regulators in the food industry [14].

Regarding enhanced transparency of business processes, BCT poses a great potential to reduce counterfeit in various sectors for different types of products, such as drugs [15], luxury products [16], food fraud [17] etc. One of the products that is facing a high volume of counterfeit and fraud scams is wine. For instance, European Union is facing with nearly 1.3 billion Euros of counterfeit wine trade per year, which makes 3.3% of the whole industry and is causing such consequences as economic level damage, brand reputation loss and potential health issues of final consumers [18]. Thus, this study is focused on a wine industry and the potential benefits that BCT-based application can bring to it.

Thus, the purpose of this paper is to investigate the ability of a BCT-based solution in providing a safe and veritable wine to the final consumer. The goal of this study is therefore to explore the potential counterfeit reduction and traceability enhancement enabled by BCT application throughout the SC by proposing an architecture of a smart contract for a wine distribution SC. This paper is built as following: Sect. 2 reviews the current literature and identifies current state of the art – SC principles for BCT and the types of BCT existing. Section 3 is dedicated to the wine production and counterfeiting; it also shows the current architecture of a wine SC and defines the quality and traceability standards for food industry. Section 4 talks about methodology applied, and Sect. 5 introduces the implementation itself. Section 6 provides the conclusion and future gaps that can be addressed.

2 Literature Review

BCT is a Distributed Ledger Technology (DLT), which is an immutable database of information about each transaction that is shared across a network of participants [19]. This technology is based on the concepts of decentralization and disintermediation, which means that data may be collected, stored, and updated in a dispersed way by all network participants [20]. This kind of architecture enables actors to store and exchange data in a synchronized manner, at the same time guaranteeing their integrity via consensus-based validation procedures and cryptographic signatures [21]. The governance is based on a broad and dispersed system of mutual trust in which no actor may assert dominance and in which decision-making is consensus-based [22].

2.1 Supply Chain Principles Based on Blockchain

BCT is an integrative technology designed to defragment SCs by synchronizing the data captured along it. More precisely, each product is defined by a processing cycle involving many actors. Each actor is assigned a unique digital identity (supplied by an accreditation provider) and is responsible for documenting (tracking) critical information about the product's (or service's) development procedures and status throughout the network. Each product is given a unique digital identity via the use of a unique tag (a barcode, RFID or QR Code). This tag is a one-of-a-kind digital cryptographic identification that links the physical product to its network-based virtual identity, allowing any actor to access all or any related information. To safeguard the process against theft and counterfeiting, BCT entails the generation of a digital token linked with the digital identity whenever the product/service is manufactured or transferred amongst SC actors [23]. As a result, the ultimate product recipient (e.g. a final consumer) may verify the token and trace the item's history back to its inception [24].

When transferring (or selling) a product to another actor, both parties have to sign a digital contract to verify the transaction [25]. Once all parties have signed the contract, the transaction's information will be kept. The actors' privacy may be adjusted according to the subject's preferences: they can stay anonymous, but their identity must be verified by the trust-building certifiers [23]. Thus, BCT's fundamental features that are essential for the business processes improvement of SC's are as follows:

- **Transparency:** Any network participant may see all recorded transactions at any time [26], that is why BCT is considered as a trustworthy technology.
- **Immutability:** BCT guarantees that all data is completely unalterable and uncorruptible. The sole exception is when a node's control exceeds 51% [27].
- **Decentralization:** By its nature, BCT eliminates a need in a central entity, who is usually responsible for transaction verifications [28].
- **Autonomy:** BCT is a consensus-based system that is available to all networks participants and guarantees same information access and visibility throughout all the participants [29] and may be changed only with the agreement of all members.
- **Anonymity:** Both the data transmission and the individual transaction may be anonymous, as long as the person's blockchain address is known [30].
- **Security:** Data security in terms of information sharing is guaranteed for BCT-based applications [31] as it is a tamper-proof technology.
- **Authenticity:** BCT enables access to verified information and data about transactions[32] and protects SCs from counterfeiting and fake assets [33].

Although the principles of transparency, fair trade, and sustainability are increasingly important in customers' purchasing decisions, most companies still deal with complex, non-integrated SCs with high exposure to risks towards, but not limited to counterfeit, human rights abuses, and other illegal practices. Implementation of BCT in SC cases enables organizations to manage business processes is a more active and efficient way [34], guaranteeing the truthfulness of the transaction data and a possibility to trace backwards the production of a particular product [35].

2.2 Types of Governance in Blockchain and Smart Contracts

BCT architecture may be permissioned or permissionless from a governance perspective. The permissioned (private or authorized), chain is an alternate development to the unauthorized chain (the one where anybody may join) [36] with Bitcoin and Ethereum serving as examples. Transparency is limited to authorized participants in this instance, making it impossible to handle data that need some level of privacy [37]. There are two kinds of roles in this sense: (1) **participants -** who are restricted to using the system (2) **validators -** who have access to the system and a copy of the current ledger. Validators are in charge of the distributed consensus process [38].

Permissionless BCT systems (public or unauthorized), vice versa, do not need owners and allow for the ownership of a copy of the updated ledger to be shared among all participants. Participants may also act as validators in this scenario, and are therefore accountable for both the distributed consensus process and the system's integrity [39].

From an immutability standpoint, public blockchain transactions are much more difficult to manipulate due to the increased number of participants who keep the records.

The primary distinction between the three blockchain types is that the public blockchain is fully decentralized, while the consortium blockchain is partly decentralized. The private blockchain, on the other hand, is wholly centralized and managed by a single node.

One of the biggest innovations that BCT brings is the automation. Transactions can be automatically triggered between the nodes, when predefined criteria are met; this is enabled with the use of smart contracts, which can be described as digital protocols that automatically execute contract terms [40]. The use of smart contracts eliminates the need in third-parties, that usually execute transactions and, as a result, improves SC efficiency [41]. Like this, smart contracts provide transparency, thus improving trust among stakeholders [42].

3 Wine Production and Counterfeiting

Wine production includes all kinds of activities that allow the transformation of grapes into wine. There are five basic stages when making wine: (1) Harvesting; (2) Crushing; (3) Fermentation; (4) Pressing; (5) Aging; and finally (6) Bottling. It all starts at the "raw material" stage, which is the grape harvesting, then it goes throughout all the necessary procedures in order to produce wine and give it to the bulk wine distributor. This is only the wine production flow, but after that more stakeholders are involved in processes like bottling, transportation, warehouse and retailing points distribution etc.

The current architecture of a wine SC is based on a barcode system (GS1) and according to the Standards defined by GS1, stakeholders have to fill in some mandatory information throughout each stage of the SC flow, which includes the following [43]:

Grape Grower - Name and address of the vineyard, plot map reference, size of plot/number of wines, wine variety, contract details.

Wine Producer - Identification of the wine producer, product identification, shipping container identification, quality of wine dispatched, batch number of each product.

Bulk Distributor -wine container Serial Shipping Container Code (SSCC).

Transit Cellar - identification of the transit cellar; identification of a container; product identification; quality of the wine dispatched; batch number of each product.

Distribution - SSCC of the inbound pallet, SSCC of the outbound pallet, links between the SSCC of the created pallet and the SSCC of the pallets used in its creation, Global Location Number (GLN) of the retail location to which the pallet is dispatched.

Retail - Global trade item number; lot number; packaging date; batch/lot number [43].

3.1 Wine Counterfeit

Wine counterfeiting itself has many edges, from production fraud to wine investment fraud; when talking about production fraud/counterfeit, final consumers have an impression of buying a specific good quality wine, when in reality the drink can be harmful and dangerous to health [44]. This counterfeiting poses very serious problems for society, implying not only into financial losses but also human losses.

Human losses –Earlier this year, 26 people died and 80 had a heavy poisoning after consuming counterfeit alcohol in Dominican Republic [45]. In Turkey, due to a rise on alcohol taxes, homebrewing became popular and in the end of 2020, 44 people died after consuming counterfeit bootleg liquor with ethyl alcohol [46]. More than 700 people died in Iran in 2020 due to a deadly methyl poisoning of a counterfeit alcohol [47].

Financial losses: There is around €2.8 billion sales losses every year across EU because of counterfeit wine and other spirits [48], which leads not only in sales loss per se, but to consequences such as workplace reductions for registered manufacturers.

Under these circumstances, BCT as a transparent and tamper-proof technology with an ability to address and reduce counterfeiting levels, is inducing growing interest from the side of wine producers and wine related SCs.

3.2 Quality and Traceability

In general, defining the quality of a product is difficult since it is dependent on a variety of variables and may take on a variety of meanings based on the perspective of the SC players. While the term "quality" is often linked with goods, it really refers to processes and material flows. Indeed, according to [49]. Quality refers to both the physical characteristics of the meal and the methods by which those properties were obtained. The capacity to trace the whole route used to get the final result is critical for ensuring its quality, for example, by detecting mistakes in real time and halting the process if it does not comply with criteria.

[49] established a list of categories for formalizing the quality standards or quality control systems used in agri-food production. We accept the fundamental definition given by the International Standards Organization (ISO), specifically ISO 8402:1994 [50], which defines quality as "the sum of a product's or service's features and qualities that affect its ability to fulfill expressed or inferred customer requirements." In simpler terms, a product is considered to be of high quality if it meets a variety of criteria and meets the user's specifications.

Quality is also associated with maintaining provenance, or information about the area in which the product was produced. Typically, knowledge regarding the origins

and producers of the product is lost as the commodity travels downstream from the farmer [51]. As a result, a product may be difficult to track in future. [52] found in their research that both quality and safety may contribute to customer trust, and both are related to traceability. The findings, particularly in Italy, demonstrated significant correlations between traceability as a tool for food safety by offering recall and food quality mechanisms. Another fundamental issue that must be addressed is the traceability of a product. Numerous definitions of traceability and traceability system may be found in the literature [53–56] and [57]. [53] offer a generic definition for traceability that may possibly be applied to any product: "the capacity to obtain any or all information related to that which is being considered, across its full life cycle, through documented identifications."

Given the International Organization for Standardization's definition of traceability in ISO 22005:2007, a specific standard for traceability in the food and feed chain, as "the ability to follow the movement of a feed or food through specified stages of production, processing, and distribution"[58], a traceability system based on product labeling must conform to this definition. According to [53], traceability of food items is the ability to ensure that goods traveling through the food supply chain meet specified criteria.

The installation of traceability systems is essential for wine SCs, as current systems are not able to fully protect final consumers from fraud. Typically, the food and beverages SCs are less digitalized, and are mainly built on paper documentation and private databases, which may be easily altered and counterfeited. Innovation and innovative techniques for product-based traceability systems are required.

4 Methodology

In order to meet the goal of this study a collaborative environment, which includes SC scholars and technical specialists, was built. First of all, literature was reviewed to understand the current state of BCT applications and the acuteness of the anticounterfeit solution for alcohol. Based on the state of the art, the need in a traceable and trusted solution for wine production and distribution was highlighted.

Thus, in order to start, the architecture of a SC and definition of the main participants of wine SC need to be performed by identifying each stakeholder and its role. Our proposal to the implementation of the traceability of the wine is the use of smart contracts that were programmed in DAML [59], that represents an open-source smart contract language and in terms of the virtual shared ledger, it identifies who may write what events, and to whom these events would be distributed.; hence, the next step is the smart contract flow architecture creation and adaptation to the wine application. The goal is to enhance the transparency and traceability levels of wine SCs, at the same time reducing counterfeit chances and improving the brand reputation, which would allow final consumers to gain more trust in wine by tracing its origins.

5 Implementation

The global structure of the SC for this application is represented in the Fig. 1, we identified four main stakeholders of wine production and distribution process that will take part in the BCT network, which are:

Manufacturer – the party that is responsible for the wine processing and bottling of the ready wines.
Warehouser – the party that keeps packed bottles of wines until retailing points request a new consignment of wine.
Transporter – the party that is responsible for the wine transportation from manufacturer further to next parties.
Retailer – this party includes various retailing points where wine will be further sold straight to the final consumer.

It is very important to note, that as can be seen in Fig. 1 these are just the central stakeholders, but not the only ones. In practice, wine changes ownership more times during the production and distribution process, including stakeholders that are responsible for: grape harvesting and collection, packing, transitioning, wholesaleing, etc. It is also crucial to understand, that the final consumer is not a participant of a BCT network in terms of creating a new block, here the final consumer will only be able to trace backwards all the records of the production and distribution process, thus gaining confidence in the origins of the wine. We decided to focus on the four main stakeholders for this application in order to show a comprehensive implementation of a smart contract and its architecture.

As presented in Fig. 1, the main goal is to track all the records and stages through which wine goes until it gets to the final consumer, this is done based on BCT-enabled hash system, where each consecutive hash of a new block contains the hash of a previous one. Like this, for every transaction that is taking place throughout the SC, a new hash in the new block is created, allowing tracking wine at any stage and moment of the cycle. In our application, the traceability starts at the level of the manufacturer, where

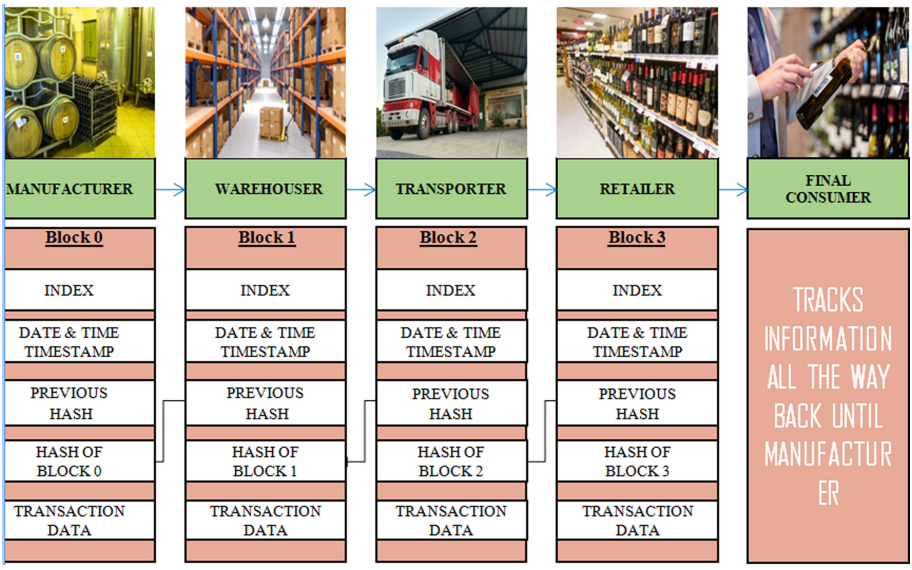

Fig. 1. Wine supply chain using blockchain

wine is processed and bottled and can be traced backwards at the moment when the final consumer is making a decision of purchasing ready bottle of wine in the retail point.

For the smart contract implementation, we built a DAML language template with the following parties: Manufacturer, Transporter and Owner. The owner role can be explained as any consecutive party in the SC, and if the application has more than four stakeholders, any party that is going to take the ownership of the wine at its own stage, can be considered as an owner and the logic of Fig. 2 would be implemented.

The general smart contract architecture for our application looks as following: starting from the moment that wine is processed and the physical bottle is created, Manufacturer transfers the ownership to the Owner by the use of the smart contract. In our case, the next Owner of wine would be a warehouse. Once warehouser accepts the ownership transfer, it would change the holder to the Transporter, who further accepts the holdership, transits wine to the next stakeholder, registers the delivery and assigns it to the next respective Owner. In our application, the next Owner would be a retailer, who receives ready bottles and further sells it to the final consumer. Thus, the last block would be created by the retailer, and the final consumer would be able to trace all the records of ownership change and transactions that took place, starting from the production stage. Like this, the final consumer can be assured with the origins of each particular bottle that can be found at the shelves of the retailing point and check that it is not a counterfeit wine.

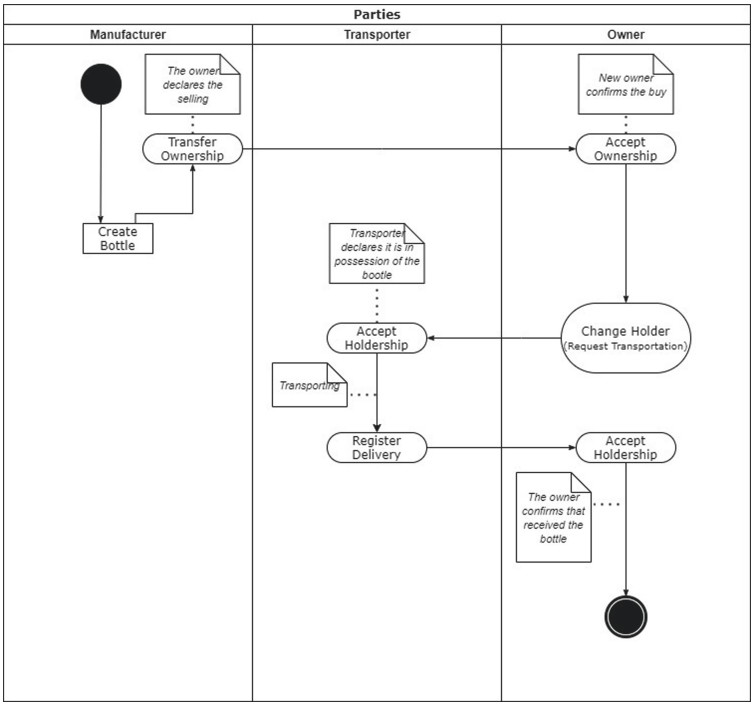

Fig. 2. Smart contract flow

The use of BCT-enabled smart contracts in the wine SC case enables a possibility to make wine traceable and creates a full visibility for the final consumer to see the origins of wine, which brings improvements of several factors.

First of all, anticounterfeiting measures would be met, since smart contract is triggering and recording transactions that meets a predefined protocol, the assurance of wine safety and originality can be guaranteed. As claimed in [60] consortium blockchain and smart contract use creates a decentralized environment, with robust level of guarantees on the integrity of stored and recorded data.

Secondly, it improves the visibility of the final consumer, where final consumer can trace backwards the full production and distribution related transactions that are stored on the BCT networks records and due to the immutable nature of the technology [61] it improves the credibility and trust towards the product from the perspective of the final consumer.

The third improvement that decentralized and trusted wine distribution process potentially brings is the strengthening of a brand reputation. As mentioned in [24], veridical data of each product that can be traced backwards by the final consumer is potentially able to improve the satisfaction level, thus reinforcing an overall brand reputation.

6 Conclusion

With our proposal of implementation, we can conclude that the use of the smart contracts (DAML language) can actually bring advantages in terms of its simplicity: to see all the transactions and clearly track the final product since the moment that it was just a raw material. However, this language is early iterations, contributing to a diffuse documentation and some conflicts with IDE's, with that we can say that this language needs to be a little more community enrollment.

The main contribution of this study is the universal smart contract architecture introduction, which can be used for specific applications. This study also contributes in practical terms, as it shows the potential boost in trust of final consumer when using BCT-based products. Our blockchain-based system helps to track and record all the main transactions between the SC participants in wine production and distribution industry shows a great potential of BCT-based solutions to reduce counterfeit levels and assure the final consumer with the origin of the wine. The origin knowledge further avoids health risks chances that counterfeit wine can cause. Like this the traceability may even boost an increase in overall wine brand reputation.

As BCT solutions for SCs are still in an infancy stage, it represents a great opportunity for the future of SC applications. This technology guarantees immutability and irreversibility, making it possible to control the entire supply chain from the producer to the final consumer. For future research, we suggest applying the proposed system to see the actual level of an end consumer trust and satisfaction with the feature.

Acknowledgement 1. We would like to thank ISTAR-IUL students Carlos Lourenço, David Inglez, Gonçalo Martins, Inês Carvalho and Joana Ascenso for contribution in DAML prototype development.

Acknowledgement 2. This work was supported by EEA Grants Blue Growth Programme (Call #5). Project PT-INNOVATION-0045 – Fish2Fork.

References

1. Berdik, D., Otoum, S., Schmidt, N., Porter, D., Jararweh, Y.: A survey on blockchain for information systems management and security. Inf. Proc. Manag. **58**(1), 102397 (2021)
2. Wan, P.K., Huang, L., Holtskog, H.: Blockchain-enabled information sharing within a supply chain: a systematic literature review. IEEE Access **8**, 49645–49656 (2020)
3. Ukanah, O., Obimbo, C.: Blockchain application in healthcare. In: International Conference on Computational Science and Computational Intelligence (CSCI), pp. 1167–1172, IEEE (2020)
4. Shuaib, M., Alam, S., Alam, M.S., Nasir, M.S.: Self-sovereign identity for healthcare using blockchain. Mater. Today: Proc. (2021, in press)
5. Ahmad, D., Lutfiani, N., Ahmad, A.D.A.R., Rahardja, U., Aini, Q.: Blockchain technology immutability framework design in e-government. Jurnal Administrasi Publik : Pub. Admin. J. **11**(1), 32–41 (2021). https://doi.org/10.31289/jap.v11i1.4310
6. Fallucchi, F., Gerardi, M., Petito, M., De Luca, E.W.: Blockchain framework in digital government for the certification of authenticity, timestamping and data property. In: Proceedings of the 54th Hawaii International Conference on System Sciences, p. 2307 (2021)
7. Bumblauskas, D., Mann, A., Dugan, B., Rittmer, J.: A blockchain use case in food distribution: Do you know where your food has been? Int. J. Inf. Manag. **52**, 102008 (2020)
8. Stranieri, S., Riccardi, F., Meuwissen, M.P.M. Soregaroli, C.: Exploring the impact of blockchain on the performance of agri-food supply chains. Food Control **119**, 107495 (2021)
9. Choi, T.-M.: Supply chain financing using blockchain: impacts on supply chains selling fashionable products. Ann. Oper. Res. **1**, 23 (2020). https://doi.org/10.1007/s10479-020-03615-7
10. Choi, T.M.: Blockchain-technology-supported platforms for diamond authentication and certification in luxury supply chains. Trans. Res. Part E: Logist. Trans. Rev. Elsevier **128**(April), 17–29 (2019)
11. Thakker, U., Patel, R., Tanwar, S., Kumar, N., Song, H.: Blockchain for diamond industry: opportunities and challenges. IEEE Internet of Things J. **8**(11), 8747–8773 (2021). https://doi.org/10.1109/JIOT.2020.3047550
12. Garcia-Teruel, R.M., Simón-Moreno, H.: The digital tokenization of property rights. A comparative perspective. Comput. Law Security Rev. **41**, 105543 (2021)
13. Chang, S.E., Chen, Y.: When blockchain meets supply chain: a systematic literature review on current development and potential applications. IEEE Access **8**, 62478–62494 (2020)
14. Wu, H., et al.: Data management in supply chain using blockchain: challenges and a case study. In: Proceedings 28th International Conference on Computer Communication and Networks (ICCCN), pp. 1–8 (2019)
15. Adsul, K.B., Kosbatwar, S.P.: A Novel Approach for Traceability & Detection of Counterfeit Medicines Through Blockchain (2020)
16. Li, G., Fan, Z.-P., Xue-Yan, W.: The choice strategy of authentication technology for luxury e-commerce platforms in the blockchain era. IEEE Trans. Eng. Manage. **1**, 14 (2021). https://doi.org/10.1109/TEM.2021.3076606
17. Leung, H.W., Chapman, A., Fadhel, N.F.: Identifying Food Fraud using Blockchain (2021)
18. Counterfeit products steal 1.3 billion euros from the EU wine market. https://winenews.it/en/counterfeit-products-steal-1-3-billion-euros-a-year-from-the-eu-wine-market_438742/. Accessed 20 Oct 2021
19. Tian, F.: A supply chain traceability system for food safety based on HACCP, blockchain & internet of things. In: IEEE 2017 International Conference on Service Systems and Service Management, pp. 1–6 (2017)

20. Monteiro, M.: Blockchain: tecnologia da bitcoin está a chegar a múltiplas indústrias, MaisTic (2018)
21. Adam, V., Ankit A.S., Robert, K., Sophia, M.: Using blockchain to drive supply chain innovation. https://www2.deloitte.com/us/en/pages/operations/articles/blockchain-supply-chain-innovation.html. Accessed 20 Oct 2021
22. Deloitte Homepage, Continuous interconnected supply chain. https://www2.deloitte.com/content/dam/Deloitte/lu/Documents/technology/lu-WP-Supply-Chain-Blockchain-18102017.PDF. Accessed 20 Oct 2021
23. Selinko Homepage, Anti-counterfeiting study wines and spirits market.docx. https://selinko.com/. Accessed 20 Oct 2021
24. Tokkozhina, U., Martins, A.L., Ferreira, J.C. :Adopting blockchain in supply chain – an approach for a pilot. In: Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST, vol. 364 LNICST, pp. 125–141 (2021)
25. Abeyratne, S.A., Monfared, R.P.: Blockchain ready manufacturing supply chain using distributed ledger. Int. J. Res. Eng. Technol. **5**(9), 1–10 (2016)
26. Min, H.: Blockchain technology for enhancing supply chain resilience. Bus. Horiz. **62**(1), 35–45 (2019)
27. Vyas, N., Beije, A., Krishnamachari, B.: Blockchain and the Supply Chain: Concepts, Strategies and Practical Applications. Kogan Page Publishers (2019)
28. Esmaeilian, B., Sarkis, J., Lewis, K., Behdad, S.: Blockchain for the future of sustainable supply chain management in Industry 4.0, Resour. Conserv. Recycl. **163**, 105064 (2020)
29. Gonczol, P., Katsikouli, P., Herskind, L., Dragoni, N.: Blockchain implementations and use cases for supply chains-A survey. IEEE Access **8**, 11856–11871 (2020)
30. Lu, Y., Tang, Q., Wang, G.: Zebralancer: private and anonymous crowdsourcing system atop open blockchain. In: 2018 IEEE 38th International Conference on Distributed Computing Systems (ICDCS), pp. 853–865 (2018)
31. Leng, K., Bi, Y., Jing, L., Fu, H.C., Van Nieuwenhuyse, I.: Research on agricultural supply chain system with double chain architecture based on blockchain technology. Futur. Gener. Comput. Syst. **86**, 641–649 (2018)
32. Perboli, G., Musso, S., Rosano, M.: Blockchain in logistics and supply chain: a lean approach for designing real-world use cases. IEEE Access **6**, 62018–62028 (2018)
33. Cui, P., Dixon, J., Guin, U., Dimase, D.: A Blockchain-based framework for supply chain provenance. IEEE Access **7**, 157113–157125 (2019)
34. Sternberg, H.S., Hofmann, E., Roeck, D.: The struggle is real: insights from a supply chain blockchain case. J. Bus. Logist. **42**(1), 71–87 (2020). https://doi.org/10.1111/jbl.12240
35. Kamble, S., Gunasekaran, A., Arha, H.: Understanding the blockchain technology adoption in supply chains – Indian Context. Int. J. Prod. Res. **57**(7), 2009–2033 (2019)
36. Namasudra, S., Deka, G.C., Johri, P., Hosseinpour, M., Gandomi, A.H.: The revolution of blockchain: state-of-the-art and research challenges. Arch. Computat. Methods Eng. **28**(3), 1497–1515 (2021)
37. Ameyaw, P.D., de Vries, W.T.: Transparency of land administration and the role of blockchain technology, a four-dimensional framework analysis from the Ghanaian land perspective. Land **9**(12), 491 (2020)
38. Jalal, I., Shukur, Z., Bakar, K.A.A.: A Study on Public Blockchain Consensus Algorithms: A Systematic Literature Review (2020)
39. Li, Z., Barenji, A.V., Huang, G.Q.: Toward a blockchain cloud manufacturing system as a peer to peer distributed network platform. Robot. Comput. Integ. Manuf. **54**, 133–144 (2018)
40. Wang, Y., et al.: Making sense of blockchain technology: how will it transform supply chains? In: International Journal of Production Economics. Elsevier B.V., 211(February), pp. 221–236 (2019)

41. Kamble, S.S., Gunasekaran, A., Sharma, R.: Modeling the blockchain enabled traceability in agriculture supply chain. Int. J. Inf. Manag. Elsevier **52**, 101967 (2019). https://doi.org/10.1016/j.ijinfomgt.2019.05.023
42. Omar, I.A., et al.: Automating procurement contracts in the healthcare supply chain using blockchain smart contracts'. IEEE Access **9**, 37397–37409 (2021)
43. GS1: Wine Supply Chain Traceability GS1 Application Guideline. https://www.gs1us.org/DesktopModules/Bring2mind/DMX/Download.aspx?Command=Core_Download&EntryId=660&language=en-US&PortalId=0&TabId=134. Accessed 20 Oct 2021
44. The fake wine epidemic. https://wisermarket.com/blog/the-fake-wine-epidemic/. Accessed 20 Oct 2021
45. Deaths in Dominican Republic linked to tainted alcohol. https://www.foodsafetynews.com/2021/04/deaths-in-dominican-republic-linked-to-tainted-alcohol/. Accessed 20 Oct 2021
46. Turkey: Dozens dad in bootleg alcohol poisoning. https://www.dw.com/en/turkey-dozens-dead-in-bootleg-alcohol-poisoning/a-55255560, Accessed 20 Oct 2021
47. Bouscaren, Pandemic's deadly side effect: Global rise in bootleg alcohol poisonings (2020). https://www.pri.org/stories/2020-10-20/pandemic-s-deadly-side-effect-global-rise-bootleg-alcohol-poisonings. Accessed 20 Oct 2021
48. Whitworth: Wine and spirits one of top sectors affected by counterfeiting – EUIPO (2018). https://www.foodnavigator.com/Article/2018/06/25/EUIPO-assesses-counterfeiting-cost-in-spirits-and-wine-category. Accessed 20 Oct 2021
49. Morris, C., Young, C.: Seed to shelf' teat to table' barley to beer' andwomb to tomb': discourses of food quality and quality assurance schemes in the UK. J. Rural Stud. **16**(1), 103–115 (2000)
50. Quality management and quality assurance Vocabulary (1994)
51. Galli, F., Bartolini, F., Brunori, G., Colombo, L., Gava, O., Grando, S., et al.: Sustainability assessment of food supply chains: an application to local and global bread in Italy. Agricult. Food Econ. **3**(1), 21 (2015)
52. Van Rijswijk, W., Frewer, L.J.: How consumers link traceability to food quality and safety: an international investigation. Technical report 736-2016-50767, pp. 2–7 (2006)
53. Olsen, P., Borit, M.: How to define traceability. Trends Food Sci. Technol. **29**(2), 142–150 (2013)
54. Bosona, T., Gebresenbet, G.: Food traceability as an integral part of logistics management in food and agricultural supply chain. Food Control **33**(1), 32–48 (2013)
55. Galli, F., Gava, O., Bartolini, F., Marescotti, A., Brunori, G.: Global and Local wheat-to-bread supply chains. Glob. Local Food Asess. **104** (2015)
56. Karlsen, K.M., Dreyer, B., Olsen, P., Elvevoll, E.O.: Literature review: does a common theoretical framework to implement food traceability exist? Food Control **32**(2), 409–417 (2013)
57. Dabbene, F., Gay, P., Tortia, C.: Traceability issues in food supply chain management: a review. Biosys. Eng. **120**, 65–80 (2014)
58. Traceability in the Feed and Food Chain—General Principles and Basic Requirements for System Design and Implementation (2016). https://www.iso.org/standard/36297.html
59. DAML. https://daml.com. Accessed 20 Oct 2021
60. Aniello, L., Halak, B., Chai, P., Dhall, R., Mihalea, M., Wilczynski, A.: Towards a supply chain management system for counterfeit mitigation using blockchain and PUF. arXiv preprint arXiv:1908.09585
61. Ferreira, J.C., Martins, A.L.: Building a community of users for open market energy. Energies **11**(9), 1–21 (2018)