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Use of blockchain in the agri-food value chain: State of the art in Spain and some lessons from the perspective of public support.

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ABSTRACT

The Common Agricultural Policy (CAP) of the European Union, in effect since January 2023, seeks to differentiate products on quality, provide greater transparency on food origin, and on the transactions and the actors involved in the supply chain. At the same time, in Spain, the adoption of new technologies for the digitization of the agri-food sector has been proposed as a solution to address structural issues such as lack of competitiveness and innovation. In fact, systems using blockchain-related technologies for food control and traceability have seen great progress in recent years and, currently, the use of blockchain in supply chain management is almost doubling year on year. In this context, this paper investigates the level of development of blockchain technology in the agri-food sector in Spain and its applications for certifying food production conditions within the supply chain, and how it is supported by public policies. It identifies several challenges that need to be addressed for a widespread adoption could take place, such as data recorded on the blockchain, lack of standards, limited scope of projects, and integration of data capture automatically or with other technologies like RFID and AI. The document proposes to reorient public development policies to address these challenges, such as reusing data from, already in place, European data collections for production control and food traceability, educating users and stakeholders about the use of blockchain technology, and fostering legal and technical provisions which ensure system transparency to facilitate a successful implementation of blockchain.

1. Background

The implementation of the new European Union's Common Agricultural Policy (CAP) from 2023 is an important step towards the modernization of Spanish agriculture. The eventual success of this policy requires the usage of new technology to ensure compliance with regulations and provide evidence of Farm-to-Fork tracking (European Commission, 2020).

The agri-food industry is the largest industrial subsector in the Spanish economy[2] (Ministerio de Agricultura, Pesca y Alimentación,

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[2] The sector generates a value of 107,000 million euros in sales at year and accounting for almost a quarter of the entire Spanish manufacturing industry. It also provides 19% of all Spanish industrial employment.

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2021). According to available reports, it is in need of renewal and requires a thorough digital transformation.[3] Additionally, the firms in the sector are small compared to its European counterparts,[4] which increases their difficulty to compete on a larger scale. The recipes proposed to remediate this situation, display that the sector must use its ability to innovate and gain value from what it already produces and create a more unified and efficient value chain to make it more sustainable (Orden PCM/81/2022, de 9 de febrero, (PERTE Agroalimentario, 2022)).

From all the possible technologies helping with this agri-food industry digital transformation,[5] this article focuses on blockchain and its potential to increase confidence in the information provided in terms of food safety, traceability, and transparency on key production conditions for consumers (Degli-Esposti & Arroyo, 2021). It also explores where, how, and why blockchain projects are being implemented in the agri-food sector in Spain, identifies the difficulties they face, and investigates how public policies can address these challenges.

Likewise, evaluating the state of the art and the interest in and potential of the incorporation/appropriation of an incipient technology such as blockchain technology into a traditional and mature sector of the Spanish economy such as the agri-food sector can be very useful, not only to assess the potential of its implementation, but also to assess how public policies to promote the digitization of Spanish companies have influenced its implementation and if there are any lessons to be learnt during the process. However, it is worth mentioning that available information on relevant projects for the implementation of blockchain used for farm-to-fork traceability in the Spanish agri-food sector is scarce, so another objective of this research is to know about, collect and study practical examples of these solutions in Spain. In addition, the underlying reasons for the apparently low state of deployment of these projects will be analysed. In this regard, a starting hypothesis of this work is that, either because there are structural problems or because the already existing traceability assurance system through official controls makes it unnecessary, the blockchain solutions developed to date in the Spanish agri-food industry are not being consolidated despite their usefulness in offering added value and differentiating certain agri-food products, even if Spain has favourable starting conditions in terms of both access to financing and the availability of technology.

To answer the questions and to confirm the hypothesis, the paper is structured as follows: After this introductory section, the next section will describe the methodology used for the literature review, the interviews with experts and the questionnaire. The following section explains the status of the deployment of blockchain technologies in the agri-food sector in Spain. The focus is on specific projects that use of blockchain technology to certify the production conditions of food or raw materials throughout the supply chain. Subsequently, the results of the analysis of projects, the survey and the interviews are discussed in detail. A section on conclusions and lessons for potential further public action closes the paper.

2. Methodology

For this article, the methodology to gather evidence from the widest possible range of sources on blockchain implementation in the agri-food industry in Spain used both desk research and field work conducted through semi-structured interviews complemented with snow-ball sampling.

Desk research involved both articles from peer-reviewed journals as well as reports from companies and organizations that have implemented blockchain farm-to-fork solutions. Desk research, however, fell short on drawing conclusions to advice public policies, for instance: the reason why blockchain was chosen over other technologies or the best practices for participation and involvement of the agents.

Semi-structured surveys provided the opportunity to collect more in-depth information from individuals and organizations and evidence on the state of execution of relevant projects developed in Spain, specific agents involved, financing and access to public support, success or causes of abandonment, types of blockchain implementation and governance models.

2.1. Desk research

The article initially used a bibliographic analysis conducted using the SCOPUS database on the food and agricultural industry in search of innovative applications based on blockchain technology from 2019 to 2022 (Mazzù et al., 2021). The research method was inspired by similar approaches in the literature (Stranieri et al., 2021). The search pattern applied was the following: "BLOCKCHAIN and FOOD or AGRICULTURE" and "Blockchain and FOOD and AGRICULTURE". The search model has been described in Appendix 1.

To identify Spanish projects, the screening of the search in Scopus was done in two ways, in a first case circumscribing the search to the Subarea "Spain" and in a second case using Spain as a keyword. The result of the search in Scopus has generated few number of articles.

The initial bibliographic analysis was revised using an alternative repository through Google Scholar. In this second search, the filtering of the results could not be reproduced with the same search pattern due to the limitations of the repository, which does not

[3] https://www.caixabankresearch.com/es/analisis-sectorial/agroalimentario/industria-agroalimentaria-espanola-estructura-empresarial-y.

[4] https://www.expansion.com/economia/2020/10/06/5f7b7d33468aeb5e1d8b45d3.html.

[5] The Declaration on "*A smart and sustainable digital future for European agriculture and rural areas*" (Council of the European Union, 2019), highlighted this double mission—economic and environmental sustainability—for new technologies: "technologies such as Artificial Intelligence (AI), robotics, blockchain, High Performance Computing (HPC), Internet of Things (IoT) and 5G have the potential to increase farm efficiency while improving economic and environmental sustainability. Such technologies can transform all types of farming and enable better decision making."

allow discrimination by thematic areas, although the same keywords were used. Due to these limitations, the filtering of relevant results was done by analysing the results case by case. In addition to the grey literature from previous steps, 5 new academic papers were identified.

Finally, the literature review was complemented by commercial publications and reports using the databases of bibliographic collections and journals of the Spanish Ministry of Agriculture and its associated bodies. In addition, new bibliographic sources cited by the agents during the interviews were identified.

Additionally, regardless of the relevance of the articles, when searching for specific use cases and technological solutions of blockchain technology that could be applied in Spain, not all of them identified use cases of applications or provided relevant information for the work, focusing mainly on applications for using blockchain technology to certify production conditions throughout the supply chain. Therefore, only those that were finally used as an explicit reference are those collected in the bibliographic references.

2.2. Survey plan and stakeholders' identification

From the background provided by the literature review, the paper has used semi-structured interviews to contrast, complete and validate the information on the current use of blockchain in Spain applied to the agri-food supply value chain. This methodological approach is similar to others found in the literature when researching on the introduction of new technology applications (Patelli & Mandrioli, 2020), and semi-structured interviews are generally considered an effective tool to explore the opinions of respondents and collect in-depth data on complex issues (Nienaber et al., 2021). In fact, this method has recently been used in articles focusing on blockchain and food chain value creation and on the attitudes and decision-making of farmers and other stakeholders linked to agricultural issues (Chang et al., 2020; Q. K. Nguyen, 2016, pp. 51–54).

2.2.1. Survey plan

For the preparation of the questionnaire, similar survey models (Mark Easterby-Smith, Richard Thorpe, Paul Jackson, Andy Lowe, 2008; Nienaber et al., 2021; Petersson, 2005) were adapted to the agri-food field. Although these questionnaires already provided a suitable set of relevant questions for this research, the content of the survey was completed with gaps identified in the literature review (see Section 3.1), and modified depending on whether the agents were directly involved in the supply chain or belonged to the group of facilitators (i.e. providers of technological solutions to the public sector: see Fig. 1). The questionnaires used are presented in Appendix III.

The interview began by outlining the objectives of the survey, who the respondents would be, and why the survey was important. The estimated time to complete the interview was 2 h. However, due to the expertise of the respondents, it often took longer to allow for the possibility of getting further information of projects and the opinions of the experts.

From the interviews some other relevant stakeholders were identified and included in the survey. This snowball sampling is not a random sampling method of selecting respondents, so it carries the risk of leading to bias in the sample. Nevertheless, results are still representative of the population due to the limited number of projects and experts. To authors' knowledge, and at the time of writing the paper, the ample majority -if not all-of projects in Spain that used blockchain for production conditions in the agri-food industry were included. To ensure that respondents felt comfortable and secure in sharing their opinions, their anonymity was guaranteed.

2.2.2. Selection of respondents

The target population of the survey consisted of relevant stakeholders who have an in-depth knowledge of blockchain technology and its applications in the production/certification agri-food industry. This includes providers of technological applications of blockchain, regulatory authorities, and academic experts in the field of new technologies applied to agri-food traceability.

This choice agrees with previous studies where similar semi-structured interviews have been conducted with representatives of these interest groups with the aim of identifying a range of perspectives on the factors that underlie transparency and added value within the entire food supply chain (Barry, 2021; Stranieri et al., 2021). In the case of this paper, special attention has been paid to examining the determining factors that lead to the adoption of blockchain in those cases that integrate agricultural production conditions and the influence of external financing in decision-making.

The selection of respondents started with a map of agents identified from the literature review, from specialized magazines and from the directories and agendas of public administration and universities. By applying the European Commission's transparency register,[6] a second series of agents working with blockchain solutions in Spain were identified (see Table 2 in Appendix IV). From here, the same respondents helped to identify a next layer of stakeholders following the mentioned snowball sampling technique, typically used when the number of individuals making up the sample is very limited (Mark Easterby-Smith, Richard Thorpe, Paul Jackson, Andy Lowe, 2008).

In the first phase of the investigation, 14 interviews were conducted with experts from the five relevant areas of the logistics chain (23 per cent valid responses[7]) and with representatives of providers of technological solutions and public administration. In the second

[6] The transparency register is a database that lists the organizations that try to influence the law-making process and the implementation of policies of the institutions of the European Union.

[7] From 60 people identified (participants and facilitators, agents related to technology, in principle), only 14 agreed to participate. The rest did not answer, excused because of not enough knowledge about the technology in depth, or referred the survey to more expert people.

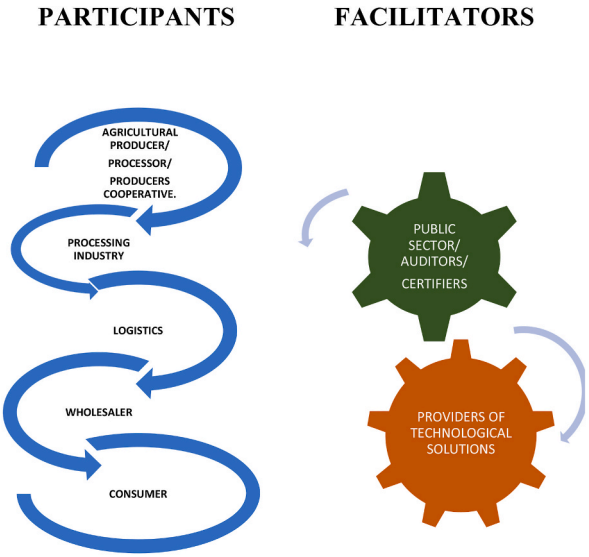


Fig. 1. Participants and facilitators in the blockchain implementation process.

stage, another six interviews were derived from recommendations (60 per cent valid responses). Snowball sampling was complemented by direct exchanges through the LinkedIn social network. In total, more than 60 experts and players were contacted; 46 were called for an interview and 23 were finally interviewed (see Table 3 in Appendix IV). The survey was carried out over a period of two months, from December 15, 2021 to February 15, 2022.

2.3. Analysis of data

The data gathered from the interviews was systematically analysed using a thematic procedure based on Nowell et al. (2017): transcription, analysis, data organization, relevance, and aggregation with respect to the research questions. Therefore, when an opinion was only relevant to one of the interviewed individuals, or when the implications did not go in the same direction, the result was not considered.

The interviews were also used to validate and complete the data collection for the analyzed projects, 17 in total, that use blockchain technology to guarantee certain production conditions through the supply chain (see Table 5 in Appendix IV), a list that also serves as the basis for this study..

3. Analysis and results

This section covers the results from the literature review, the desk research, and the interviews with relevant players. First, trend and gaps are identified, followed by an overview of existing deployments. From here, different sections analyze usefulness and functionalities, standardization and data, governance, scalability, costs, and public support for these deployments.

3.1. Trends and gaps on the use of blockchain technology in the agri-food industry

The literature review on the agri-food industry showed how the general application of blockchain technology began in 2016, along with several studies on the limitations of blockchain technology for scalability and its use to prove production conditions (Tripoli & Schmidhuber, 2018). From there, blockchain for the agri-food industry continued to receive more and more attention from academics, especially in 2019 and the first half of 2020 (Niknejad et al., 2021). This was probably due to the development of applications based on permissioned blockchain systems that gave rise to new generations of Distributed Ledger Technologies systems (DLTs), and to further developments in 2020 during the Covid crisis with the aim of controlling the supply chain.

However, the international scientific production on generic blockchain solutions for the agri-food industry is changing rapidly. For 2021, within a decreasing trend in the total number of papers still too early to be ascertained, this paper has found a new strand of studies that present technological solutions based on different DLTs (Hyperledger, R3, IBM Blockchain, Ethereum or Stellar) to ensure traceability of the supply chain. These papers point out that, so far, the practical applications of the use of this technology aimed at guaranteeing production conditions often do not go beyond a pilot project or have just lasted for a very limited number of trials. Several authors agree on the limitations of existing solutions in terms of the number of transactions per second and scalability (Srivastava & Dashora, 2022)

Another interesting result from the bibliographic research is that India, China, and the US are the countries producing the most articles dedicated to this technology. It should also be noted that, in general, the results of the literature review show how developing

countries have devoted more attention than others to blockchain technology in the agri-food field in their scientific articles (Qian et al., 2020), probably in direct relation to the weight of the agri-food industry in their economies and the relevance that blockchain technology might have to take a leap forward in a key sector in the creation of value for the country (Kamilaris et al., 2019).

Perhaps the most renowned set of deployment cases is that compiled by the Food and Agriculture Organization (FAO) in its publication "E-agriculture in action: blockchain for agriculture"[8] (Berneis, 2021), where several application cases are documented in relation to agribusiness: insurance, land identification, water treatment and forest transformation processes. However, little is said about the use blockchain technology to secure production data throughout the supply chain, specifically in the agri-food sector.

In summary, the most recent scientific literature is beginning to examine consolidated applications in the agri-food supply chain—for example, as a means of payment (Nihit Choudhary, 2020), or to control the origin of batches and transport time (Yohan et al., 2022). However, according to these papers, utility of blockchain technology in safeguarding data related to production conditions throughout the supply chain of a product still presents many challenges (Srivastava & Dashora, 2022).

From the content of the scientific publications that appear in the different geographical areas, it seems that in Western countries, and especially in Europe, interest in blockchain technology applied to ensuring the origin and production conditions of food and its healthiness is lower than in Asia, in spite of Europe currently is developing a series of guarantee seals aimed at certifying origin, environmentally sustainable production conditions, and other factors such as production working conditions.

This apparently lower interest in food safety through blockchain technologies may be due to the already existing public official control systems in Europe, which are largely aimed at guaranteeing the origin and food safety from a health point of view and might be working sufficiently. In this regard, a set of control/monitoring regulations and standards are included in Appendix II to provide a framework for the research. This, without being an exhaustive list, describes an extensive set of regulations that apply to agriculture, fishing, and official food control in Spain, as derived from European Union regulations. Blockchain technology is not so far used in official reports or records.

For example, in the case of fishing, the vessel monitoring system (VMS) tracking system for fishing boats has been in force since the 1990s and the catch certificates since 2010. As another example, the EU's General Food Law entered into force in 2002: it makes traceability compulsory for all food and feed businesses, comprising a complex system of official controls. These initiatives have been complemented by electronic registration systems for imported food and computerized and electronic means of registration and control. In Europe, there is also an extensive system of additional rules on labelling and guarantee seals, so that, in general, the consumer in Europe has a health and origin assurance system that is already largely covered by the public control system[9] (Zhang, J. & Bhatt, 2014). The acquis Communautaire in this matter is perhaps the most complex, but it is not the only one. In fisheries, for example, there are equivalent initiatives in other Western-minded countries such as the US seafood import and monitoring programme and Country of Origin Labelling (COOL) laws.

Even though there is a robust official control system in Europe for production and traceability, official regulations coexist with multiple market-oriented applications using blockchain technology, from those offered by non-governmental organizations (NGOs), such as certifications and eco-ratings, to others aimed at improving traceability, especially when the production integrates food or raw materials from different origins or there may be counterfeits. These 'private' applications are not standardized and not all technology providers integrate the same data or do it in the same way, and there are several academic references to the need to incorporate the sharing of crucial data or to undertake verification of the manually integrated data as a key constituent of these applications. There are, in fact, several academic references underlining the need to integrate robust and relevant data in the system (Xiong et al., 2020; Zhang, Z., Song, Liu, Yin, Wang, & Lan, 2021).

Consistent with the above, and in practice, companies that offer solutions to provide traceability to agri-food products and that use DLT have been increasing significantly, especially since 2018. During 2020, the pandemic drove an explosion of investment in supply chain management technology, mostly connecting downstream operators such as processors, distributors, and verifiers, and including other functionalities such as payment applications like Full Profile,[10] Heifer[11] or FIE[12] (Vaghani et al., 2022).[13]

However, despite companies' prospects, there are several references in both scientific papers (Vaghani et al., 2022) and informative articles (Gartner Blog Network, 2021) to "blockchain fatigue", derived from the fact that many of the projects remain in a pilot stage due to the lack of standards, the lack of convergence of technologies, immaturity, the problem of scalability and of interoperability, an overly ambitious scope, and a lack of understanding of how technology could help solve the problem at hand.

By sector, within the agri-food field, although there are quite a few feasibilities analysed in the scientific literature, there are few examples in which the use of blockchain has translated into solutions that can be scaled up and consolidated by providing true added value. Due to its appearance in the bibliographic citations, the best-known case is probably the blockchain platform created between Walmart and Hyperledger and the IBM Trustchain project (which is no longer in use and has been replaced by IBM Food Trust).

These experiences pioneered the emergence of third-party BAAS (blockchain as a service) services, which offer functional platforms that can be adapted to customer needs. Currently there is many companies that offer these services (Microsoft, IBM, Oracle, Amazon, Alibaba, SAP, Accenture, Baiddu, Huawei, Kaleido Hewlett-Packard Enterprise, among others) (Jesús Alfonso & Muñoz Jiménez,

[8] https://www.fao.org/3/ca2906en/CA2906EN.pdf.
[9] https://www.betelgeux.es/noticias/europa-lider-trazabilidad-alimentaria/.
[10] Agridigital; https://www.fullprofile.com.au/.
[11] https://www.heifer.org/campaign/2019/blockchain-initiatives.html.
[12] Fletcher International Exports; https://www.fletchint.com.au/the-fletcher-group.
[13] https://www.gartner.com/en/newsroom/press-releases/2019-05-07-gartner-predicts-90_of-blockchain-based-supply-chain.

2020) and some have developed specific solutions for the agri-food sector[14] (Berneis, 2021).

In the paper's analysis of the market-based solutions being used in Spain (see Table 1 in Appendix IV) it is shown that not all are specifically designed to certify production conditions. Based on the analysis carried out in this study and within the agri-food field, IBM's 'Food Trust' seems to be the only scalable project that is in production[15] at the time of writing (*Noticias Carrefour,* 2018) The set of cases in the paper also shows that most projects have developed customized solutions using the available blockchain infrastructures belonging to the European Blockchain Infrastructure (EBSI), specifically in Spain, the Alastria platform.

By sub-sector, the fishing industry has been one of the most active in the development of software solutions based on DLT technologies, offering certification systems or product guarantee seals (authenticating aspects related mainly to the origin, its handling, and the time) to gain consumer trust. In fishing, it has been possible to identify twenty informative articles that refer to the use of blockchain to guarantee their product, but in practice few providers of solutions or seals have been consolidated these solutions on a stable and long-term basis. Some of those currently operating are listed in Table 1 in Appendix IV.

As of 2020, and as new DLT architectures appear, scientific articles (Berneis, 2021) have challenged the notion that these DLT systems really exchange truthful, accurate and validated data; the articles also question their usefulness, which translates into an academic interest in the analysis of external inputs (gateways) and oracles—that is, how to introduce external data into the network. The most recent articles give increased importance to artificial intelligence to manage external data without human intervention, or as an automatic means of data verification.

Likewise, the relevance of the information is analysed in practical applications, considering to what extent these data certify relevant information for the consumer (for example, identity, production conditions, etc.), and what is the role and status of standards. Another issue of interest is the added value of the use of these systems for the producer, which seems to only occur in products of value for the producers where, for instance, the existence of counterfeits is a problem.

We can also find several articles that propose mixed systems, such as data collection using IoT sensors[16] in addition to blockchain (Akhtaruzzaman Khan et al., 2022) (Zhang, Z. et al., 2021) to ensure data integrity (truth and immutability) (Alonso et al., 2020) The objective is to improve the integration of the information derived from the production conditions, which is stored in a blockchain system, an improvement on other systems that are based on information provided through declarations that do not have sufficient audit guarantees and supervision.

In this regard, there is scientific interest in studying the gateways and developing standards on the collection and inclusion of data or its certification that guarantee that the chain of blocks not only makes the information immutable, but that what is recorded through the blockchain is accurate, adequate, and consists of relevant information for the purpose. It should be noted regarding this purpose that not all applications integrate the same data or pursue the same objective. Several international projects of interest have been identified from the bibliography (see Table 4 in Appendix IV).

3.2. Status of blockchain projects in the Spanish agri-food industry

In terms of research on applications, in Spain there have been some contributions to the literature, mostly theoretical, focusing on food traceability issues (Mirabelli & Solina, 2020). However, existing scientific literature has not yet answered the question of the situation of the implementation of this technology in Spain, what challenges it faces, and, specifically, its role in ensuring the conditions of food production throughout this same supply chain.

Likewise, both from the bibliographic study in Spain and the one carried out internationally, there is hardly any scientific information on public policies and the use of public or public-private financing mechanisms to contribute to the deployment and adoption of blockchain technologies in the agri-food sector.

To this regard, the first of the research questions in the paper was related to the interest and the conditions found in Spain for the adoption of blockchain technologies in the agri-food field and the identification of relevant cases of implementation. Through the survey and desk research, many projects using blockchain technology to certify aspects related to production conditions were identified and 17 of then were analysed. Therefore, despite the low impact of these projects in the scientific literature so far, there is significant experience in Spain.

In fact, the use of blockchain technology is becoming increasingly prevalent in the Spanish agri-food sector to increase transparency and traceability in the supply chain.

The most common use cases for blockchain in the agri-food sector in Spain include tracking food from farm to store, tracking livestock and animal welfare, and verifying product origins.

Nevertheless traceability, understood to control the requirements of food legislation at all stages of production, transformation, and distribution, and the guarantee of control of mandatory data and its conformity is carried out in Europe by public administrations,

[14] The best-known company is the current Food Trust (IBM). In principle, it was an alliance between the DOLE companies—Driscoll's, Golden State Food, Kroger, McCormick, McLane, Nestlé, Tyson Foods, Unilever and Walmart—to address food safety and to ensure traceability in the face of contamination. It has been used to present proof of concept focused on specific solutions for SMEs related to some actors. Another famous blockchain system is SAP, used by the company Bumble Bee Foods for documenting the traceability of tuna from Indonesia (Berneis et al., 2021).

[15] The IBM system has been used for Carrefour's free-range chicken projects (Carrefour, 2018), Cargill's turkey (Cargill, 2018) and CHO olive oil (Wolfson, 2020), one of the most important producers of Italian olive oil. In these procedures, different process quality points were used that could be traced using this blockchain technology.

[16] These capture information automatically (temperature, location, humidity level) by a measurable electrical signal.

which are not implementing blockchain projects with these objectives.

It may seem redundant to add more traceability to the existing traceability system; however, data from official food controls may not be adequately stored and organized to bring them to the attention of the consumer. By utilizing blockchain technology, large retail companies or producer associations gain access to real-time data and provide an additional certification of production conditions to consumers providing an additional guarantee to prevent fraud in existing control systems. Therefore, Blockchain technologies are used to test the quality of products for the consumer, as well as to ensure compliance with voluntary industry regulations.

In the analysed cases blockchain technology is not being used with the main objective of simplifying the process, enabling more efficient and secure transactions, or ensuring compliance with official requirements, rather, the use of blockchain offers an extra, additional layer of control on top of the industrial controls or official controls that are already communicated in other ways.

In addition, the technological solution of blockchain construction and the external databases used have been implemented in most cases without there being a previous analysis (Xiwei Xu et al., Apr 2017), or a debate among the actors involved on the technological alternatives that respond to specific needs.

Note also that most of the solutions analysed in this study have not advanced beyond the pilot phase, either because they are currently still being tested or because they have not been consolidated. Those interviewees who had participated directly in the implementation of non-consolidated projects agreed that the reason that these are not scaled up lies in the difficulty of translating the added value of the system (traceability guarantees) into economic benefits. For this reason, some cases that that can be considered successful disappear when the financial support that facilitated their initial implementation stops.

From the analysis it is deduced that the design of the computer applications used that use blockchain to certify production conditions generally responds to the scheme presented in Fig. 2.

3.3. On the usefulness of blockchain technology deployments in the agri-food industry

The first deductions drawn from the interviews carried out is that although there is considerable interest in this technology among professionals in the sector in general, those who work in the transformation and distribution industry are particularly convinced of the benefits of the implementation of blockchain. In relation to the usefulness of the blockchain, it is mentioned that it considerably helps the mandatory registration of transactions and sometimes, the registration of additional controls that guarantee the traceability of production at a point in the chain where fraud can occur (for example, the preparation of batches after auction (skewered hake), after milling (olive oil), or at cutting (the meat industry).

All the interviewees, regardless of the platform used, highlighted the following common advantages in the use of blockchain technology: immutability of the information provided, real-time location of the products, transparency and visibility of the information stored in the system. However, they also see difficulties in its use as a tool to certify production conditions due to difficulty integrating all the required data into the system. They also agreed that, compared to other industries, the food supply chain is perhaps one of the most complex and fragmented chains from a logistical point of view.

Also, the interviewees agree all that the implementation of blockchain makes it necessary to improve data management across the value chain. The interviewees stated that the integration of the data in a blockchain system is expected "to end the lack and the confusion of information". In all the cases analysed, the blockchain acts as a database combined with other external and centralised databases. In general terms, it could be said that Blockchain can change how and what data is shared along the food supply chain, moving from opaque and isolated data traditionally stored on paper or centrally controlled internal databases to a more open and transparent system. Therefore, the value of the technology lies in guaranteeing the complete flow of data saved in the blockchain and the information between companies throughout the entire system so it can become a reference. The competitive advantage of systems using blockchain thechnology over other systems is that the data cannot be manipulated and integration into a decentralized system provides greater transparency. The implementation of these systems has also meant, in all cases, improved data collection and integration of process information in the entire system since the data must be recorded completely and adequately to generate a hash and move on to the next link in the chain. From the results of the interviews, it can be deduced that the main value of blockchain compared to traditional distributed databases is that the system guarantees that important transaction data is properly recorded and that those stored in the blockchain are unalterable.

A study of the projects reveals that, despite an improvement in information and transparency, the use of blockchain has not been utilized to additionally improve the management of product flows or the intrinsic quality attributes of the products. Furthermore, the system has not incorporated new forms of sale or create monetization opportunities[17]; all of these remain as they were at the beginning of the blockchain deployment. A minimum level of performance is seen as a necessary condition for agents to decide where to implement blockchain technology. Thus, suppliers have not viewed this technology as a tool to access the retail network market, since fundamental elements such as process and quality standards and well-established commercial relationships are prerequisites in the projects which have been implemented.

As a summary of the points above, all the interviewees agree that the implementation of blockchain technology in the agri-food industry is complex, and that the cost and effort are only worthwhile and become consolidated when there is both a verified need to secure the information and the results provide some commercial competitive advantage. For this reason, there is increasing use of

[17] However, without it being a subject of study because it does not certify production conditions, there are monetization projects in Spain, for example the Olivacoin project, developed by the University of Seville, which aims to become a reference for the entire olive oil production chain, from farmers to distributors, and includes its own currency, the olivacoins. https://olivacoin.com/.

this technology in the logistics part of the value chain for the control of certain parameters (for example, in product entry in containers[18] and the international transport conditions), since these parameters that are easily identifiable and exchanged across the value chain (Qian et al., b 2020). In contrast, projects to certify quality parameters linked to the production conditions that involve all the agents and cover the whole value chain (from the producer to the consumer) have not so far been consolidated. Therefore, although all the agents appreciated the general virtues of blockchain, they also agreed that its effective implementation in the logistics chain during transport between companies (B–B) is more consolidated than along the entire producer-companies-consumer (P–B–B–C) supply chain, which coincides with the conclusions drawn from the literature review (Berneis, 2021).

3.4. On-going standardization of blockchain technology and data in the agri-food industry

From the perspective of standard practices, the interviewees agreed that for logistics control a de facto 'normalization' of the use of blockchain technology was already taking place, making it very suitable to guarantee the control of certain parameters (temperature, origin, storage time of food products), providing improved guarantees of the data not being manipulated, and even improving access to these records, ensuring their availability, and increasing the speed of consultation.

However, when blockchain is used, there is a considerable heterogeneity of data as it might be recorded for different purposes, complicating scalability, and usefulness. Systems that in principle guarantee the same parameter (for example: origin) are designed to host different information in different formats. Therefore, the guarantees of identity, origin, and production conditions currently offered by the blockchain systems used are only comparable/valuable to the extent that they use the same standards for data collection, transactions and integration both on-chain and off-chain.

Among the Spanish projects analysed, some projects currently in the testing phase, such as Svotan or Iberchain, use data processing formulas that can be extrapolated to relevant production volumes so that they can be sufficiently scalable or serve as inspiration for relevant de facto standards, although in no existing case are there de jure harmonized standards.

Regarding the treatment and utilization of data through blockchain systems, all parties that implemented these systems agreed that the projects enhanced the gathering and traceability of the data managed by the different parties involved due to having to identify, arrange, document, and record data that identifies the transactions. However, most of those interviewed expressed that, in a system that wants to guarantee 'farm to fork' production conditions, all members of the supply chain must have access to digital platforms, otherwise part of the information is lost (Borrero, 2019). Normally, blockchains allow for a limited amount of transaction data to be saved. If there is much more data that needs to be stored, this will require the use of a blockchain system (on-chain data) together with other databases or servers which are not centrally controlled (off-chain data).

In all the cases studied, data required by legislation are included in the system (in chain or off chain), together with additional data. This amounts to a large quantity of data already being reported to public administrations in Europe in different channels and formats, to which several of the agents referred. This information is part of the EU's system of quality and health guarantee (Hernández San Juan, 2019). However, this information cannot be exploited automatically, linked, or reused with private applications, despite being basically the same information reported to the administration (such as registers of phytosanitary treatments, fishing catches, transport notes, or delivery notes).

Existing databases also depend on and are reported to different public or private organizations in the different EU quality schemes.[19] The lack of centralization and reuse of data are also disadvantages in terms of their use for or allowing the scalability of projects which, in principle, could be extrapolated to various regions of Spain. This is the case of production traceability of quality oil, wine, cheese, and meat products derived from extensive livestock or other products that have production conditions of great organoleptic and environmental quality, but that cannot be differentiated in distribution or before reaching the consumer to explain the price segmentation. Having to provide the same information several times in different formats, through different channels and to different organizations, together with the lack of centralization and reuse in general of these data or information, is currently an inconvenience in the adoption of any improved information management system (including blockchain) due to the additional bureaucracy involved.

3.5. Governance of blockchain-based implementations in the agri-food industry

Improved governance of agri-food value chain across different stakeholders is a main potential advantage of blockchain due to the transparency, integrity of information, and open collaboration ensured by a decentralized model. However, those who directly participated in the implementation of systems agreed on the difficulty of involving all the required operators in the introduction of additional data and records and on the additional effort involved in maintaining the system.[20]

Although most of the interviewees pointed to governance (in its different facets) as a problem to be addressed, barely any specified concrete solutions. For this reason, perhaps, the agents describe an unequal interest in the adoption of these systems depending on their participation in the chain. In the purely logistical part and in B–B solutions, blockchain systems have been integrated as a way to ensure

[18] Blockchain en el transporte marítimo: caso de éxito | Revista Ingeniería Naval https://sectormaritimo.es/blockchain-transporte-maritimo-caso-exito.

[19] https://ec.europa.eu/info/food-farming-fisheries/food-safety-and-quality/certification/quality-labels/qual%20ity-schemes-explained_en

[20] After the disappearance of the public financing line, some projects that were already in production were abandoned since the competitive advantages did not translate into lower costs for the producer, nor were there other economic advantages.

initial conditions and the traceability of transport times and conditions (Chang et al., 2020), and it seems that there is a certain consolidation of these solutions.

In the P–B–B–C solutions, the position is more sceptical. All the agents that have participated in projects agreed on the benefits of blockchain for ordering and guaranteeing data (by having to enter it into the system at a certain time and not being able to alter it), but they also agreed on the difficulty of involving all agents in the system and on the low effective profitability of the use of technology (Ferreira et al., 2021) by small producers compared to the effort and demands of feeding/implementing or maintaining the information.

Of all the pilot projects identified, only in the project where the customers were willing to pay a higher price for particular products and this price was passed on to the producers[21] was a real interest expressed in keeping the system running by the primary sector.

In the cases studied, which are all permissioned (public/private or consortium) systems, the rules defined in the consensus process and from which it is decided which transactions are valid (protocol definition) must involve all the participants, and that may be why, in the cases studied, these systems, even if still rather complex, work better in companies where the chain is controlled by a major agent who supervises everything from production to sale.[22]

Implementing distributed registry technologies between multiple entities implies that all the parties that wish to carry out transactions must agree on the chosen platform and on the data formats and processes to follow. In this sense, a good governance system implies involving all the relevant actors and reaching a consensus on the conditions, participation, entry, permissions, data saved (on/off) chain, information provided, oracles (Al-Breiki et al., 2020) and algorithms used.

After reaching an agreement, once the system has been implemented, chosen, or configured—which will be the oracle and the taped information—the implementation of blockchain empowers the developers (or node controllers) to be the main organ behind company decisions, which also generates doubts about its adoption.

Furthermore, in relation to the governance of the system, those scientific experts consulted who had participated as advisors in projects referred to the previously discussed need for standardization. Currently there are not de jure standards in the field of blockchain. In the specific case of governance, there are only recommendations at the ISO level regarding the automation of processes in situations with multiple participants (ISO/TC 307/WG 5 N 102, 2022)

3.6. Scalability of blockchain implementations in the agri-food industry

The projects studied and analysed through interviews present two scalability problems. The first, already discussed, is derived from the lack of standards (whether de facto or de jure), of governance, and the heterogeneity of the data managed off-chain, which makes it difficult for the pilots studied to be extrapolated to similar cases. In fact, regarding the reuse of the designs of the tested blockchain systems, it seems that most of the pilot projects that integrate production/batch tracking data have been designed with an individual perspective and are not scalable.

The second problem concerns the interoperability of platforms. When setting up a blockchain system between different organizations in a multi-entity DLT, there is a coordination issue. This issue can be partially solved by the formation of consortiums. For instance, in Spain there is the Alastria consortium, one of the largest of the world. Other consortiums in Europe (Adan) or in South America (b-Connect) are becoming increasingly active. However, the integration of information through consortiums that use the same DLT is not yet complete, because part of the information that differentiates one product from another is lost in the process.

Integration of the information derived from the production conditions in a P–B–B–C blockchain system is particularly challenging, since the more the information reflects the specific particularity of a product and the whole system is adapted to particular situations, the more the scalability of the projects will be conditioned. In contrast, the scalability of very small systems adapted to cases where the information generated in the cultivation process is fully owned by each of the relevant agents (producers, processors, transporters, distribution) is perfectly possible from a technical perspective. However, the scalability issue here lies in the fact that these ad hoc systems have not yet achieved an economic impact for these producers because the economic size was probably not enough to create a brand or promotion effect that would mean that the intermediate agent or the consumer would recognize them and pay more for the product.

In any case, it can be deduced from the interviews that most of the projects completed and implemented successfully have not been consolidated, much less scaled up. The motivation of the most important agents (those closest to agri-food production) to continue providing genuine information for the blockchain system usually ends with the public financing of the project, as discussed in the next section.

Therefore, the respondents considered that the involvement of large-scale distribution and marketing agents would make it necessary to design common models for different geographical regions (for example, applicable to several appellations of origin or to differentiated quality brands in the same DLT), allowing the development of a sort of de facto standard. In addition, standards and protocols also impact scalability, since they should be developed to arrange/audit the information that would allow isolated DLT systems to be connected.

[21] Galpagro supplied certain customers in the Netherlands who wanted to purchase from small farms.

[22] For example, Lidl or Carrefour promote these projects to promote or differentiate a certain product range and it is therefore a condition of the supplier (COREN's free-range chicken or Lidl's virgin olive oil). If an investment in time and capital is required, it is logical that those who do not perceive a clear benefit from the implementation of the system lose interest in maintaining it.

3.7. Cost, availability and public support

In terms of the availability of technology, there are distinct cases depending on the year of implementation of the project. In those that were deployed in 2018 and 2019, the cost of maintaining the system was considered by respondents to be a barrier to introduction, which (depending on the number of transactions stored in the blockchain) the interviewees estimated at a minimum monthly cost of around 3000 euros per producer organization (OP), hard to bear for small businesses.[23]

Projects deployed after 2020 seem to benefit not only from public financial support, but also from solutions belonging to the European Blockchain Infrastructure for Services (EBSI) and, specifically in Spain, from the Alastria consortium which provides the necessary technology (the nodes) without incurring any transaction costs. Therefore, once the system has been developed or implemented, costs are limited to the maintenance of the required computer system. In this regard, in Spain, some research institutes working with the industry have developed custom applications based on blockchain.[24]

Looking into public support, under the heading of recovery funds, national plans are typically grouped in accordance with European guidelines for financing the process of digital transformation in Spain.[25] This remarkable public support (Consejo Economico y Social, 2017) has made possible for all these projects based on blockchain in the agri-food industry to be developed. From 2021, the economic support for the deployment of technologies, particularly in the primary sector, has been increased even more with the support of the EU's Next Generation Funds.[26] Starting in March 2022, these types of projects will have even more significant support through the funding directed by the program "PERTE Agroalimentario" .[27]

In fact, all the projects identified, without exception, had received some public funding, and, at the time of writing, there are many opportunities for agricultural SMEs in terms of access to aid for technological modernization, which is facilitated and offered by some of the surveyed consulting firms themselves. Still, and despite the above, respondents considered that the costs linked to the complexity of starting up and maintaining the blockchain system are a barrier to its deployment. In all the projects aimed at certifying high-value foods due to their production conditions, agents in the primary sector and producer organizations stated that the implementation of information management systems that used blockchain had improved transparency, organization and guarantees of the information associated with these foods. However, the additional effort required and the cost of maintaining the system were not compensated by an increased price for the final product. Therefore, the end of public financing, expected in most existing deployments, will probably lead to the abandonment of projects.

In terms of public support to make the technology available to the private sector, Spanish administrations at different levels are already using EU funds to incorporate digital technologies in the agricultural sector, especially in the production sector.

This has resulted in some relevant projects already being integrated into producer organizations with sufficient volume, with both bargaining power[28] with public administrations and a commitment to modernization, including conscientious and well-trained employees that surveys have highlighted as a main factor in the adoption of these technologies.

4. Conclusions and critical discussion

From the evidence presented in the paper, the use of blockchain technology seems pertinent to the Spanish agri-food sector, even if most of the available projects at the time of writing where in a pilot stage. The current focus of these blockchain projects is mainly on

[23] There is a lack of supporting infrastructure. It seems partially developed, with solutions provided by Alastria but in order to fully adopt a DLT-based platform into a business, the supporting infrastructure must be completed by the introduction of digital identities and payment gateways and explored together with the legal infrastructure and more international standards.

[24] At this point it is worth making a point about the unexpected results of this research, such as the fact that, despite the bibliographic search yielding an insignificant number of scientific papers in our country, the contribution of Spanish innovation agents to the employment effectiveness of blockchain technology in Europe is quite significant. The country has a significant number of research agents of recognized prestige, in particular the promotion of research institutes such as the CSIC and certain universities—the Polytechnic University of Córdoba, Seville, the University of Madrid, the technological centre of Asturias. Relevant experts at the ITU level include David Arroyo or Ismael Arribas, convenor of Group 3 on Smart Contracts and their applications in ISO TC 307 and liaison officer between CEN CENELEC JTC19 and ETSI ISG PDL. In Spain there is an important blockchain consortium, Alastria, which is probably the largest in terms of infrastructure and relevant partners in the world, though less active than some other consortiums. In addition, the connectivity plan in the Next Generation EU (NGEU) Resilience and Recovery Mechanisms framework plans to invest more than 2.3 billion euros until 2025 to extend broadband internet coverage and infrastructures for Industry 4.0 to promote interconnectivity.

[25] The SME digitalization plan, with public investment of close to 5 billion until 2030 (beneficiaries SMEs), the National Digital Skill Plan (3.75 billion euros 2021–2023), the connectivity plan (more than 2.3 billion euros until 2025), the public administration digitalization plan (2.6 billion euros over the next three years), and the national Artificial Intelligence Strategy (600 million euros in the period 2021–2023) (https://planderecuperacion.gob.es/). Together these initiatives foresee 16.25 billion euros in public investment, 25.4 euros billion being financed by European funds from the NGEU Resilience and Recovery Mechanisms.

[26] https://nexteugeneration.com.

[27] In March of 2022, the agri-food PERTE was approved, which pursues the objective of modernizing. Axes 2 and 3 contemplate specific aid for the digitalization of the agri-food sector and the connection between agents: Axis 2 finances actions to transform the industry with innovative strategies, projects, and programs. This axis has an allocation of 454.53 million euros.Axis 3 is a R&D&I program applied to the agri-food sector and that focuses on food security, diversification in production and the rational price of food. This axis has been allocated 148.56 million euros to achieve a more competitive sector, increasing production levels while optimizing resources.

[28] Covap, Cofradía de Celeiro, Galpagro.

the traceability of products with higher added value, what makes sense in terms of economic sustainability if -and only if-consumers also value highly the trust on this information. When it comes to assessing and implementing blockchain projects, the most significant obstacles for stakeholders are the need to understand and manage the technology, the lack of adequate expertise, and the cost of implementation. In terms of governance, blockchain projects in the sector are still in search of displaying a defined-enough set of policies, regulations, and protocols to ensure trust, and that the applications derived from blockchain store the appropriate data to guarantee production conditions to the consumer.

Therefore, we can say that the utilization of blockchain in this area to certify production conditions to the consumer is still in its primary stages and it confronts a number of fundamental challenges as discussed below, noting, as main caveat, that the number of cases studied and their current status (mostly in the testing phase) do not provide enough evidence to draw definitive conclusions, although they on authors' view they are sufficient to extract some insights and propose new lines of work.

Firstly, the low percentage of companies that displayed adequate understanding of blockchain technology during the survey may indicate that in many cases small companies are operating with little knowledge of the technology. It seems that, even in some cases, the choice to use this technology derives from its popularity and not because of its advantages.[29] Respondents included comments such as "it was fashionable" or was, in part, "sold by the consultants".

Regarding the challenges of implementing blockchain technology in the agri-food industry, the first challenge is related to how the data necessary to ensure production conditions is managed or organized, which data are stored on the blockchain or off-chain and, in particular, the treatment of the raw data prior to its recording on blockchain. If the data collection is not correct, wrong information will be stored in the blockchain, destroying the whole aim of the implementation. Next, there has also been talk of the need to integrate heterogeneous data sources in a homogeneous way to allow the scalability of projects.[30] Another related relevant aspect, it is that the data and information provided, integrated and stored in the system is also supplied, several times, in different formats and through different channels, to various types of official records. In this regard, the availability of this information and its reuse could be an opportunity for the implementation or validation of blockchain systems if a homogeneous and automatic exploitation of data were possible not only in Spain but within Europe. Therefore, from this study, it can also be concluded that a considerable part of future success in the implementation of this technology depends on its ability to connect to/reuse data from existing databases, both public and private—that is, registry systems and official European controls, and industrial production and marketing systems related to resource planning, warehouse management and manufacturing. For this reason, and due to the proliferation of infrastructures to facilitate the use of blockchain, the development of middleware and communication protocols that can unite existing systems constitutes an important research and development niche for the effective deployment of this technology. On this same topic, research is being done on automatic data collection through sensors in order to avoid data manipulation and excessive bureaucracy (Arroyo-Guardeño David, Diaz-Vico, Jesús, Hernandez Encinas, Luis., 2019) which is an interesting way to explore.

A next challenge is the absence of relevant regulations or standards related to the implementation of blockchain technology, an aspect that goes beyond the agri-food sector. Its full compatibility with other regulations such as the European Data Protection Regulation is also unclear (Hernandez San Juan et al., 2020). The experts who responded in detail to the more technical questions in the survey also spoke about the need to finish developing the technology, referring in particular to aspects such as interoperability and security.

Beyond standards, and in relation to the challenges presented by the governance of the system, it should be noted that in all the cases studied, permissioned systems are being used. In fact, there is currently a proliferation of heterogeneous permissioned DLTs with different size and reputation. This heterogeneity calls into question the virtues of the technology because of the fragmentation it can induce and its difficult relationship with governance.[31] The present findings open space for further research: it would be highly beneficial to have a standardised evaluation system that could validate the consensus methodology used and the suggested conceptual framework in such blockchain systems.

Regarding public involvement, the financial support of European funds has been instrumental in developing the necessary infrastructure and resources to ensure the successful implementation of blockchain projects in the primary sector. Nevertheless, the limited scope of fundable projects and a lack of strategic vision for companies' digital transformation projects based on real economic long-term sustainability hide a considerable gap for the dissemination and adoption of blockchain in the agri-food industry in Spain.

Also, public support in Spain happens mostly in the experimental or pilot phase. For the full deployment of solutions, however, this is clearly not enough, as their consolidation would require a transition path that incorporates other measures beyond financing pilot projects: technological, administrative, and legal developments, and, as mentioned, training in this technology. In particular, updating the legal and administrative framework would allow official information already being collected—such as certificates of origin and health, bills of landing, and other data derived from official controls and documents—to be reused in the blockchain system, as previously discussed. This is a main way in which the blockchain would provide a real utility, by not generating added bureaucracy but rather helping to simplify the bureaucratic processes related to the registration of animal and plant identifiers, exchanging data records related to sanitary and animal and plant management and production.

Looking into financial sustainability in general, not just from initial public support, it would be interesting to direct future research

[29] https://chaise-blockchainskills.eu/publications-and-reports/.

[30] Blockchain could and should contribute to the European data space to be built in GAIA-X: https://www.data-infrastructure.eu/GAIAX/Redaktion/EN/Artikel/UseCases/agri-gaia.html.

[31] Nevertheless, the IBM or Alastria system based on Hyperledger fabric was used in the projects studied. In Quorum and Hyperledger Besu (Alastria), the systems are interoperable (https://alastria.io/en/la-red/).

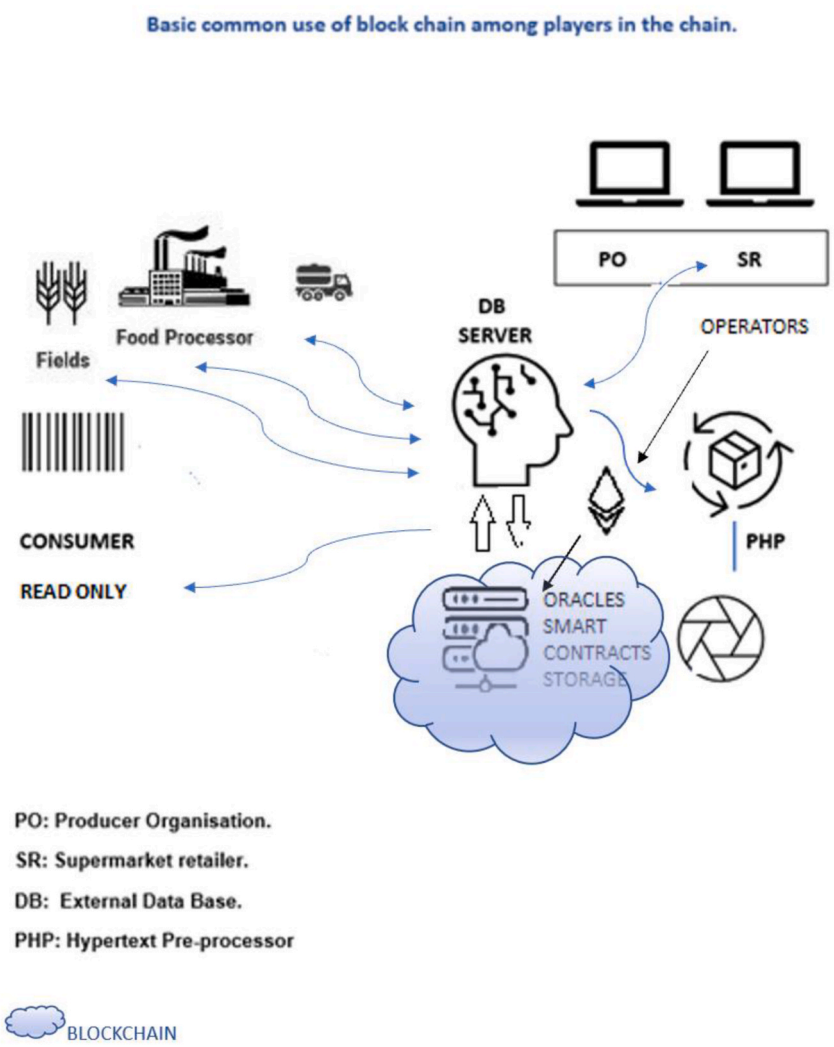


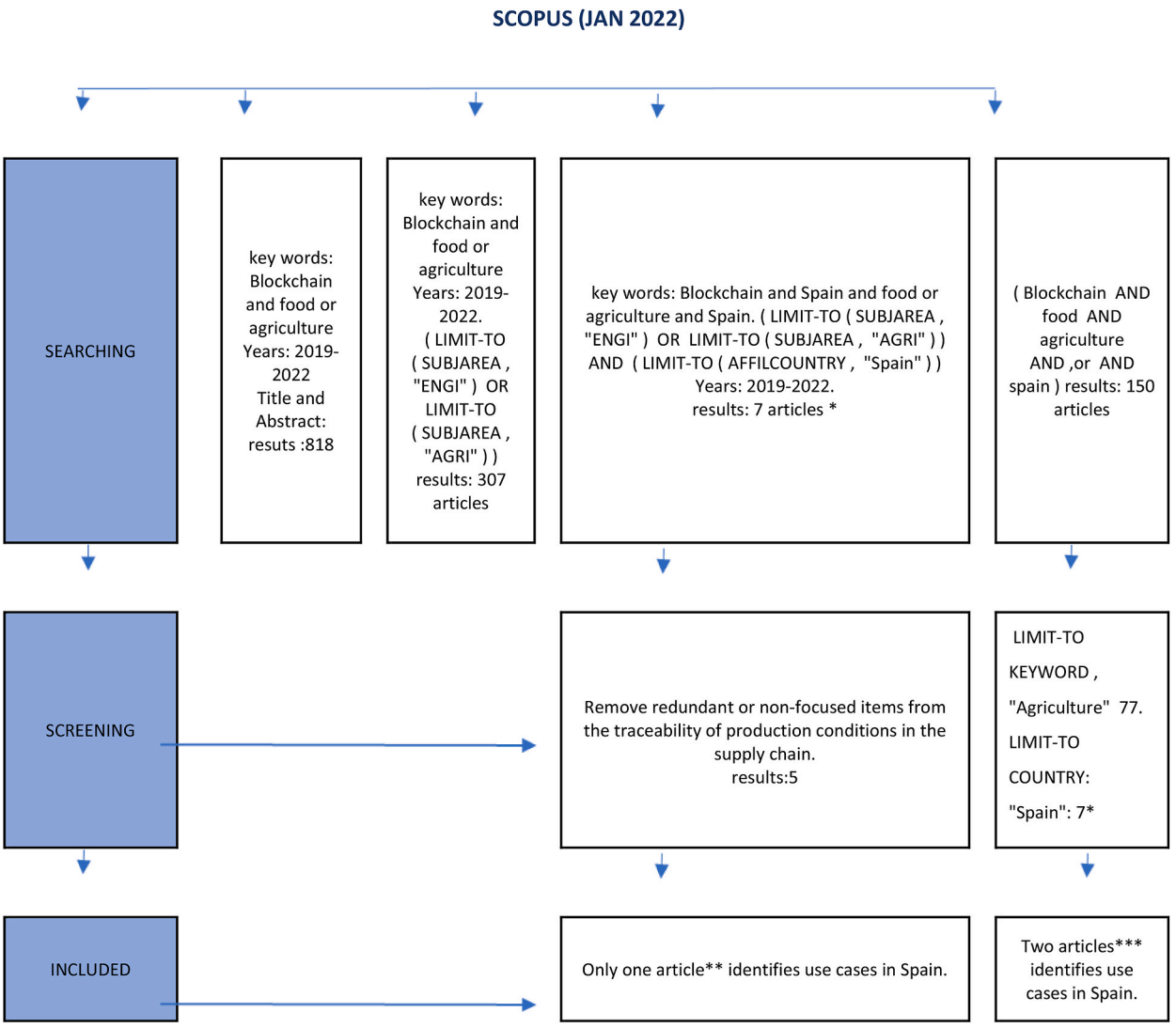
Fig. 2. Basic common use of blockchain among players in the chain.

towards exploitation of data in the blockchain system that could offer some competitive advantage to producers and value chains that bet on quality and connect with untapped demand.

As a summary of possible public intervention, there are many advisable lines of work for policies, ranging from how to improve the re-use of data reported to public administrations, to awareness, training and understanding of the fundamentals of blockchain technology in a context of digital transformation and a shortage of projects in digital skills training (Palomo-Zurdo & Dopacio, 2022). Additionally, guidance is needed in the selection and integration of control data to create de facto standards. The successful implementation of blockchain technology depends also on its ability to connect to existing databases, and the development of middleware and communication protocols for effective deployment.

All in all, when looking from an innovation perspective, the success of blockchain technology in the agri-food industry is not a problem concerning generation of the opportunity or new innovations, with the minor exception of data capture and reliability, as the advantages of the technology are well recognized. Rather, it is a problem of innovation dissemination, that requires, formation, cultural change, smart funding, best practices, and success stories; and adoption—issues about the reuse of existing information, standardization, and governance-especially in cases with a diversity of players.

Appendix I



*The result of the search is presented in Appendix I.

**Only the practical analysis of a tested application in the exploitation of Hermanos Olea Losa, S.L. (Castrillo de la Guareña, Zamora, Spain) which has evaluated the application can be found.

***Agri-food supply chain traceability for fruit and vegetable cooperatives using Blockchain technology | [Sistema de trazabilidad de la cadena de suministro agroalimentario para cooperativas de frutas y hortalizas basado en la tecnología Blockchain]

Search pattern in Scopus database

The result of the search is presented in Appendix I.

Only the practical analysis of a tested application in the exploitation of Hermanos Olea Losa, S.L. (Castrillo de la Guareña, Zamora, Spain) which has evaluated the application can be found.

Agri-food supply chain traceability for fruit and vegetable cooperatives using Blockchain technology | [Sistema de trazabilidad de la cadena de suministro agroalimentario para cooperativas de frutas y hortalizas basado en la tecnología Blockchain].

Screening (1)

This Scopus search result is looking for articles published between 2019 and 2022 with a subject area of engineering (ENGI) or agriculture (AGRI) that are related to blockchain and food or agriculture and are published by authors in Spain in 2021 or 2020. It is limiting the results to articles that meet all the specified criteria.

Screening (2)

This Scopus search is for articles that contain the keywords "Blockchain", "Food" and "Agriculture", with the country limit set to "Spain". The search yielded 150 articles, 77 of which contain the keyword "Agriculture". There are two articles which identified use cases of Blockchain in Spain.

Appendix II

Main regulatory control, monitoring provisions that require the registration and exploitation of data derived from agri-food production in Spain.

Regulation (EC) No 178/2002 of the European Parliament and of the Council of January 28, 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.

Directive 2001/95/EC of the European Parliament and of the Council of December 3, 2001 on general product safety.

Ley 17/2011, de 17 de Julio, on food safety and nutrition.

Real Decreto 1808/1991, de 13 de diciembre, that regulates the mentions or marks that allow to identify the batch to which a food product belongs (BOE December 25, 1991).

Real Decreto 2207/95, de 28 de diciembre, on hygiene of food products (B.O.E 27.02.1996), result of the transposition of the Directive 93/43/CEE.

Real Decreto 479/2004, de 26 de marzo which establishes and regulates the General Registry of Livestock Farms.

Real Decreto 728/2007, de 13 de junio by which it is established and regulates the General Registry of Livestock Movements and the Registry general identification of individual animals.

Real Decreto 1614/2008, de 3 de octubre, relating to the animal health requirements of animals and aquaculture products, as well as the prevention and control of certain diseases of aquatic animals.

Electronic Record of Transactions and Operations with Phytosanitary Products (RETO) established the Real Decreto 285/2021, de 20 de abril.

Real Decreto 1311/2012, de 14 de septiembre which establishes the framework for action to achieve a sustainable use of plant protection products amended by Real Decreto 1050/2022, de 27 de diciembre, modifying Royal Decree 1311/2012, of September 14, establishing the framework of action to achieve a sustainable use of phytosanitary products.

PROLAC database. Real Decreto 95/2019, de 1 de marzo, which establishes the contracting conditions in the dairy sector and regulates the recognition of producer organizations and interprofessional organizations in the sector,

ARCA system regulated in the Real Decreto 45/2019, de 8 de febrero which establishes the zootechnical standards applicable to purebred breeding animals, hybrid breeding pigs and their reproductive material, updating the National Program for the conservation, improvement and promotion of livestock breeds.

Computer system for registering animal feed establishments. Real Decreto 629/2019, de 31 de octubre.

ECOGAN system created by the Royal Decree that regulates the general registry of best available techniques in farms and the support for the calculation, monitoring, and notification of emissions in livestock.

The National Registry of Producer Organizations and Associations of Producer Organizations regulated in the Real Decreto 532/2017, de 26 de mayo.

The State Register of organizations and associations of organizations of producers of raw tobacco referred to in the Real Decreto 969/2014, de 21 de noviembre, which regulates the recognition of producer organizations, the extension of standards, contractual relations and the communication of information in the raw tobacco sector.

The National Register of organizations and associations of organizations of milk producers regulated in the Real Decreto 95/2019, de 1 de marzo.

The National Registry of organizations and associations of producer organizations provided for in el Real Decreto 541/2016, de 25 de noviembre, which regulates the recognition of producer organizations and their associations in the rabbit sector.

Wine Sector Market Information System del Real Decreto 739/2015, de 31 de julio.

Unified information system of the dairy sector regulated in the Real Decreto 319/2015, de 24 de abril, on mandatory declarations to be made by first buyers and producers of milk and dairy products from cows, sheep and goats.

REGMAQ System: Real Decreto 448/2020, de 10 de marzo, on characterization and registration of agricultural machinery.

Information system of the olive markets regulated in the Real Decreto 861/2018, de 13 de julio, establishing the basic regulations on mandatory declarations in the olive oil and table olives sectors.

El Real Decreto 1054/2021, de 30 de noviembre which establishes and regulates the Register of professional plant operators, the measures to be complied with by professional operators authorized to issue phytosanitary passports and the obligations of professional operators of reproductive plant material and modifies various royal decrees in matters of farming.

Other data sources

The data of the application for CAP aid established in the Real Decreto 1075/2014, de 19 de diciembre revoked by Real Decreto 1048/2022, de 27 de diciembre, on the application, from 2023, of interventions in the form of direct payments and the establishment of common requirements in the framework of the Strategic Plan of the Common Agricultural Policy, and the regulation of the single application of the integrated management and control system.

The data related to payments of the European agricultural funds, FEAGA and FEADER, compiled based on the provisions of the Real Decreto 92/2018, de 2 de marzo.

Sistema TRACES (*TRAde* **C***ontrol and* **E***xpert* **S***ystem*) is a web-based veterinarian certification tool used by the European Union for controlling the import and export of live animals and animal products within and without its borders. Its network.

Real Decreto 1045/2022, de 27 de diciembre, on basic income support rights for the sustainability of the Common Agricultural Policy.

Real Decreto 1046/2022, de 27 de diciembre, regulating the governance of the Strategic Plan of the Common Agricultural Policy in Spain and of the European agricultural funds FEAGA and Feader.

Real Decreto 1047/2022, de 27 de diciembre, regulating the management and control system of Strategic Plan interventions and other Common Agricultural Policy aids.

Real Decreto 1049/2022, de 27 de diciembre, establishing the rules for the application of reinforced conditionalities and social conditionalities that beneficiaries of Common Agricultural Policy aids receiving direct payments, certain annual development payments and the Programme for Specific Options for Distance and Insularity (POSEI) must comply with.

Real Decreto 1051/2022, de 27 de diciembre, establishing rules for sustainable nutrition in agricultural soils.

Real Decreto 1054/2022, de 27 de diciembre, establishing and regulating the Information System for agricultural and livestock holdings and agricultural production, as well as the Autonomous Register of agricultural holdings and the Digital Farm Record.

Appendix III

Questionnaires.
(Original version in Spanish)
Fecha de entrevista: _____
Nombre del entrevistado: _____
Nombre de la compañía: _____
Departamento: _____
Posición: _____
Años de experiencia: _____

Parte A: Introducción

Introducción: Gracias por su tiempo para contribuir a esta investigación. Explicaré brevemente mi papel, el objetivo de este estudio de investigación y cómo se llevará a cabo la entrevista.

El propósito de la investigación es analizar el grado de conocimiento en España sobre la tecnología blockchain aplicada a la cadena agroalimentaria y la percepción que existe su posible utilidad.

Además, queremos conocer las ventajas o desventajas que se observan por parte de los actores que han participado de experiencias de uso de sistemas basados en blockchain y las ventajas/oportunidades y dificultades/desafíos que han observado en relación con la implantación de la tecnología.

Asimismo, en la utilización de la tecnología de la cadena de bloques a su caso concreto nos interesa conocer que "prueba de concepto" se utiliza para perfeccionar el algoritmo y qué interesares satisface de las que están involucradas en la cadena.

Confidencialidad: La información obtenida de esta entrevista es confidencial. Los datos adquiridos serán utilizados de manera agregada y con el único objetivo de documentar este estudio y no se transmitirán a terceros. El nombre de su empresa, su nombre y cualquier otro será tratado de manera confidencial y se codificará la información que lo identifique a usted o a su empresa.

Puede contactarme a través del siguiente número de teléfono: 615XXXXX.

La parte B y C contienen las preguntas concretas planteadas a los distintos grupos de agentes.

Parte b: guía de entrevista para empresas que podrían estar interesadas o están ya utilizando tecnología blockchain

Preguntas generales

1. ¿Puede describir brevemente su puesto dentro de su empresa?
2. ¿Cuál es el negocio principal de su empresa?
3. ¿Puede describir brevemente el papel de su empresa dentro de la cadena de suministro agroalimentario? ¿dentro de la cadena en qué tipo de actividades están involucrados?
4. ¿Qué actividades/procesos necesitan de una tecnología de encriptado/seguridad de los datos? ¿cuáles son los aspectos más y menos importantes en el proceso de valor de los productos con los que trabajan?

Forma actual de trabajar

5. ¿En qué parte del proceso se identifican la mayoría de los problemas/desafíos?
6. ¿Qué tipo de problemas se perciben en este memento para la cadena de suministro agroalimentario? (Gran cantidad de documentación, ineficacia, colaboración, retrasos, problemas de comunicación, datos/TI, ¿otros?)
7. ¿Qué tipo de problemas se ven mejorados con el empleo de la tecnología blockchain? ¿Consecuencias?
8. ¿Qué actividades pueden y deben ¿mejorarse ? ¿cómo se pueden mejorar?
9. ¿Qué tipo de mejoras en relación con la comunicación/documentación o digitalización de la cadena de suministro agroalimentario se han realizado en los últimos años? ¿Fueron exitosas? ¿Por qué y por qué no?

Preguntas de seguimiento relacionadas con la documentación

10. ¿Qué tipo de documentación se necesita/se prepara para los envíos?
11. ¿Cómo se percibe el proceso de documentación en su organización?
12. ¿Cuánto tiempo se dedica a verificar/preparar documentos? ¿Es posible estimar esto en costos?
13. ¿En qué medida cree que la forma actual de trabajar en materia de documentación es suficiente para el futuro? (Para seguir siendo competitivo/exitoso)

Preguntas de seguimiento relacionadas con la comunicación

14. ¿Cómo percibe la cantidad de comunicación necesaria con otros actores de la cadena de suministro agroalimentario?
15. ¿Cómo percibe la colaboración a lo largo de la cadena para realizar/recibir pedidos con éxito?
16. Preguntas relativas a la incorporación de Tecnologías de la Información a la cadena de suministro agroalimentario.
17. ¿Cómo describiría el panorama actual de las tecnologías de la información? ¿Es suficiente?
18. ¿En qué medida las tecnologías de la información que están utilizando son suficientes para permitir un seguimiento o recabar la información de los procesos realizados (Datos disponibles, interfaces con otros sistemas, etc.)?
19. ¿Qué opina sobre la digitalización comercial de la cadena de suministro agroalimentario?
20. ¿Hasta qué punto es necesaria la digitalización del comercio?
21. ¿Qué le gustaría lograr en los proyectos de digitalización? ¿Qué aprendió de los proyectos de digitalización ejecutados en el pasado?

Preguntas de seguimiento relacionadas con la estandarización

22. ¿Conoce algún proceso de estandarización en su ámbito? ¿participa del mismo?
23. ¿Forma parte de iniciativas internacionales para mejorar la logística?
24. ¿Ha adoptado algún tipo de estándar o procedimiento de uso común? ¿en qué ámbito: nacional/europeo/internacional?
25. ¿Cuál es la fuente de su conocimiento tecnológico aplicado a estandarización? ¿Cómo se mantiene al día?

Conocimiento e interés sobre la tecnología blockchain

26. ¿Qué sabe sobre la nueva tecnología blockchain? (¿Qué tipo de aplicaciones de blockchain conoce (Instituciones financieras, bitcoin, etc.)? ¿Cuándo surgió por primera vez su interés en blockchain?
27. ¿Ha cambiado su interés en blockchain con el tiempo?
28. ¿Qué tipo de oportunidades le ofrecen las soluciones basadas en blockchain? ¿Cuáles considera que son las características más importantes/interesantes que ofrece la tecnología blockchain? (Descentralizado, inmutabilidad, consenso, transparencia, contratos inteligentes, escalabilidad, etc.) frente a otras tecnologías? Específicamente para su empresa, ¿de qué manera la tecnología blockchain sería beneficiosa/no beneficiosa?
29. ¿participa en un proyecto donde implementar blockchain? ¿Está involucrado en el proceso de implementación? ¿Cómo promotor/colaborador? ¿se trata de un proyecto internacional/nacional/local?
¿Ve posibles limitaciones para la tecnología en su cadena de suministro agroalimentario?
30. ¿Por qué te interesa implementar blockchain en tu empresa?
31. ¿Cómo le gustaría implementar blockchain en tu empresa?
32. ¿Cuáles han sido sus experiencias con empresas que ofrecen soluciones blockchain?
33. ¿Cómo son sus relaciones con sus socios de la cadena de suministro agroalimentario?
34. En la literatura, muchos investigadores afirman que las empresas en una colaboración a menudo enfrentan con problemas en relación con el intercambio de información y la falta de confianza.

- ¿Cuáles son sus experiencias con estos desafíos?
- ¿Tiene algún problema con el intercambio de información?
- ¿Tiene problemas de confianza?
- ¿Ve alguna posibilidad de cómo blockchain podría afrontar estos problemas de colaboración?
- ¿En qué medida espera que blockchain resuelva los problemas mencionados anteriormente u otros? ¿qué problemas?

35. Si pudiera desarrollar una plataforma blockchain conforme a sus necesidades, ¿qué requisito consideraría importante incluir?
36. ¿Qué cree que cambiará en su negocio al adoptar una tecnología tan nueva como
37. blockchain?
    - ¿Hasta qué punto cree que su empresa está preparada para adoptar una nueva tecnología como blockchain?
    - ¿En qué período de tiempo?
    - ¿Qué barreras debe superar su empresa para estar preparada?
    - ¿Qué aspectos considera motivadores para adoptar blockchain?
    - ¿Por qué no implementaría la tecnología blockchain en su organización y por qué?
38. ¿Alternativas para la tecnología blockchain? ¿Hasta qué punto su empresa siente la necesidad de involucrarse en proyectos de digitalización/blockchain para permanecer competitivo en el futuro?
39. ¿En qué condiciones o bajo qué supuestos participaría su empresa en una gran plataforma blockchain?
40. ¿Qué vías de apoyo o de financiación conoce para la transformación tecnológica de su empresa? ¿se han financiado inversiones o experiencias de implementación de tecnología blockchain con cargo a los fondos europeos?
41. ¿Qué otro agente me recomendaría que contactara al objeto de conocer mayores detalles del impacto o la utilidad del blockchain en las cadenas de suministro en España?

Parte c: guía de entrevista para agentes del sector público/academia

1. ¿Conoce la tecnología blockchain? ¿sus usos? ¿y sus posibles aplicaciones a la cadena de suministro agroalimentario?
2. ¿conoce experiencias o personas en su entorno que estén utilizando esta tecnología?
3. ¿Cuándo surgió por primera vez su interés en blockchain?
4. ¿ha trabajado/impulsado/analizado/participado directamente en algún proyecto o estudio que utilice la tecnología blockchain? ¿podría describir brevemente en qué consistía?

4.1) ¿qué utilidad concreta prestaba esta tecnología?

4.2) ¿ha intervenido/supervisado algún proyecto que utilice esta tecnología?

5. ¿Con qué tipo de proyectos/expedientes trabaja (sector/industrias/ámbito académico etc.)?
6. ¿Qué experiencia puede transmitir sobre opiniones de terceros en relación con el uso de blockchain?
7. ¿en su entorno, puede decir que ha cambiado el interés por el uso del blockchain con el tiempo?

Soluciones blockchain en cadenas de suministro agroalimentario

8. ¿Conoce la utilidad la tecnología blockchain en la cadena de suministro agroalimentario?
9. ¿Qué conocimiento tiene con las aplicaciones blockchain en las cadenas de suministro agroalimentario? ¿nacionales/internacionales? ¿sectores? ¿utilidad? ¿ámbito académico/industrial/experimental?
10. ¿Qué tipo de oportunidades señalaría en relación con las soluciones blockchain en las cadenas de suministro agroalimentario?
11. ¿Cuáles son las limitaciones de esta tecnología en las cadenas de suministro agroalimentario?
12. ¿en su opinión, qué industrias específicas que podrían estar especialmente interesadas en la tecnología?
13. ¿conoce/existe/ha utilizado algún sistema de financiación con cargo a fondos europeos para apoyar el proceso transformador de las empresas?

Razones para implementar la tecnología blockchain

14. ¿sus administrados/alumnos/investigadores ya tienen una idea de cómo implementar la tecnología blockchain?

    14.1) ¿Conocen áreas problemáticas específicas que la tecnología podría resolver?

    14.2) ¿A la hora de lanzar un proyecto, necesita identificar primero la utilidad que esta tecnología podría tener para el mismo?
15. En la literatura, muchos investigadores afirman que entre las relaciones empresariales que se producen en la cadena de suministro y distribución alimentaria a menudo surgen problemas en el intercambio de información y también problemas de confianza. (por ejemplo, en materia sanitaria/origen/garantía de pago/falsificación de producto) ¿cree que en España existen esos problemas?

    15.1) ¿Cuáles son sus experiencias con estos desafíos? ¿nacionales/internacionales?

    15.2) ¿Ve otros problemas en las cadenas de suministro agroalimentario que podrían resolverse? ¿a través de blockchain?
16. ¿Ve posibilidades del uso de blockchain para resolver problemas de confianza?
17. ¿Cuándo evalúa o analiza una experiencia o proyecto concreto en el que introduce la tecnología blockchain en España diría que existe un impacto en la relación entre los socios de la cadena de suministro agroalimentario durante y después de la implementación?
18. ¿Qué otros agentes me recomendarían que contactara al objeto de conocer mayores detalles de la utilidad del blockchain en las cadenas de suministro agroalimentario en España?

Questionnaires

(Translation into English)
Date of interview: _____
Name of interviewee: _____
Company name: _____
Department: _____
Position: _____
Years of experience: _____
Part A: Introduction

Introduction: Thank you for your time in contributing to this research. I will briefly explain my role, the objective of this research study and how the interview will be conducted.

The purpose of the research is to analyze the degree of knowledge in Spain about blockchain technology applied to the agri-food chain and the perception of its potential usefulness.

In addition, we want to know the advantages or disadvantages observed by the actors who have participated in experiences using blockchain-based systems and the advantages/opportunities and difficulties/challenges they have observed in relation to the implementation of the technology.

Likewise, in the use of blockchain technology to their specific case we are interested in knowing what "proof of concept" is used to perfect the algorithm and what interests it satisfies of those involved in the chain.

Confidentiality: The information obtained from this interview is confidential. The data acquired will be used in aggregate form and for the sole purpose of documenting this study and will not be passed on to third parties. Your company name, your name and any other name will be treated confidentially and information that identifies you or your company will be coded.

You can contact me through the following telephone number: 615XXXX.

Part B and C contain the specific questions posed to the different groups of agents.

Part b: interview guide for companies that might be interested in or are already using blockchain technology.

General questions

42. Can you briefly describe your position within your company?
43. What is your company's core business?
44. Can you briefly describe your company's role within the agri-food supply chain? Within the chain what kind of activities are you involved in?
45. What activities/processes require data encryption/security technology? What are the most and least important aspects in the value process of the products you work with?

Current way of working

46. In which part of the process are most problems/challenges identified?
47. What kind of problems are perceived now for the agri-food supply chain? (Large amount of documentation, inefficiencies, collaboration, delays, communication problems, data/IT, other?)
48. What kind of problems are improved with the use of blockchain technology? Consequences?
49. What activities can and should be improved, how can they be improved?
50. 9What kind of improvements related to communication/documentation or digitization of the agri-food supply chain have been made in the last few years? Were they successful? Why and why not?

Follow-up questions related to documentation.

51. What kind of documentation is needed/prepared for shipments?
52. How is the documentation process perceived in your organization?
53. How much time is spent verifying and preparing documents? Is it possible to estimate the cost of this?
54. To what extent do you think the current way of working with documentation is sufficient for the future (to remain competitive/successful)?

Follow-up questions related to communication.

55. How do you perceive the amount of communication needed with other actors in the agri-food supply chain?
56. How do you perceive the collaboration along the chain to successfully place/receive orders?

Questions related to the incorporation of Information Technology into the agri-food supply chain.

57. How would you describe the current IT landscape? It is sufficient?

58. To what extent are the information technologies you are using sufficient to allow you to monitor or collect information on the processes conducted (available data, interfaces with other systems, etc.)?
59. What is your opinion on the commercial digitization of the agri-food supply chain?
60. To what extent is trade digitization necessary?
61. What would you like to achieve in digitization projects? What did you learn from digitization projects implemented in the past?

Follow-up questions related to standardization.

62. Are you aware of any standardization process in your field? are you involved in it?
63. Are you part of any international initiatives to improve logistics?
64. Have you adopted any standards or procedures in common use? at what level: national/European/international?
65. What is the source of your technological knowledge applied to standardization? How do you keep up to date?

Knowledge and interest in blockchain technology.

66. What do you know about the new blockchain technology? (What kind of blockchain applications do you know about? (Financial institutions, bitcoin other?) When did your interest in blockchain first arise?
67. Has your interest in blockchain changed over time?
68. What kind of opportunities do blockchain-based solutions offer you? What do you consider to be the most important/interesting features that blockchain technology offers (Decentralized, immutability, consensus, transparency, smart contracts, scalability, etc.) compared to other technologies? Specifically for your company, in what ways would blockchain technology be beneficial/non-beneficial?
69. Are you involved in a project to implement blockchain, are you involved in the implementation process, as a promoter/collaborator, is it an international/national/local project?
70. Do you see possible limitations for the technology in your agri-food supply chain?
71. Why are you interested in implementing blockchain in your company?
72. How would you like to implement blockchain in your company?
32. What have been your experiences with companies offering blockchain solutions?
33. How are your relationships with your agri-food supply chain partners?
34. In the literature, many researchers state that companies in a collaboration often face issues regarding information sharing and lack of trust.
    - What are your experiences with these challenges?
    - Do you have any problems with information sharing?
    - Do you have trust issues?
    - Do you see any possibilities for how blockchain could address these collaboration issues?
    - To what extent do you expect blockchain to solve the above or other problems? which problems?

If you could develop a blockchain platform according to your needs, what requirement would you consider important to include?

36. What do you think will change in your business by adopting a technology as new as blockchain? 37.
37. blockchain?
    - To what extent do you think your company is ready to adopt a new technology such as blockchain?

Over what period?

    - What barriers must your company overcome to be ready?
    - What aspects do you consider motivating to adopt blockchain?
    - Why would you not implement blockchain technology in your organization and why?
38. Alternatives to blockchain technology? To what extent does your company feel the need to engage in digitization/blockchain projects to remain competitive in the future?
39. Under what conditions or assumptions would your company participate in a large blockchain platform?
40. What support or funding channels do you know of for the technological transformation of your company? Have any investments or experiences of blockchain technology implementation been financed by European funds?
41. Which other agent would you recommend that I contact to learn more about the impact or usefulness of blockchain in supply chains in Spain?

Part c: interview guide for public sector/academia stakeholders.

1. Are you familiar with blockchain technology, its uses, and its possible applications to the agri-food supply chain?
2. Do you know of experiences or people in your environment who are using this technology?
3. When did your interest in blockchain first arise?

4. have you worked/driven/analysed/participated directly in any project or study using blockchain technology? could you briefly describe what it consisted of?

4.1) what was the specific use of this technology?

4.2) have you been involved/supervised any projects using this technology?

5. What type of projects/files do you work with (sector/industry/academia …)?
6. What experience can you convey about third party opinions regarding the use of blockchain?
7. In your environment, can you say that interest in the use of blockchain has changed over time?

Blockchain solutions in agri-food supply chains.

8. Are you aware of the usefulness of blockchain technology in the agri-food supply chain?
9. What knowledge do you have with blockchain applications in agri-food supply chains? national/international? sectors? usefulness? academic/industrial/experimental?
10. What kind of opportunities would you point out regarding blockchain solutions in agri-food supply chains?
11. What are the limitations of this technology in agri-food supply chains?
12. in your opinion, what specific industries that might be particularly interested in the technology?
13. do you know/do you exist/have you used any financing system from European funds to support the transformative process of the companies?

Reasons to implement blockchain technology.

14. Do your administrators/students/researchers already have an idea of how to implement blockchain technology?
    14.1 Do they know specific problem areas that the technology could solve?
    14.2 When launching a project, do you need to first identify the utility this technology could have for the project?
15. In the literature, many researchers state that among the business relationships that occur in the food supply and distribution chain, problems often arise in the exchange of information and trust issues (e.g., sanitary/origin/guarantee of payment/product counterfeiting). Do you think that such problems exist in Spain?
    15.1 What are your experiences with these challenges? national/international?
    15.2 Do you see any other issues in agri-food supply chains that could be solved using blockchain?
16 Do you see possibilities of using blockchain to solve trust issues?
17 When evaluating or analysing a specific experience or project in which you introduce blockchain technology in Spain would you say that there is an impact on the relationship between agri-food supply chain partners during and after implementation?
18 What other actors would you recommend that I contact to learn more about the usefulness of blockchain in agri-food supply chains in Spain?

Appendix IV

Summary tables

Table 1
Market-based solutions

market-based solutions.	URL	main objective	Integration of associated production requirements
Trazable	https://trazable.io/software-trazabilidad-alimentaria/	promotion the automation of the production chain	no
Iberchain	https://iberchain.es/	traceability from the origin of the product	yes
Zertifier	https://www.zertifier.com/#	traceability from the origin of the product	Not verified in the study
Blocktac	https://www.blocktac.com/otros-sectores/	Authenticity	no
Vestigia	https://www.programaminerva.es/vestigia/	traceability from the origin of the product	yes
Asseco	https://es.asseco.com/divisiones/manufacturing/blockchain/	promotion the automation of the production chain	no
Foodxain (Foodchain global)	https://foodxain.com/	traceability from the origin of the product	no
Gouze	https://gouze.io/es/industria-conectada/	traceability from the origin of the product	no
IBM food trust	https://www.ibm.com/es-es/blockchain/solutions/food-trust	traceability from the origin of the product	yes

Table 2
Companies that provide software for the traceability of fishery products that use blockchain technology.

Pacific FishTrax	traceable canned tuna	USA
Golfo Salvaje	traceable canned tuna	Mexico
John West Australia	traceable canned tuna	Australia
Peces legítimos	" Smart digital identity (Mowi)	USA
OpenSC	low carbon food	Australia
fishworldtrack	origin of the seafood fish	SPAIN

Table 3
Blockchain lobbies in Spain from database: "transparency register EU".

ORGANIZATION	ACTIVITY	INDUSTRY	REFERENCE	Blockchain application example
FOODRATION4ALL S.L.	Food NGO	FOOD BANKS	https://foodration4all.com/	Purse card to obtain food/reduce food waste
MEDIAPRO GROUP	Technical services supplier to the audio-visual sector.	AUDIO-VISUAL	AUDIO-VISUAL MEDIAPRO | leader of the European Audio-visual	Market Copyright
STARUP VILLAGE	Support for entrepreneurship for the development of rural areas	RURAL DEVELOPMENT	http://startupvillage.eu/	Support for tourism activities, rural geolocation
UNESPA	Insurance	INSURERS	http://www.unespa.es	Smart contract applied to the management of insurance procedures.
FUNDACIÓN CTIC CENTRO TECHNOLOGICAL CENTRE (CTIC)	Research and development of technological solutions in various fields	MULTIPLE PROJECTS IN MANY AREAS OF ACTIVITY (Several projects based on TELOS are identified)	Telos blockchain	Several, among others: a query application for the final consumer of the product, who wants to know more information about its origin and other characteristics
HEALTH IDENTIFICATION CARD	Technological applications health sector	IT APPLIED TO THE HEALTH FIELD	http://www.fundacionctic.org	Health Code
AEI CYBERSECURITY	Business group computer security services	CYBERSECURITY	https://www.aeiciberseguridad.es/	"Cybersecurity Seal", a collaborative project of a group of partners to provide a robust cybersecurity certification
COLEGIO DE REGISTRADORES DE ESPAÑA (CORPME)	FE PUBLICA REGISTRAL	PUBLIC REGISTRY	Registradores de España	Notarization of documents and authenticity.

Table 4
Agent's map

Source[a]	Industry	Company/Agent*
Blockchain in distribution industry		
TGA	Enablers/drivers. Large retailers	FM (interviewed)
JG	Large retailers	Carrefour
TGA	Large retailers	Mercadona
TGA	enablers/drivers. Large retailers	JJ (interviewed)
Magazine	Large retailers	LIDL
Blockchain in the primary agricultural and fishing sector		
TGA	Olive oil producers	Oleoestepa
TGA	Fruit and Vegetable Sector	Unica (NA)
TGA	Olive oil producers	Coexpal
JA	Fruit and Vegetable Sector	
TGA	Fruit and Vegetable Sector	Federación empresarial de agroalimentación de la Comunidad Valenciana
Magazine	Meat sector	Covap (proyecto iberchain)
Magazine	Fruit and Vegetable Sector	Cooperativa frutas y hortalizas Huelva
JE	Olive oil producers	Almazara de la Subbética (interviewed)
JG	Fisheries	Puerto de Celeiro (interviewed) EML
JE	Olive oil producers	Galpagro (MAM)
TGA	Citrus	Inmaculada Sanfeliu
Magazine	Meat sector	COREN
JG	Fisheries	Nueva Pescanova
JE	Olive oil producers	Rurápolis
Consulting digital services agri-food sector (Blockchain)		
Source	**Company**	**Agent***

(*continued on next page*)

Table 4 (*continued*)

Source[a]	Industry	Company/Agent*
TGA	Thoffod	OGA (interviewed)
TGA	Ecoagra	
Linkedln	D	IBM (interviewed)
Linkedln	Fish World Track (fisheries)	JIA (interviewed)
JE	Rurápolis	MAM (interviewed)
MLM	Hispatec	
MLM	Certificadora Comité Andaluz de Agricultura Ecológica	
JE	Wealize digital	MAC (interviewed)
JE	Overtrace	MAM (interviewed)
Linkedln	IBM	GSC
Linkedln	IBM Blockchain Transparent Supply,	DM
JE	IBM	LC (interviewed)
DA	KUNFUD®	IA (interviewed)
JE	Galpagro	JMC (interviewed)
UNIVERSITIES/RESEARCH CENTERS		
Source	**University**	**Agent***
JE	Universidad de Córdoba	JDB (interviewed)
Linkedln	Universidad Politécnica de Sevilla	MLM (interviewed)
Linkedln	Universidad Politécnica de Madrid	AM (interviewed)
Agenda	Universidad Politécnica de Madrid	
JE	Universidad de Granada	FLB (interviewed)
JE	Universidad de Córdoba	JE (interviewed)
JE	Universidad de Granada	FLB (interviewed)
JE	Universidad de Córdoba	JE (interviewed)
MITECO	CSIC	DE (interviewed)
WEB	CTIC (Asturias)	
WEB	Universidad de Salamanca	
PUBLIC SECTOR (national level)		
Agenda	MITECO (Ministry of Industry)	PGP (interviewed)
Agenda	MAPA (Ministry of Agriculture)	CG (interviewed)

[a] For reasons of data protection, only the expert reference codes are used.

Table 5
Relevant international projects.

PROJECT	REFERENCE	OPERATION/CHECKPOINTS	DEVELOPER
Fish Best 360	https://360seafood.com/en/https://images.axfoundation.se/uploads/2018/09/Final-Report_Axfoundation_Designing-Blockchain-Use-Cases-to-Deliver-Greater-Sustainability-in-the-Food-Chain_2019-04-25.pdf	printed traceability code which embeds the relevant data that allows the tracking of a product to its underlying and the relevant data sets about its origin (primary data of fisheries and farms).	IBM
Turkey Cargill's Blockchain	https://thecounter.org/cargill-blockchain-traceable-turkey-contract-farming-reality-thanksgiving/	8 checkpoints. plot, mill, facilities, and distribution	IBM
Aceite de oliva Extra virgen "terra Delyssa"	https://newsroom.ibm.com/2020-01-14-CHO-Taps-IBM-Food-Trust-to-Provide-Insight-on-Quality-and-Origin-of-Terra-Delyssa-Extra-Virgin-Olive-Oil	information on the place of origin and fed, treatments, place of slaughter and distribution.	IBM
Carrefour quality line de auvenia	https://gccviews.com/carrefour-se-moderniza-y-pone-a-sus-pollos-en-blockchain/	combined with radio frequency capture zone	IBM
Sea Quest Fiji Ltd & WWF	https://www.wwf.org.nz/what_we_do/marine/blockchain_tuna_project/	cultivation places, dates, quality control of potatoes (ingredients of potato puree)	ConsenSys
Carrefour and Mousline Nestlé	https://www.ift.org/news-and-publications/news/2019/april/16/nestle-and-carrefour-test-blockchain-platform-with-mousline-puree?fullsite=true	origin and place of transformation	IBM
Sales platform	https://dashboard.karyonfood.com/		

Table 6
Ongoing or completed projects that use blockchain technology to guarantee certain production conditions through the supply chain. (Projects identified through the bibliography and references cited by the agents)

COMPANY	PROJECT	INDUSTRY	UTILITY	DEGREE OF IMPLEMENTATION	VERIFIED	PLATFORM	WEB INFORMATION
Nutrasing	(various) raspberry traceability	fruit and vegetable	secure digital regulatory process	pilot	no	Food Track™	https://www.nutrasign.io/
Fish world track	fish world track	fisheries	track fish from sea to table	in production	yes	META	https://fishworldtrack.com/

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Table 6 (*continued*)

COMPANY	PROJECT	INDUSTRY	UTILITY	DEGREE OF IMPLEMENTATION	VERIFIED	PLATFORM	WEB INFORMATION
Cofradía Puerto de Celeiro	"Merluza de pincho" Hake	fisheries	origin, fishing conditions, and lot traceability after auction	implemented but abandoned after end of financing.	yes	Food Trust (IBM)	carrefour lanza el primer blockchain de pescado fresco - detalle nota de prensa - carrefour españa
Navidul	Navidul pork	meat	storage and record management	pilot	no	Food Trust (IBM)	https://www.interempresas.net/industria-carnica/articulos/313905-navidul-pionera-en-la-implantacion-de-blockchain-en-jamon-iberico.html
ITCL technologic centre	Agraria	fruit and vegetable	apply artificial intelligence to the entire value chain	conceptualisation	yes	Alastria	https://itcl.es/en/itcl-about-us/
covap	Pork meat	meat	certify Iberian meat improve the traceability of 100% Iberian pork	pilot	no	Iberchain	https://static.covap.es/notas-prensa/2021/np-el-iberico-100-entra-en-el-blockchain.pdf
Oleoestepa	Oil quatity	olive oil	origin, production plots, delivery time and batches.	Pilot 2018	yes	Food Trust (IBM)	https://www.oleoestepa.com/aceite-de-calidad/produccion-sostenible/
pEVASA, Alvacora y Code Contract	Traceability of fish	Tuna	origin.	In production	no	(Red T, red B) Future: Besu Alastria	https://alastria.io/trazabilidad-y-automatizacion-de-la-cadena-de-suministro-pesquera/
Unica	Traceability of citrus	fruit and vegetable	traceability for export.	no information (beginning in 2019)	no	Sistema informático de trazabilidad citrícola(SITC)	https://www.agritotal.com/nota/40637-citricos-el-sitc-ahora-incorpora-la-tecnologia-blockchain/
CTIC	dopchain	various pdo (protected designation of origin)	authenticity	in project	no	solution dopchain (based in Ethereum) Alastria	https://www.fundacionctic.org/es/proyectos/dopchain-solucion-basada-en-tecnologias-blockchain-para-la-trazabilidad-de-productos-de
Universidad de Córdoba and Fedacova.	Carne de ternera	meat	certify production conditions farm to fork	in project	no	IBM	https://www.iof2020.eu/trials/meat/iot-and-blockchain-for-beef-supply-chain
VOTTUM	Supply chain (Safety)	perishable products	control warehouse and supplycontrol.	In production (early stage)(beginning in 2019)	no	Alastria	https://alastria.io/plataforma-para-la-trazabilidad-de-productos-perecederos/

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Table 6 (*continued*)

COMPANY	PROJECT	INDUSTRY	UTILITY	DEGREE OF IMPLEMENTATION	VERIFIED	PLATFORM	WEB INFORMATION
Grupo operativo SOSTVAN-	Certified cows'meat	meat	technological strategies to improve the sustainability of the suckler cow	in project University of León	no	universidad de león. hyperledger. linux	https://www.sostvan.com/
Iberchain (pdo)	Iberico	meat	native Iberian breed iberico pig. avoid fraud	the system bases quality criteria on nirs analyses applied to racial discrimination. (start of the project 2019) no Alastria https://iberchain.es/	no	Iberchain	https://iberchain.es/
Lechazo clm (PDO)	control of traceability from birth to slaughterhouse as an anti-fraud mechanism for documentary	meat	avoid fraud. control of traceability from birth to slaughterhouse as an anti-fraud mechanism for documentary suckling lamb clm	in project (starts to work in june 2022)	yes	SMES led by kunfud on alastria's t-net (quorum-base) and EBSI (european blockchain services infrastructure)	https://www.kunfud.com/
Vinassure	Eprovenance wine	wine sector	trace the wines from the vineyard to the final consumer.	in project (starts to work in june 2022)	no	platform to record data on the supply of wine in the Food Trust (IBM)	https://www.eprovenance.com/home/services/vinassure/
Vestigia	porcinova pilot	pork meat	control of traceability f and anti-fraud mechanism for documentary	pilot	no	Vestigia/ Alastria	https://porcinnova.es/financiacion-pilot/

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