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Why blockchain technology is no panacea for documenting meat quality and traceability in broiler and pork value chains

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ABSTRACT

Blockchain technology (BCT) has been touted as a panacea for improving traceability and quality documentation in globalized food value chains and potentially changing how these value chains are governed. This paper studies the potential adoption of BCT in pork and broiler value chains and why adoption levels are below expectations. Based on semi-structured interviews, the paper analyses the experiences and viewpoints of value chain actors in Denmark, the Netherlands and Spain, thus grounding the discussion of adopting BCT for quality documentation and traceability purpose in real-world operational contexts rather than theoretical optimism. Contrary to what has been proposed in the literature, we find that BCT does not eliminate the need for trust — it shifts trust from individual relationships to the governance of the shared data system. The role of retailers illustrates what we term the 'enforced adoption paradox': on the one hand, their power over suppliers enables them to impose requirements; on the other hand, this hinders the collaboration and transparency that successful BCT adoption depends upon. Although current quality documentation systems are cumbersome, and there is a risk of human error, our informants see several barriers to adopting BCT and limited potential in the short to medium term. Our findings suggest that sector-wide BCT adoption is unlikely without external pressure such as regulatory requirements or a dominant actor willing to lead implementation.

1. Introduction

Modern agri-food value chains are complex (Lambert & Enz, 2017) and involve many geographically dispersed actors engaging in inter-linked processes of production, processing, distribution, retailing and consumption. The numerous commercial and non-commercial actors in and around these value chain have different interests and are often reluctant to share information with each other, which can hamper efforts to make value chains more efficient, transparent and sustainable (Behnke & Janssen, 2020).

Globalized food chains use significant resources for tracking and tracing the flow of goods, and on documenting the quality of products to meet regulatory requirements and customer demands. Over time, these efforts have evolved from paper-based systems into using Internet-of-Things (IoT) applications and devices such as radio-frequency identification (RFID) tags, wireless sensors, barcodes, quick response (QR) codes, etc. (Feng et al., 2020; Kshetri, 2018; Li et al., 2024). Blockchain technology (BCT) has been proposed as technology that can enhance the traceability and transparency of value chains (Kshetri, 2018; Lin et al., 2022; Montecchi et al., 2019), thereby reducing risk and assuring consumers about the quality of the food products they buy (Montecchi et al., 2019). This is relevant for multiple reasons, including ensuring food safety, combating food fraud (authentication), documenting credence characteristics that buyers cannot otherwise reliably verify even after purchase, e.g., provenance or process attributes, and to reduce food loss and waste (Collart & Canales, 2021).

These challenges are particularly relevant for pork and broiler value chains in the European Union (EU). In traditional meat value chains, full traceability from farm to fork is often compromised, making food recalls expensive and difficult to manage (Patel et al., 2023). Food chain information systems for both pork and broilers vary considerably between European countries and even between slaughterhouses, limiting harmonized safety assurance (Bonardi et al., 2021; Langforth et al., 2023). These pressures highlight the need for more robust traceability solutions and motivate the exploration of BCT implementation in pork and broiler value chains as part of the EU-funded *mEATquality* project as studied in this work.

A blockchain is a distributed ledger for storing and maintaining a

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permanent and tamper proof record of transactions and products across a decentralized peer-to-peer network, thereby ensuring transparency while safeguarding the anonymity of the traceability chain (Chang et al., 2020; Feng et al., 2020; Iansiti & Lakhani, 2017; Petersen, 2022). This structure also ensures immutability and auditability of the data stored within the system (Caro et al., 2018).

BCT can *"provide a platform for the integration and automation of processes and information across organizations"* in value chains (Petersen, 2022, p. 177), thus potentially changing how business networks are governed (Lumineau et al., 2021). For instance, transactions can be automated using smart contracts. Full traceability and accountability are enabled with every transaction and product movement logged onto the BCT. This level of transparency should enhance cooperation and nurture trust among all stakeholders involved (Bagraff et al., 2024; Doshi et al., 2024). However, to support effective BCT adoption, food chains must set up unified policies on the use of new technologies as well as data usage and management (Astill et al., 2019).

Proponents of BCT claim that *"blockchain-based traceability are safer, more transparent, traceable and efficient"* (Feng et al., 2020, p. 3). Why, then, are there so few large-scale BCT applications in operation? There have in fact been many BCT initiatives in the agri-food sector; including early high-profile applications by retailers such as Carrefour[1] and Walmart.[2] However, there are few tangible results and large-scale solutions in operation, with many companies scaling back on BCT solutions with it seeming to enter the technology 'Valley of Death' where, despite early-stage funding and widespread excitement, it struggles to bridge the gap to practical commercialization adoption (Ellwood et al., 2022). For example, Walmart's high-profile BCT initiative for food traceability, launched in 2018, has seen limited expansion beyond initial pilots. Similarly, a review of BCT projects in the agri-food sector found that the majority remained at pilot stage, with few progressing to full-scale commercial implementation (Kouhizadeh et al., 2021; Vasileiou et al., 2025). Setbacks do not necessarily mean that we should write off the technology, as BCT has the potential to be transformative, although it can take decades to reach its full potential, as some observers noted early on (Iansiti & Lakhani, 2017). However, there are many barriers that will have to be overcome before BCT takes hold. Therefore, an important research gap is the lack of empirical studies which capture the experiences and viewpoints of value chain actors regarding the potentials and barriers of BCT implementation.

The purpose of this study is to explore the potential adoption of BCT in pork and broiler value chains for quality documentation and traceability purposes, and why adoption levels are below initial expectations. We study the governance and current collaboration practices within pork and broiler value chains, with particular focus on the devices currently used to ensure traceability and documentation of the quality of pork and broiler meat, to understand the context in which BCT might play a role. We seek to answer two main research questions:

1. How do actors and pork value chains currently work with documenting quality and traceability of products?
2. What potentials and barriers do value chain actors see for introducing BCT in pork and broiler value chains both now and in future?

This paper grounds the BCT discussion in real-world operational contexts rather than theoretical optimism. Specifically, this study makes three contributions. Empirically, it provides multi-country evidence from three European countries covering multiple actor types across entire value chains. We thereby provide an empirical explanation of why BCT has failed to live up to hype by identifying the barriers to BCT adoption seen by practitioners. Theoretically, it shows that BCT adoption is shaped not only by technological readiness but by power asymmetries and governance structures. Practically, it identifies the conditions under which BCT could add value and the barriers that must be overcome. One of the insights from our study is that powerful actors are needed to push BCT adoption, but that using their power is likely to hamper the collaboration needed to improve transparency. We introduce the concept of the 'enforced adoption paradox' to capture this tension: the actors with sufficient power to drive BCT adoption are simultaneously the actors whose use of that power undermines the trust and collaboration successful BCT adoption depends upon.

The paper is structured as follows. Section 2 provides background on the use of BCT in the food sector; from early work focusing on the potential benefits of BCT adoption to more recent work focusing on barriers for widespread BCT use. Section 3 presents the methodology used to gather and analyze data from semi-structured interviews with actors in the pork and broiler value chains. In section 4, we present the results of our analysis. Next, we discuss our findings by going back to the existing literature and providing ideas for how to overcome the main barriers identified. Finally, we offer a brief conclusion.

2. Background

Along with artificial intelligence (AI), cloud computing and data analytics, BCT is one of the main technologies driving digital business transformation (Akter et al., 2022). Although still in its early stages of development (Kouhizadeh et al., 2021), BCT is regarded as having the potential to transform global supply chain management (Chang et al., 2020; Kshetri, 2018; Vasileiou et al., 2025).

Early on, BCT was seen as a panacea for all kinds of supply chain management issues (Kshetri, 2018; van Hilten et al., 2020). Initial research and applications in agri-food chains focused on traceability and provenance, automation and data security (Müßigmann et al., 2020), food safety (Sri Vigna Hema & Manickavasagan, 2024), quality assurance, food integrity and supply chain management (Kamilaris et al., 2019).

BCT was introduced in pilot projects across a variety of food products and value chains in both developed and developing countries (Feng et al., 2020; Kamilaris et al., 2019; Kshetri, 2018, 2021; Kshetri & DeFranco, 2020). However, as many BCT implementations failed to live up to the initial hype,[3] expectations dampened (Kietzmann & Archer-Brown, 2019; Kouhizadeh et al., 2021; Vasileiou et al., 2025). There are thus few, if any, large-scale applications currently in use. A recent systematic review found that despite a rapid increase in research publications on BCT in agri-food chains, empirical evidence of successful large-scale deployment remains scarce (Vasileiou et al., 2025). Most documented applications are limited to controlled pilot environments, often involving a single commodity or a small number of value chain actors.

Previous work has identified several opportunities and potential benefits of BCT adoption in the context of agri-food chains related to issues like informational security, supply chain collaboration and trust, operational efficiency and transparency (Feng et al., 2020; Kamilaris et al., 2019; Yogarajan et al., 2023). For instance, Chang et al. (2020) argue that BCT can address several value chain challenges, including dispute resolution, cargo integrity and security, digitalization of documentation and compliance issues. Simulations suggest that implementation of BCT in food chains could potentially result in significantly lower IT infrastructure costs than current traceability systems (Pongnumkul et al., 2025). Because transactions can be authenticated and settled without intermediaries, BCT is also claimed to offer

[1] https://www.carrefour.com/en/group/food-transition/food-blockchain (accessed 17 April 2026).

[2] https://www.nytimes.com/2018/09/24/business/walmart-blockchain-lettuce.html (accessed 17 April 2026).

[3] For instance, Maersk has discontinued its TradeLens platform - https://www.maersk.com/news/articles/2022/11/29/maersk-and-ibm-to-discontinue-tradelens (accessed 17 April 2026).

opportunities for cost reduction through automation (Akter et al., 2022; Michelman & Catalini, 2017). Some studies suggest that BCT can reduce moral hazard by shifting trust between actors to BCT applications that execute smart contracts, since it provides time-stamped, immutable and transparent data that reduces information asymmetries (Cai et al., 2021; Tan & Saraniemi, 2023).

In their systematic review of research on BCT applications in agri-food supply chains, Vern et al. (2025) distinguish between five categories of benefits (functional, food security, environmental, social, and business), which will create value for stakeholders, along with five groups of challenges (cultural, technical, social and institutional, regulatory, and organizational) to BCT adoption in food chains. However, it is important to note that validation of these claimed benefits and challenges through empirical studies of actual cases of implementation is needed.

Most of the expected BCT benefits are functional and business related, followed by security, social and environmental. Transparency and traceability are two highly cited functional benefits (Astill et al., 2019; Dasaklis et al., 2022; Feng et al., 2020; Rejeb et al., 2020; Sri Vigna Hema & Manickavasagan, 2024; Vern et al., 2025; Yogarajan et al., 2023). BCT provides data transparency and immutability, ensuring that tampering is not possible once data is entered, which benefits consumers and regulators. By recording product transactions and movements on an immutable ledger, real-time product tracking is ensured. Through its transparency and immutability, food security benefits are unlocked such as preventing food fraud (Feng et al., 2020; Rejeb et al., 2020; Sri Vigna Hema & Manickavasagan, 2024; Vern et al., 2025; Yogarajan et al., 2023). Because BCT eliminates intermediaries, automates transactions using smart contracts and simplifies certification processes, particularly in the long term through automation, this can lead to cost reduction as a business benefit (Feng et al., 2020; Rejeb et al., 2020; van Hilten et al., 2020). Other business benefits include decentralising operations, and enhancing integrity, collaboration and trust (Vern et al., 2025). BCT is not just a neutral technology that is being introduced in existing value chains. BCT has the potential to autonomously execute and enforce agreements between business partners (Lumineau et al., 2021; Petersen, 2022). 'BCT governance' has thus been proposed as an alternative to contractual and relational governance, with BCT governance representing a *"self-contained and autonomous system of formal rules"* (Lumineau et al., 2021, p. 506). Research has only begun to consider how BCT might influence governance of relationships and networks (Lumineau et al., 2021; Petersen, 2022), with administrative, platform and application-level governance mechanisms potentially substituting traditional contractual and relation governance in the coordination and safeguarding of transactions (Petersen, 2022). Accordingly, the adoption of BCT might change the governance of dyadic relationships and entire value chains, and it is therefore relevant to consider the context in which BCT is potentially introduced and how that context can frame the adoption decision and is itself shaped hereby.

Supply chain readiness is critical for adopting more digitalized traceability systems, yet many actors lack the necessary resources or digital infrastructure. However, for chains that are sufficiently prepared, BCT offers the potential to reform supply chain management by enhancing key elements such as transparency, security, efficiency, collaboration, cost-effectiveness and regulatory compliance (Bagraff et al., 2024). Through BCT adoption companies should be able to streamline operations, mitigate risks and build trust.

Implementing BCT requires firms to work together. Often this collaboration takes the form of BCT consortia, which can be defined as inter-organizational arrangements *"in which different organizations collaboratively design, implement, govern, and eventually operate a shared BCT-based system"* to stabilize collaboration between the involved parties (Hacker et al., 2023, p. 114). Trust is not needed, it is claimed, but recent research shows that in practice the opposite is true, with soft factors of collaboration like trust playing *"a decisive role in forming and consolidating BCT consortia"* (Hacker et al., 2023). Furthermore, BCT consortia tend to include companies that are familiar with each other and already do business with each other (Hacker et al., 2023).

Recent empirical research indicates that, in practice, the benefits of BCT adoption fall short of theoretical expectations (Lustenberger & Spychiger, 2025). Thus, Lustenberger and Spychiger (2025) found that BCTs ability to create trust and transparency in value chains is hampered by barriers related to insufficient digitalization of value chains, the complexity of BCT and network management, protection of self-interest by value chain actors and limited value added of BCT adoption. This underscores the importance of studying how the governance and context of value chains frame and shape BCT adoption success or failure.

Because there are few full-scale applications in operation, researchers have shifted their focus to examining technological, organizational, social, cultural, and regulatory obstacles that hinder BCT adoption (Kouhizadeh et al., 2021; Vasileiou et al., 2025; Vern et al., 2025).

Prominent technological challenges include privacy concerns, supply chain readiness, BCT suitability, inaccurate inputs, scalability, interoperability across value chain and existing systems, and energy consumption (Akella et al., 2023; Astill et al., 2019; Bagraff et al., 2024; Bosona & Gebresenbet, 2023; Dasaklis et al., 2022; Demestichas et al., 2020; Feng et al., 2020; Hastig & Sodhi, 2020; Jabbar et al., 2021; Rejeb et al., 2020; Vern et al., 2025; Zhang & Ling, 2023). Many companies are reluctant to share sensitive data on a decentralized platform, especially for competing businesses, because the immutability and permanent visibility of BCT records can threaten data privacy. Furthermore, not all actors, especially smaller companies, have the necessary technical infrastructure and digital systems in place to adopt BCT effectively. Some companies remain uncertain whether potential benefits justify the financial and operational costs of adoption. Despite its tamper-proof design, inaccurate inputs or false data can compromise the integrity of BCT records. As BCT networks scale, they require high data storage and processing capacity to maintain performance, creating further technical strain. Regarding interoperability, different BCT platforms and existing IT systems often lack shared standards and protocols, complicating seamless data exchange. Finally, BCT operations require heavy computational resources and energy consumption, raising concerns about harming environmental sustainability.

Some key organizational, social, cultural, and regulatory challenges include lack of knowledge and expertise, high implementation costs, fragmentation of value chains/sector, communication with farmers and damaging business relationships (Bagraff et al., 2024; Bosona & Gebresenbet, 2023; Caro et al., 2018; Dasaklis et al., 2022; Demestichas et al., 2020; Doshi et al., 2024; Feng et al., 2020; Hastig & Sodhi, 2020; Jabbar et al., 2021; Rejeb et al., 2020; Sri Vigna Hema & Manickavasagan, 2024; Sunny et al., 2020; van Hilten et al., 2020; Vern et al., 2025; Zhang & Ling, 2023). BCT adoption can be challenging because many stakeholders lack the knowledge and skills to implement and manage BCT systems effectively, creating a human capacity barrier to adoption. Cost related to IT infrastructure and training make it financially challenging for many supply chain actors, particularly small and medium-sized enterprises, to implement BCT systems, especially in the short term. The large number of independent actors with incompatible systems makes it difficult to achieve the sector-wide coordination needed for BCT implementation, while primary producers may be hesitant to adopt these new digital solutions. Furthermore, increased transparency through BCT could expose sensitive business information, disrupting existing power dynamics and fragile relationships between chain actors. Hence, reaping the potential benefits of BCT also requires co-operation from other actors, which involves overcoming trust issues and problems in collaboration, communication and coordination (Chang et al., 2020; Kouhizadeh et al., 2021).

To address the challenges or barriers, Vern et al. (2025) suggests future work to focus on investigating the willingness of value chain stakeholders to adopt different types of BCT platforms, the influence of BCT on value chain governance, improving its overall sustainability, and conducting empirical studies to develop strategies to overcome the challenges.

It is important to note that some benefits and barriers represent two sides of the same coin. For instance, while BCT can reduce operational costs in the long term through automation, high implementation costs remain a significant short-term barrier. Similarly, increased transparency benefits consumers and regulators, but may simultaneously threaten business confidentiality and disrupt existing relationships between chain actors. These trade-offs are often not extensively considered and discussed in existing theoretical studies and conceptual frameworks. For instance, Vern et al. (2025) lists 'Immutability' as a functional benefit but also a technical challenge, while trust enhancement among stakeholders is a business benefit but also a cultural challenge. In our study, we examine these opposing benefits and barriers through the perspectives of chain actors and thereby provide empirical insight into how these trade-offs play out in practice.

3. Methodology

3.1. Qualitative data collection

We collected data from January 2022 to November 2024 through online and face-to-face interviews with key informants working on traceability and quality documentation issues along the pork and broiler value chains in Denmark, the Netherlands, and Spain. All three countries have export-oriented agricultural sectors, making documentation of quality and traceability pertinent issues.

Our selection was purposive, as we sought to interview individuals with diverse perspectives and roles in relation to the issues across different links of the value chain. The informants were approached by phone and email. Potential informants were identified through an exploratory internet search, and additional contacts were obtained through the author's personal and professional networks. For instance, in the Dutch broiler case, a systematic method was employed by exploring the website www.bedrijvenopdekaart.nl. Further, specific filters were applied to narrow the search to broiler operators and their distinct actors. In the selection of informants, we looked for (1) professionals, who had worked within the relevant sectors in the pork/broiler value chain for over 5 years, and (2) held a managerial role in relation to quality and traceability.

In total, we conducted 28 semi-structured interviews along the entire pork and broiler value chains. Table 1 provides an overview of all informants and their roles in their organizations. Some farmers had multiple roles, as they were also active in industry bodies. An effort was made to recruit actors in both the broiler and pork value chains in all three countries.

Recruitment differed across countries. In the Netherlands, referrals within the industry facilitated access and resulted in a larger sample. In Spain, most companies declined to participate despite being contacted by a native Spanish speaker, resulting in a smaller sample where all chain actors were not represented. This limits direct cross-country comparisons for the broiler chain. However, as the study aims to explore perceptions rather than make representative claims, this variation in sample composition does not undermine the validity of the findings. Given the uneven distribution of interviews across countries, with the Netherlands accounting for most interviews (20 out of 28), the analysis primarily draws on the Dutch data. Interviews from Denmark and Spain are used to contextualize and contrast the Dutch findings, rather than to serve as the basis for a systematic cross-country comparison. Furthermore, the distribution across the stages of the value chain largely focused on slaughterhouses and processors, based on the assumption that these are critical points for aggregating and differentiating end products and ensuring data integrity in the supply chain.

We used an interview guide developed based on existing literature on BCT adoption, quality documentation, and value chain collaboration. The interview guide revolved around three major themes: (1) how informants perceived the market for pork/broilers, (2) how value chain actors worked with quality documentation and traceability, as well as barriers and potentials for introducing BCT in the pork and broiler value chains and (3) current collaboration practices along the value chain with a focus on quality documentation and traceability. The semi-structured format allowed interviewers to follow a consistent set of topics while

Table 1
Overview of informants.

No	Informant ID*	Country	Organisation type	Role of informant	Interview length
1	DK-R-1	Denmark	Retailer (R)	Product manager	42 min
2	DK-R-2	Denmark	Retailer (R)	Buying manager and category manager**	50 min
3	DK-PS-1	Denmark	Slaughterhouse and processor (P)	Head of sustainability	59 min
4	DK-BS-1	Denmark	Slaughterhouse (B)	Commercial director	45 min
5	DK-IA-1	Denmark	Industry association (IA)	Head of department	55 min
6	SP-PS-1	Spain	Slaughterhouse and processor (P)	Quality manager	90 min
7	SP-PS-2	Spain	Slaughterhouse and processor (P)	Quality manager	90 min
8	SP-PS-3	Spain	Slaughterhouse and processor (P)	Purchasing and production	54 min
9	SP-PF-1	Spain	Pig farmer (P)	Farmer, pork producer, and head of farmers' union	87 min
10	NL-BS-1	Netherlands	Processor (B)	Quality manager and QSR supply chain expert**	51 min
11	NL-BS-2	Netherlands	Slaughterhouse (B)	Business manager	62 min
12	NL-BS-3	Netherlands	Slaughterhouse (B)	Head of quality assurance	46 min
13	NL-H-1	Netherlands	Hatchery (B)	Account manager	45 min
14	NL-BS-4	Netherlands	Slaughterhouse and processor (B)	Group technical manager	59 min
15	NL-R-1	Netherlands	Retailer (R)	Quality manager	58 min
16	NL-BS-5	Netherlands	Slaughterhouse (B)	Quality assurance manager	70 min
17	NL-SU-1	Netherlands	Feed (F)	Manager quality feed A.I.	43 min
18	NL-SU-2	Netherlands	Technical equipment (B)	Research director	63 min
19	NL-BF-1	Netherlands	Broiler farm (B)	Owner	48 min
20	NL-BS-6	Netherlands	Slaughterhouse and processor (B)	Quality assurance and technical director, Quality assurance**	40 min
21	NL-PB-1	Netherlands	Pig breeder (P)	Chief technology officer	57 min
22	NL-PS-1	Netherlands	Slaughterhouse or processor (P)	Farm chain specialist/Product manager	59 min
23	NL-PR-1	Netherlands	Retailer (R)	Quality assurance manager	49 min
24	NL-PF-1	Netherlands	Pig farm (P)	Managing pigs and Vice president	57 min
25	NL-PB-2	Netherlands	Pig breeder (P)	Project manager and marketer	55 min
26	NL-PF-2	Netherlands	Pig farm (P)	Farmer and board of the Dutch pig farmer association	40 min
27	NL-PF-3	Netherlands	Pig farm (P)	Farmer and Vice president	77 min
28	NL-PR-2	Netherlands	Retailer (R)	Quality assurance manager	58 min

Note: *The following abbreviations were used: DK = Denmark; NL = Netherlands; SP = Spain; P = Pig/Pork; B = Broiler; F = Farm; H = Hatchery; S = Slaughterhouse/Processor; SU = Supplier; R = Retailer; IA = Industry Association.** Two informants participated.

remaining flexible enough to probe interesting responses. The interview guide was adapted to suit the role and position of the different actors in the value chain, and interviews lasted approximately 1 h on average. To ensure replicability, the full interview guide is provided in Appendix 1. To encourage open discussion of sensitive information, we offered anonymity to informants and had them sign a consent form before the interview.

Interviews were conducted in the informant's native language (Danish, Dutch, and Spanish). We recorded the interviews with the informants' permission. The interviews were then transcribed and translated into English.

3.2. Qualitative data analysis

To explore the potential, benefits, and barriers to BCT adoption in pork and broiler value chains, we followed Gioia's systematic, three-step approach to theory building (Gioia et al., 2013; Magnani & Gioia, 2023). The following criteria were used to aggregate the first-order codes and subcodes, second-order themes, and dimensions: (1) the subcodes should explain the details of the context of the first-order codes, (2) the wording of the first-order codes may be repeated in a different context; however, their first-order subcodes and second-order themes were embedded distinctly, (3) second-order themes were generated by comparing the combinations of first-order codes and subcodes, while provided the similar meaning, context, and terms consulted from literature, (4) aggregate dimensions were created by grouping the first-order codes and second-order themes into similar context and definition.

In the first-order code and second-order theme analysis, we compared the data across all informants and grouped similar contexts and meanings into several codes and themes. Constant comparison techniques were also applied in both analyses, as we compared newly collected interview data with previously published literature (Magnani & Gioia, 2023).

First, we developed first-order codes from the interview data that represent the informants' terms by carefully selecting all the relevant answers from the interviewees and categorizing them into first-order codes and subcodes. We also decided to provide first-order subcodes to make it easier to distinguish similar contexts of first-order codes that emerged. For all first-order sub-codes and codes, we strived to stay close to the language of informants. For instance, 'genetics' and 'feed' were generated in the first-order codes, and the associated box on the left was the first-order subcodes, which were the relevant answers from the informant's terms (see Fig. 1). Second, we grouped first-order codes into second-order themes based on categories and terms that suitable for combining first-order codes, without losing context, that conveyed a similar meaning to the first-order codes and subcodes. For example, 'farmers', 'retailers', 'consumers', and 'stakeholders' were grouped into 'Perception of value chain actors', referring to the context in the first-order subcodes (Fig. 1). Finally, we distilled these themes into four aggregate dimensions: value chains for pork and broilers; current quality and traceability documentation systems; perceptions of BCT; and market and technology outlook.

The interview data were independently coded to ensure the credibility of the coding analysis results. Each researcher analyzed a set of interview data, generated first-order codes and subcodes, and then discussed coding and labeling until consensus was reached. A similar procedure was applied to establish the second-order themes and aggregate dimensions, so that the findings were not solely based on a

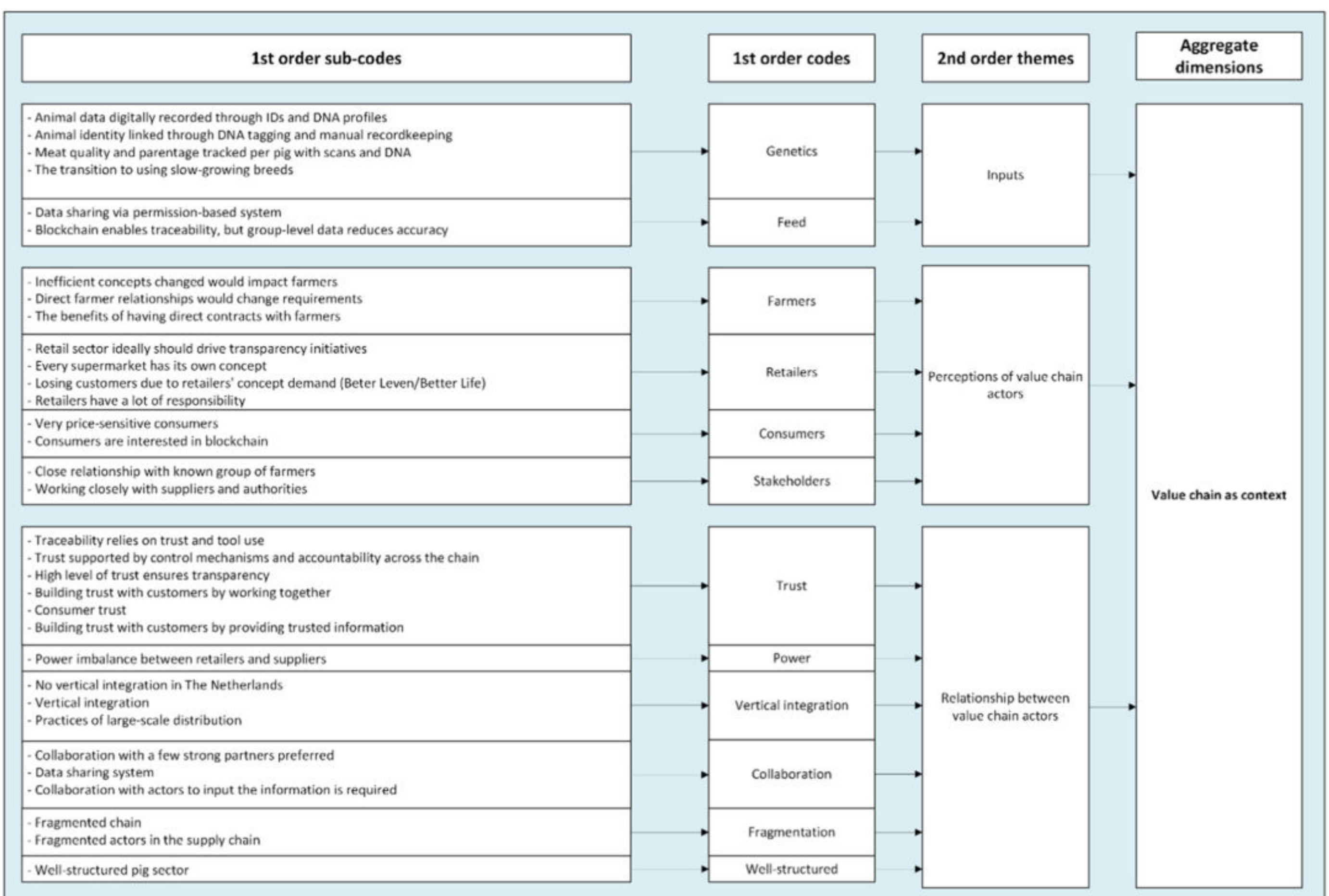

Fig. 1. Example of coding scheme.

single researcher's interpretation; instead, they represent a consensus among all four authors (Villena & Gioia, 2018). Overall, 61 first-order codes, 18 second-order themes, and four aggregate dimensions were generated. An example of the coding scheme inspired by Villena and Gioia (2018) is shown in Fig. 1, and the others are provided in the Supplementary Materials.

4. Results

To understand how actors in the broiler and pork value chains approach quality management and BCT adoption, we begin by examining how pork and broiler value chains are structured and current collaboration practices between value chain actors.

4.1. Value chains for pork and broilers

Driven by regulatory requirements, there is a high degree of traceability and transparency in both the pork and broiler value chains although there are considerable differences in how these value chains are structured and actors are inter-related (Wilkinson, 1990), both between countries and between broilers and pork. For instance, the Spanish pork sector is seen as *"very well structured [..], both productively, sanitarily and industrially speaking"* (SP-PP-1), with increasing vertical integration and where the whole chain from farmer to slaughterhouse in some cases are in the hands of one company, thus making *"organizing collaboration relatively simple"* (NL-PF-3). In the Netherlands, vertically integrated actors play an increasing role in the broiler sector, though not universally — while some slaughterhouses prescribe which hatcheries suppliers of broilers must use, others only require that suppliers meet their quality conditions (NL-BS-4). In contrast, the Dutch pork sector is seen as having *"a super fragmented chain with all sorts of links: farmers, breeding, rearing, sub-breeding, piglet production, fattening pig farmers, slaughterhouses, traders and retailers"* (NL-PB-1). The fragmented nature of the Dutch pork value chain is argued to make *"standardization and transparency much harder"* to achieve (NL-PB-1).

Trust is seen as essential for how the different actors in value chains are inter-related, as quality systems rely on self-reporting and announced inspections. As one retailer noted:

> "It's important to really know your chain, trust your partners, and build in enough testing and analysis throughout the process. This makes sure that suppliers and their suppliers know they're responsible, and that if they try to cheat, they'll get caught fast. It's all about trust in the end. But that trust has to be backed up by a solid program and control systems. Just because you've done business with someone for years doesn't mean there's no risk" (NL-PR-1).

Across countries, retailers are seen as the most powerful actors in the food sector, with their dominance often hindering collaboration and transparency needed for BCT adoption:

> "In my world, there's often a power dynamic—especially between suppliers and retailers. The retailer usually has more power and can more easily enforce this. But that makes it harder to get the collaboration and transparency needed" (NL-PR-2).

Some retailers realize that because of their position, they have a responsibility to use their influence to steer *"things in the direction of better animal welfare, higher quality, less meat, and that is also our agenda"* but at the same time highlight the role of authorities *"in helping us to establish common guidelines on what consumers should look for when they are out shopping, in order to tap into this trend of eating better but eating less meat"* (DK-R-2).

There is a tendency for animal welfare labels and concepts to proliferate, as retailers try to differentiate their product ranges: *"every supermarket that respects itself has got their own chicken products"* (NL-BS-1). However, this proliferation does not necessarily translate into more meaningful consumer choice regarding animal welfare. For instance, the shift to the '*Beter Leven [Better Life]*' concept in the Netherlands involves streamlining value chains, which results in some actors losing business as conventional meat is delisted. Moreover, major food companies operate internationally and must respond to consumer demands across multiple countries with different regulatory requirements. This global scale makes it challenging to implement highly tailored schemes for specific customer segments (Esbjerg et al., 2024).

These structural differences have direct implications for BCT adoption. Vertical integration in Spain reduces the (perceived) added value of BCT, while fragmentation in the Netherlands creates an implementation challenge. Power asymmetries, particularly the dominant role of retailers, further complicate coordinated adoption across the chain. These structural differences shape BCT adoption. Understanding these structural differences provides the context for examining how quality is currently managed in these chains, and where existing systems may fall short. In this connection, it is important to keep in mind that asymmetrical relationships between retailers and suppliers are common and can persist for extended periods of time (Hingley, 2005; Sutton-Brady et al., 2015), as long as retailers do not use their power in ways that are perceived as illegitimate (Blois, 2010) or unfair (Samaha et al., 2011). On the one hand, some informants argue that retailers need to use their influence to push BCT adoption. On the other hand, by using their power, retailers risk hindering the collaboration needed for actors to willingly share information and increase transparency. We use the term "enforced adoption paradox" to capture this finding. Our data suggests that relational governance is prevalent in relationships between retailers and their main suppliers of pork and broilers, although market governance plays a role for retailers and their secondary suppliers (cf. (Dwyer et al., 1987; Gereffi et al., 2005).

4.2. Quality and quality management

In pork and broiler chains, quality is defined in multiple ways and managed through various systems. Informants link quality not only to product traits and production processes, but also to broader aspects such as animal welfare, food safety, genetics, and feed. To safeguard these elements, companies rely on quality management systems that combine product specifications, traceability mechanisms, certification schemes, and audits. Together, these practices ensure compliance with regulations, maintain consumer trust, and address societal and market expectations.

4.2.1. Definitions and aspects of quality

Quality was an important topic in our interviews, with one Danish actor highlighting that *"quality can be many things. Quality is everything because it is a service parameter. But it is also a functional parameter, i.e., the quality of the products"* (DK-BS-1).

Quality was associated with multiple aspects, including breed, nutrition, and production processes. For instance, the authentic breeds that are well-adapted to their living environment are highlighted by a Spanish actor:

> "We already start from a breed, let's say whatever it is, that is rustic, that is well adapted to the terrain. A breed that avoids having to use medicines because it is adapted to that terrain, those living conditions" (SP-PS-3).

Similarly, the quality of the raw materials and composition of the feed are seen as important when aiming to produce higher-quality meat.

Actors in the broiler chains in the Netherlands and Denmark agreed that the production process can affect product quality. They emphasized the importance of quality monitoring and assurance throughout the process steps, such as the slaughter process, as this will impact the quality of the final product. This is reflected in the following statement:

> "One thing is the product. And one thing is the process. It's two different things. You could say there is quality in both, and we

monitor both. In the sense that we look at, can you say what the product is? Can you say what the quality is? And then we look at it, and it's the product, in a broad sense. […] But then there is also a quality in the process, so how well do you do, how good are you at carrying out the process or the instruction, you could say, and that is also a quality." (DK-BS-1).

Most of our informants associated quality with animal welfare. In Denmark, animal welfare was claimed as a defining feature of the Danish pork brand, as highlighted by the Danish processor, who saw quality and traceability as *"a whole,"* and included animal welfare as "*a cornerstone"* in what *"we've been selling Danish pork on for many years. That's the whole thing. Basically, when you buy Danish, you can be sure that the quality is correct"* (DK-PS-1). Animal welfare is also important in the Netherlands, with some actors trying to be proactive and implementing high standards for pig breeding, even though they are not yet mandatory.

The quality of a product is not the only concern: it must also be safe. An actor in the Spanish pork supply chain expressed the importance of balancing quality, sustainability, and health:

"From the point of view of the product, in terms of processes, if you have quality people in the plant, verifying cleanliness, talking about quality, putting everything in, because we are not going to sell a product without food safety, right? If we have people in the plant keeping track of traceability, cleanliness, pests, facilities, and good personnel practices. […] To justify, to demonstrate, to have peace of mind that the processes/quality are always the same, and we put products on the street that are safe, right?" (SP-PS-2).

When examining the details of how food safety relates to quality, it is necessary to monitor the processes and conduct testing throughout to ensure the quality of the final product is maintained. This includes ensuring traceability and performing microbiological testing.

Quality is thus perceived to be influenced by multiple factors, beginning with breed selection, animal welfare standards that regulate the conditions in which animals are raised and treated, process characteristics, and food safety measures throughout processing stages and chain practices. This sets high requirements for quality management systems.

4.2.2. Existing quality management systems

Informants described how quality management systems are implemented throughout the pork and broiler chains. These systems combine specifications, traceability mechanisms at both animal and batch levels, and various supporting technologies. While systems were generally considered reliable and effective for fulfilling legal requirements, informants also pointed to persistent weaknesses. The following subsections summarize the main features, strengths, and weaknesses mentioned by informants.

4.2.2.1. Specifications. Specifications were consistently mentioned as a cornerstone of quality management. Thus, several actors emphasized detailed requirements and technical documentation for every product they bought or sold as essential for ensuring consistency in large-scale operations:

"We have specifications for everything we buy […] there are clear specifications for each individual cut, whether it is a traditional pig or animal welfare pig" (DK-R-2).

Certification schemes play a crucial role in ensuring quality and consistency. Schemes such as Global Food Safety Initiative (GFSI), British Retail Consortium (BRC), and International Featured Standards (IFS) were described as highly structured and reliable. One stakeholder described the IFS certification as "*It's really a check, check, double-check system"* (NL-PR-2). By combining product specifications with certification audits, companies ensure that their products meet both national and international requirements.

The reliance on detailed specifications and certification schemes suggests that existing systems already provide a structured basis for quality assurance. To be attractive, quality assurance schemes using BCT must offer additional value.

4.2.2.2. Animal and batch level traceability. Traceability is a central part of quality management, shaped by regulation and consumer demand for food safety and transparency. All value chains ensure that animals and products can be followed through the chain, but the level of detail and the technologies used differ. Some systems enable detailed, animal-level monitoring, while others rely on more aggregated, batch-level tracking.

Traceability is built into management systems that record animal and product flows. As a pork processor explained, *"Everything goes through the system"* (SP-PS-3). These systems are considered reliable for recalls but rely heavily on batch codes and documents. Digitalization was seen as a challenge as *"not everybody has that level of information technology today"* (SP-PS-3). Spanish systems meet regulations and provide recall capacity but remain less detailed and offer limited transparency to consumers.

In the Netherlands, stakeholders described systems that were much more advanced. In the pork chain, these systems enable highly detailed animal-level monitoring and tracking throughout the production process. Broiler and pork chains continue to rely heavily on batch-level monitoring. Some stakeholders pointed to weaknesses, with a breeder admitting that traceability data is *"often recorded per group of pigs, not per individual"* (NL-PB-2) and a slaughterhouse manager adding that *"We are all tracing all our chickens […] but every slaughterhouse has its own method to do that"* (NL-BS-2). Dutch systems thus offer advanced, consumer-oriented tools but remain fragmented and inconsistent between companies.

In Denmark, Enterprise Resource Planning (ERP) systems were highlighted as the main tool for traceability. These register each production step and link data to batches. Such systems ensure digital consistency and systematic recording but also remain focused on groups rather than individual animals.

These differences in traceability across countries indicate that the potential benefits of BCT differ but also that the challenges to be overcome are different depending on whether systems are fragmented or batch-based, as in Spain, or if the challenge lies more in standardization across actors, which would seem to be the case in the Netherlands.

4.2.2.3. Strengths and weaknesses of current systems. Across the pork and broiler chains, stakeholders utilize a combination of digital tools, management systems, and manual processes to ensure traceability and quality control. ERP systems, apps, and RFID tags are widely used, while some actors are experimenting with BCT.

The strengths of current systems lie in their ability to connect traceability with high-quality data, while also building trust across the chain. ERP systems were seen as especially valuable for integration (NL-BS-3), while RFID tags are used to automate measurements and reduce manual work (NL-PB-1). BCT was also praised because information could be easily shared with other companies by simply ticking a box (NL-PB-2). Finally, structured systems were seen as useful for countering consumer misconceptions about how chickens are produced by linking consumers directly to a farm and showing them how it works (NL-BS-4).

On the other hand, stakeholders mentioned several weaknesses of existing systems. A common theme was the administrative burden, which some said could potentially be reduced through use of BCT. Manual data entry leaves room for mistakes, but even when systems function, they were described as inefficient: *"You have to collect data constantly, and it's not real-time. It's always after the fact, aggregated info"* (NL-PF-3).

These weaknesses — particularly the administrative burden and lack of real-time data — represent the clearest opportunities for BCT to add value. Crucially, these weaknesses are most pronounced in fragmented chains, suggesting that the case for BCT is strongest precisely where coordination failures are most severe — but also where the "enforced adoption paradox" makes implementation most challenging due to lack of trust and the nature of relationships.

4.2.3. Regulation, private standards and third-party certification

Pork and broiler chains are shaped by rules at both the national and EU levels. National rules primarily address farm practices, animal numbers, and environmental concerns, while EU rules focus more on food safety and traceability. These EU-wide rules prioritize food safety and require companies to monitor themselves through established management systems, which are then verified by the relevant authorities.

4.2.3.1. Private standards. Stakeholders in the Dutch broiler and pork chains provided an overview of the private standards, which include certification controls, product verifications, and new private standards for chicken, as well as animal welfare. A Dutch pork processor explained how the structure of certification schemes follows a three-step structure:

> "Dutch certifying bodies supply auditors, who are trained by organizations like IFS. Now and then, IFS performs a check on the certifying company—an audit of the auditing party itself. The final IFS certificate for a company is then issued […] So, they double-checked. Yes, there's a kind of safety net" (NL-PR-2).

Companies have clear specifications for each product, and they set up the records and verify them through barcodes, which can be linked to a specific product specification, certifications, and annual audits (NL-PR-2, DK-R-2). A Dutch retailer was actively involved in establishing a new private standard so that actors in the broiler chain meet their demands and expectations *"in the production chain, certified by external auditing partners [that visit] slaughterhouses, processing plants, and farms to verify our demands"* (NL-R-1).

Dutch actors also highlighted numerous market concepts such as '*Beter Leven (Better Life)*' and '*Varken van Morgen (Pigs of Tomorrow)*', though their relevance is often limited to the domestic market (NL-BF-1).

The proliferation of private standards and concepts, each with their own standards and documentation requirements, adds to the administrative burden and further complicates any sector-wide BCT implementation. Actors can have conflicting interests. On the one hand, one common standard can lead to economies of scale and avoid consumers becoming overwhelmed by a plethora of competing labels. On the other hand, a common label limits possibilities for individual actors to differentiate their offerings (Esbjerg, 2020).

4.2.3.2. Third-party certification and audits. Audits are a crucial component of quality management in pork and broiler production. Dutch slaughterhouses reported very frequent audits from international customers, who *"have quite a high standard on auditing and checking and inspections"* (NL-BS-5). Some actors explained how audits go hand in hand with collaboration. For instance, a Danish retailer described *"sitting down"* and working directly with suppliers to *"figure things out"* and improve standards (DK-R-2). Others noted that while audits are useful, challenges remain with the processed product "*where it's difficult to recognize the meat, it becomes more difficult and less trustworthy"* (NL-R-1).

The limitations of audits — particularly for processed products — highlight a potential role for BCT in providing continuous, tamper-proof documentation that goes beyond what periodic audits can capture. This is a benefit frequently mentioned in the BCT literature (Lumineau et al., 2021), but which often does not materialize in practice (Lustenberger & Spychiger, 2025).

Having established how quality is currently managed and where existing systems face limitations, we now turn to how chain actors perceive BCT as a potential solution to these challenges.

4.3. Blockchain technology

Actors in the broiler and pork chains have different experiences and perceptions of BCT. This can shape the potential benefits and barriers they see for BCT adoption for quality documentation and traceability purposes. It should be noted that few of the interviewed actors have direct experience implementing BCT. Therefore, the insights presented here reflect perceived potential and barriers rather than empirically validated implementation experiences.

Although "*some companies in the Netherlands are working with it*" (NL-PF-1), BCT it is still seen as a developing technology that has not taken off, at least for the time being (SP-PS-2). Due to its limited adoption, there is an unfamiliarity with BCT and uncertainty about the "*added value of BCT for the whole supply chain*" (NL-SU-2).

Several actors expressed skepticism about BCT. This skepticism is driven by different concerns. For instance, the risk of data overload and limited added value was highlighted by NL-PR-2: "*The data is sometimes already so detailed that if I had to receive even more, I probably wouldn't do anything with it—it's just too much."* Having too much information might complicate rather than support quality assessment (NL-BS-4).

What happens with the data or information and the fear of misuse and lack of control over shared data also raised skepticism for BCT, as there is a reluctance to share information with other companies. Thus, several informants worry about giving companies access to internal information, as it is *"always a little bit tricky because you let them see you in your kitchen and that is not what we are used to in companies like us"* (NL-BS-2). Thus, "*too much transparency*" (NL-BS-4) is a concern for several actors. Farmers are particularly concerned about the perceived loss of value and control as they "*feel like they're giving away their info and others are making money with it*" (NL-PF-3).

Retailers see no clear data benefit (NL-PR-2), while the added value of BCT compared to existing traceability systems remains unclear to suppliers (NL-SU-2). Despite these concerns, several potential benefits to BCT adoption emerged from our interviews with value chain actors, along with several barriers. See Table 2 for an overview.

4.3.1. Potential benefits of BCT adoption

Improved sustainability is one potential benefit, which could be achieved through the capability of BCT to track *"exactly how much water, energy, or CO_2 a product used or caused"* (NL-PR-1). It was also suggested that BCT can reduce the need for physical inspections and boost trust through reliable data that are recorded in a tamper-proof system (NL-PF-3). One actor proposed the idea of using BCT to safeguard against food safety risks and environmental risks in high-risk countries *"by creating a system where you only accept products"* with confirmation certificates related to food safety risks (NL-PR-2).

BCT can "reduce the administrative burden and improve traceability by digitization of the paperwork (NL-PF-3, NL-PS-1). As BCT is an integrated system, it allows faster data retrieval at the push of a button, thus requiring "*fewer people, less time, fewer frustrations*" (NL-BS-1). The automated capability of BCT, is seen to allow efficiency in terms of contracts and payments:

> "Right now, the payout has to be calculated manually at the end of the month or year. But that process could be fully automated with BCT. You could easily set up an integrated payment system. Whether that would have a huge impact right away, I'm not sure. It's really more about transparency and efficiency" (NL-PB-1)

It was also suggested that BCT could have a role in storytelling *"so that we become, in some way, closer to the life of the chicken or the pig"* (DK-IA-1). For marketing purposes, it was suggested QR codes can be used to link a product back to the farm (NL-BS-4). Furthermore, BCT can be used as a tool for reliable export and competitive advantage, given the level of

Table 2
Potential benefits and barriers to BCT adoption obtained from interviews with value chain actors.

Potential benefits	Explanation	Barriers	Explanation
Improved sustainability	Reducing food waste through better inventory management and economic sustainability through effective traceability with lower costs and efficient information sharing.	Costs and benefits not shared equally	Uncertainty if the high investment costs will be outweighed by the potential benefits and profitability.
Increased efficiency	Improve operational efficiency by reducing reliance on manual data entry.	Lack of consumer interest	Consumers are not interested in information documented by BCT.
Storytelling	Communicate product information.	Limited willingness to pay	Consumers are seen as very price-sensitive and unwilling to pay extra for transparent meat.
Preventing food fraud	Preventing product tampering, mislabeling, and counterfeit products through transparency and immutability.	Cost concerns	Cost related to IT infrastructure and training make it financially challenging for many supply chain actors, particularly small and medium-sized enterprises to implement BCT systems, especially in the short term.
Enhanced traceability and transparency	Ensuring real-time tracking of product origin by recording product transactions and movements on an immutable ledger. Provides data transparency and immutability, ensuring that tampering is not possible once data is entered, which benefits consumers and regulators.	Lack of knowledge and expertise	Many stakeholders lack the knowledge and skills to implement and manage BCT systems effectively, creating a human capacity barrier to adoption.
		Fragmented data systems	The large number of independent actors with incompatible systems makes it difficult to achieve the sector-wide coordination needed for BCT implementation.
		Unclear who should drive implementation	Not all actors, especially smaller companies, have the necessary technical infrastructure and digital systems in place to adopt BCT and accordingly drive its implementation.

traceability that it offers (NL-PB-2).

Preventing food fraud is another potential benefit of BCT. This is achieved as product *"information is recorded and cannot be changed before it reaches the consumer or goes on sale"* (NL-BF-1), thereby maintaining product integrity (NL-R-1) and making it *"more difficult to cheat"* (DK-R-2).

Finally, several actors associated transparency with access to reliable data or information shared with authorized persons in an integrated system. The transparency also leads to obtaining the correct information as *"it forces you to work correctly and have the [correct] information [entered]"* (NL-BS-3). These examples suggest that BCT's efficiency benefits are most apparent in data-intensive processes where manual work can be automated.

Notably, most of these perceived benefits were expressed by Dutch actors, reflecting both their greater familiarity with digital systems and the specific inefficiencies they experience in their fragmented chain.

4.3.2. Barriers to BCT adoption

Actors see potential in BCT along with numerous barriers for widespread adoption. Chief among them are high implementation costs and unclear benefits (NL-PF-2 and NL-BS-4). As mentioned by NL-SU-1, *"it's always a scale of cost you are investing and costs you are saving. So, this should be (good/profitable) on the scale."* Profitability is important:

> "A smaller company wouldn't invest in something where it wouldn't make a profit in the end. So there has to be some profit, or [..] people saving money or doing things quicker, which also saves money. So, I don't say that every investment has to be earned back, but there has to be a kind of profit on it." (NL-SU-1)

High implementation costs are especially seen as a barrier for small companies (NL-BS-6), as for them *"it's just too expensive and too complicated"* while larger companies are likely *"relying on big subsidies"* (NL-PB-1).

Related to cost and profitability concerns are worries about consumers' limited willingness to pay extra for BCT-certified meat (NL-PF-1, NL-BS-4, and SP-PP-1), which is of particular importance for low-cost meat products. Consumers are seen as very price-sensitive, which some actors see as the main reason for not pushing BCT. For instance, one informant said that *"if the consumer says, 'I do not want to pay for it,' then the business stops"* (NL-BS-4). An important reason that our informants see for the low willingness to pay is that they think that consumers are not interested in the BCT information (DK-IA-1), as *"it's not the information that a customer needs or wants"* (NL-BS-2). For example, *"they're not interested in knowing if food safety is okay. It just is, it has to be"* (DK-IA-1).

Unfamiliarity with BCT and lack of BCT expertise further limits its adoption. According to NL-PF-1, trust is key:

> "In the end, it all comes down to trust. Without trust, it's going to be tough for people to really adopt the technology. Just explaining it won't be enough, because a lot of people feel really far removed from things like BCT, and honestly, they're scared of it."

Furthermore, fragmented data systems are seen as a barrier. There is currently an unwillingness to exchange information with other actors (NL-BS-5). The actors *"simply don't have the skills or the setup to be able to handle BCT"* (DK-BS-1), while fragmentation of the chain is prevalent and there is *"hardly any standardization"* related to existing management systems (NL-PB-1). For example, in the Netherlands,

> "There are loads of different providers, even for something basic like a sow management system. Farmers can choose from like ten different systems to register their piglets, births, and inseminations." (NL-PB-1)

Fragmentation hinders BCT adoption as it is unclear who should drive implementation. For instance, NL-PB-1 argued that

> "Maybe the government should start an initiative to build a system that everyone can use. If every company has to invest in it separately, the costs will be really high and development will be slow."

Others think that large companies should lead BCT implementation, *"there needs to be a major customer supermarket that starts with it"* (NL-H-1), while *"smaller businesses should mainly try to ride along"* (NL-PB-1). Whoever drives the implementation of BCT needs to address the concerns about privacy and the need for clear agreements to enable trust from value chain actors.

Together, these barriers reveal a structural problem: BCT requires simultaneous investment and data sharing from multiple actors with misaligned incentives (Kouhizadeh et al., 2021). Farmers fear losing control over their data, processors question feasibility, and retailers see limited consumer demand. Without a dominant actor willing to absorb initial costs and drive adoption — such as a major retailer — these coordination failures are likely to persist (Lumineau et al., 2021).

4.4. Market and technology outlook

Markets for pork and broiler meat are changing due to several interacting and sometimes conflicting factors, including sustainability concerns and inflation. According to our informants, markets are expected to continue evolving, driven by consumers, NGOs, and regulatory authorities. Despite recent price increases, some actors still believe that in future consumers will buy *"less meat of better quality and better animal welfare"* (DK-R-2).

Several actors also highlight the role that NGOs play in promoting a shift towards better animal welfare, with Dutch retailers committing to only sell *Beter Leven* chicken:

> "The NGOs are an important part of the change in this industry […]. Additionally, they push the other retailers, the convenience industry, to achieve certain welfare standards. Of course, there are also legal regulations that push us to improve" (NL-BS-1)

The meat industry is facing stricter regulations on several levels. For instance, one informant reported increasing regulatory pressure related to water and energy use (NL-BS-5). Because of these pressures, the way companies think about producing is changing, not just to meet current requirements for animal welfare and carbon footprint, but also *"with a view to the future of what is wise"* (NL-BS-5). However, concerns remain, particularly regarding consumers' willingness to pay for improved transparency or higher quality:

> "If transparent meat is always way more expensive than non-transparent meat, a lot of consumers will still choose the cheaper option, just because it's cheaper" (NL-PB-1).

Informants generally expect digitalization to continue, as they think *"it's crazy that we're still exchanging paper documents with each other"* (NL-PS-1), partly because such paperwork is still required when government inspectors visit farms. This contributes to the administrative burden. Looking ahead, companies expect to collect more data digitally and perhaps eliminate paper (NL-PF-1, SP-PS-1).

Actors are uncertain about what role BCT will play in this. Some actors see a strong potential for using BCT to improve transparency. One informant outlines the challenge as follows:

> "The challenge is to use BCT to organize cooperation in the chain while still maintaining individual entrepreneurship. So that everyone can continue making their own choices. If you can achieve that, you create a strong, virtual integration — a connection through information rather than ownership. But building that is difficult. It's about trust and voluntariness. I'm convinced we can do it, but it's just harder here in the Netherlands than in Spain. Over there, it's just a matter of a decision from management: 'This is how we're doing it,' and then it happens. Here, you really have to bring people along in the story" (NL-PF-3).

Some actors expect BCT to be relevant only for high-value products where a consumer premium can cover implementation costs. Other actors see potential for "vulnerable supply chains" where customers can be concerned about the integrity of products. Still others expect BCT to become a normal part of future supply chain management because *"technology that truly adds value cannot be stopped in the end*" (NL-PF-3).

Across countries, actors point to the importance of market leaders like Ahold, Carrefour, or Walmart promoting widespread BCT adoption because that will force suppliers to comply. Several informants also emphasize the importance of seeking a sector-wide solution involving both small and large actors to spread development costs and prevent duplication of effort.

These diverging expectations reveal a fundamental tension in BCT adoption: the actors who would benefit most from improved traceability and transparency — farmers and smaller processors — lack the power to drive implementation, while those who have the power to enforce adoption — retailers — have the least incentive to do so, as existing systems already serve their needs (Ponte & Gibbon, 2005). This power asymmetry suggests that sector-wide BCT adoption is unlikely without external pressure, such as regulatory requirements or consumer demand for verified transparency (Iyengar et al., 2024).

5. Discussion

5.1. The importance of value chain organization for BCT adoption

The way value chains are structured and the nature of relationships between actors strongly influences how quality is managed and how relevant BCT might be. Prior research shows that in vertically integrated chains, companies can control and monitor product and process quality more easily through internal systems (Behnke & Janssen, 2020; Trienekens et al., 2012). In contrast, fragmented chains with many independent actors often need stronger data-sharing systems and trust mechanisms, which in theory makes technologies like BCT more relevant (Galvez et al., 2018; Rejeb et al., 2020).

We found clear differences between countries and between broilers and pork in terms of how coordinated value chains are. In the vertically integrated chains found in both the Spanish pork and Dutch broiler sectors, there is already a high level of control and traceability because coordination and information exchange often happen within one organization. This reduces the need to adopt BCT, as data is already stored in centralized company systems (Behnke & Janssen, 2020). Similarly, the Danish pork sector is characterized by close cooperation between producers, processors, and authorities, supported by standardized data infrastructures (Hald & Kinra, 2019). These structures already ensure high transparency, so adopting BCT would contribute little to internal traceability. However, BCT could still support data exchange across platforms where information remains fragmented or difficult to verify.

In contrast, achieving transparency and data alignment is difficult in more fragmented chains, where every actor has their own systems and standards. These findings reflect what literature describes as a decentralized governance model, where coordinating activities and verifying information between many actors takes more time and resources (Trienekens et al., 2012). In a fragmented chain, BCT could potentially add value by increasing information transparency, and enabling faster and more reliable data exchange between actors.

In summary, the way value chains are organized shapes how quality is managed and how much BCT can contribute. BCT is not a solution by itself: it requires a well-structured chain, clear data standards, and collaboration before its full benefits can be realized. Yet, even when digital systems are in place, quality management still depends on human relationships. Without trust, the promise of BCT will remain unfulfilled, as actors will be reluctant to share information (Lustenberger & Spychiger, 2025). To understand BCT's potential, it is therefore necessary to examine how trust and power work in the current system.

5.2. The importance of trust for digitalization of quality management

BCT has the potential to support traceability and transparency by creating a shared record of information that cannot be altered afterward. This is especially relevant in chains where many independent actors must exchange data to verify product claims (Galvez et al., 2018; Rejeb et al., 2020). In such cases, BCT can act as a tool that strengthens trust, reduces manual documentation, and makes data easier to share. However, prior research also highlights that BCT is not a replacement for existing food safety systems, but a digital layer that can connect actors and systems that are otherwise difficult to coordinate (Casino et al., 2019).

Our findings show that trust is a key part of how actors in the pork and broiler chains work together on quality. Companies rely on partner-provided information about animal health, feed, and production, often without direct verification. As one informant said, *"It's all about trust in the end. But that trust has to be backed up by a solid program and control* *systems"* (NL-PR-1). Documentation is assumed to be correct, but few actors have full visibility of how these records are produced. This aligns with what (Manning & Soon, 2014) call *"trust by necessity,"* where food companies must depend on information they cannot directly check or verify.

The irony is that the same actors who say they depend on trust are often reluctant to share their own detailed information. Farmers and processors expressed concerns about privacy, commercial sensitivity, and losing control over their data. As one explained, *"Once you start sharing all that information, you lose control over who sees it and how it's used"* (NL-PF-2).

Contrary to what is often posited in the literature (Feng et al., 2020; Galvez et al., 2018; Lumineau et al., 2021), adopting BCT, therefore, does not eliminate the need for trust (Lustenberger & Spychiger, 2025). It shifts from individual relationships to the governance of the shared data system. Actors must now trust that whoever controls the BCT will handle data fairly and transparently. This link between trust and power becomes clearer when looking at how the sector is governed. Both our findings and prior research (Hingley, 2005; Ponte & Gibbon, 2005) show that power is concentrated among a few large retailers. Smaller farms, hatcheries, and processors must adapt to the evolving requirements of powerful retailers (Maglaras et al., 2015), often without getting what they perceive as their fair share of the benefits.

This imbalance also shapes how new technologies are introduced. Many informants said that smaller companies will only adopt innovations like BCT once powerful actors require it. Some viewed the government as the only actor capable of setting shared rules, while others believed large retailers have enough leverage to coordinate the sector. Both perspectives imply that BCT adoption will be top-down, not voluntary. As one participant explained, *"If a big supermarket chain starts using it, the rest will have to follow"* (NL-H-1).

As a result, BCT is unlikely to emerge as a transparency tool. It risks reinforcing existing power asymmetries by giving dominant actors control over both product standards and the flow of digital information. For smaller producers, this could turn BCT from a trust-building innovation into a new form of surveillance and dependence.

5.3. The potential role and limitations of BCT

Our findings suggest that the potential benefits of BCT will vary considerably depending on how value chains are structured and function.

In fragmented chains, BCT has the strongest potential. BCT can address coordination failures, reduce administrative burden, and enable more reliable data exchange between actors who currently use incompatible systems. As suggested in the literature, BCT may improve the credibility of product claims by recording transparent and immutable information (Galvez et al., 2018). BCT may thus solve coordination problems, but broader adoption of BCT requires an architecture that supports multiple value chain processes and allows actors to fulfill different roles. This would lead to further fragmentation and increased complexity in interfacing with the different BCTs (Behnke & Janssen, 2020). Correspondingly, Goduscheit al. (2026) noted that BCT implementation in B2B settings is shaped by inter-organizational paradoxes, as its decentralized, transparent, and trustless architecture still relies on coordinated action, sustained collaboration, and agreement among multiple actors. However, this is also where adoption is hardest, as power asymmetries and misaligned incentives mean no single actor is willing to take the lead. BCT requires network completeness: if relevant actors do not participate or fail to provide accurate and timely data, the traceability system does not function properly and is weakened. In such settings, no single actor may have sufficient authority, incentive, or legitimacy to impose common standards, allocate implementation costs, and govern data access across the chain. Moreover, BCT's promise of transparency can be interpreted differently by dominant and smaller actors (Goduscheit et al., 2026). While powerful actors may perceive BCT as a mechanism for coordination, efficiency, and cost reduction, smaller suppliers may view the same transparency as a form of control, surveillance, or exposure of commercially sensitive information. Thus, in fragmented chains, BCT may offer the greatest coordination value while simultaneously facing the stronger barriers to collective adoption.

In highly integrated value chains, coordination and information exchange already happen within well-functioning systems. Existing infrastructure delivers high levels of traceability and transparency, leaving little room for BCT to add value. This is in line with BCT decision frameworks, which advise that BCT should not be adopted by default, specifically where existing databases or institutional infrastructures already provide reliable coordination, traceability, and verification functions (Pedersen et al., 2019). Similarly, Behnke and Janssen (2020) suggest that the standardization of traceability processes, interfaces, joint platforms, and independent governance is a key boundary condition for BCT-based traceability.

From a governance perspective, vertical integration internalizes coordination by placing multiple stages of the chain under the authority of one or a few lead companies. It corresponds to hierarchical forms of value-chain governance, where coordination and power asymmetry are explicitly relatively high (Gereffi et al., 2005). In the Spanish pork sector, a study shows that poultry and pork production were characterized by strong vertical integration, with feed companies acting as key axes of integration, and this led to geographical and business concentration (Delgado et al., 2025). Under such conditions, BCT is less likely to be needed for internal coordination because it is already achieved through ownership, contracts, and managerial control. BCT's potential value lies in supporting external verification and consumer-facing transparency, such as product origin, authenticity, custody, and integrity (Montecchi et al., 2019).

At the same time, the interviews also reveal important barriers to BCT adoption. Adoption of BCT does not automatically improve data quality or product quality, as it can only store the information that actors enter. Research shows that without reliable source data and common standards, BCT can simply record inconsistencies faster (Behnke & Janssen, 2020). High implementation costs, unclear financial benefits and little evidence to suggest that consumers are willing to pay a premium for enhanced traceability make adoption unattractive, especially for small firms. Privacy concerns also play a role, as companies worry about sharing business-sensitive information with competitors. These limitations mirror findings in earlier studies, which show that the economic and organizational conditions for BCT must be in place before the technology can succeed (Kamble et al., 2020). These barriers do not operate in isolation but reinforce each other across technological, organizational, and institutional dimensions. Technologically, the absence of shared data standards means that even willing adopters cannot easily connect their systems, raising implementation costs further. Organizationally, the concentration of power among retailers means that smaller actors bear a disproportionate share of these costs without receiving equivalent benefits, reducing their incentive to invest. Institutionally, the lack of regulatory frameworks or sector-wide governance structures means there is no external pressure to overcome this collective inertia. Together, these dimensions create a self-reinforcing cycle of non-adoption that cannot be resolved by technological improvements alone (Kouhizadeh et al., 2021; Lumineau et al., 2021).

In summary, BCT has the potential to improve traceability, transparency, and efficiency in pork and broiler chains, especially when many independent companies need to share data. However, the technology requires a well-organized chain with shared data standards, reliable input, and clear agreements about who can access what information. Without these preconditions, BCT offers limited added value and remains difficult to scale beyond pilot projects.

5.4. Strategies towards overcoming the barriers

Based on our analysis, full-scale BCT implementation appears unlikely in the short term as widespread hesitation toward adopting BCT exists. Four main barriers to BCT adoption emerge when comparing the existing literature and our interviews: (1) lack of knowledge and expertise, (2) high implementation costs and cost concerns, (3) fragmentation of value chains/sector and data systems, and (4) privacy concerns. To facilitate BCT adoption, these will be viewed as barriers to prioritize, by proposing various strategies as guidance to overcome them.

First, integrating all value chain actors into distributed ledger technologies requires overcoming the lack of digital skills (Feng et al., 2020), technical understanding and capabilities (Rejeb et al., 2020) among these actors. Enabling BCT adoption requires leveraging existing company resources, investment strength and focus on knowledge development (Hastig & Sodhi, 2020). Organizations must either train or educate existing staff to enhance their knowledge and ability in BCT or hire professionals who already have the necessary skills (Bagraff et al., 2024; Doshi et al., 2024; Jabbar et al., 2021; Rejeb et al., 2020). Jabbar et al. (2021) stress that this is not easy, as knowledge development requires a range of software skills and a solid grasp of economic and business concepts related to the structure of the value chain. Hence, it is essential to enhance staff's skills with trained professionals to support successful implementation (Doshi et al., 2024; Rejeb et al., 2020). Concerning the chain actors responsible for trainings, Sunny et al. (2020) propose that upstream stakeholders provide the necessary training and resources to support downstream participants.

Second, substantial financial investment is needed for BCT implementation (Dasaklis et al., 2022; Demestichas et al., 2020; Doshi et al., 2024; Feng et al., 2020; Rejeb et al., 2020; Zhang & Ling, 2023). These costs can be minimized by gradually integrating BCT with existing technologies (Feng et al., 2020). When implemented, BCT has the promise to reduce expenses by cutting down reliance on intermediaries, minimizing manual operations and decreasing error rates (Bagraff et al., 2024). For example, transaction costs can be lowered by removing intermediaries and using smart contracts to automate processes. Besides, BCT can enhance inventory management through real-time tracking and improved transparency, helping reduce storage costs and prevent overstocking. Essentially, these improvements can lead to cost reductions (balancing the financial investment needed) through enhanced operational efficiency and access to reliable information (Rejeb et al., 2020).

The fragmentation of value chains refers to the splitting of production stages and their distribution across different locations, firms or countries (Burda & Dluhosch, 2002). Hence, companies specialize in specific stages of production instead of producing the entire product from start to finish. Overcoming this barrier requires viewing BCT as the means to drive collaboration between value chain actors, whereby it unites fragmented sectors under shared goals and provides a unified platform for sharing data (Bagraff et al., 2024; Feng et al., 2020). Furthermore, this transparency enabled by immutable and universally accessible records helps build trust and strengthen relationships across the network (Bagraff et al., 2024) within fragmented chains/sectors. In theory, BCT could integrate with other advanced technologies (e.g., IoT and AI), though in practice this requires significant technical groundwork and standardization efforts (Akella et al., 2023) and address the issue of data silos as it uses a decentralized shared ledger that distributes data across the network, improving transparency and collaboration (Doshi et al., 2024).

Finally, privacy concern is a main barrier to BCT adoption. Previous work has identified data ownership and fear of misuse as the main barriers to digital traceability adoption (Yen-Ting et al., 2022). Controlled access mechanisms or systems can alleviate privacy concerns and security issues (Feng et al., 2020; Zhang & Ling, 2023). Implementing advanced security solutions such as solid data encryption and using privacy-enabled technologies (Bagraff et al., 2024). Routine security testing and system audits can help to identify and address security gaps and threats (Bagraff et al., 2024). At the data entry level, innovative consensus algorithms for data security, reliability, and trustworthiness can also be developed (Akella et al., 2023). Data filtering can also be applied to prevent confidential information from entering the BCT (Bosona & Gebresenbet, 2023). Private data can be encrypted using smart contracts before uploading it to the BCT, accompanied by the hash of the corresponding public data (Doshi et al., 2024). Akella et al. (2023) recommend that regulatory bodies revise or create new privacy policies that will mandate the BCT to address these concerns.

Overall, the industry needs education and awareness programs to clarify BCT's functionality and benefits (also to consumers), and alleviate privacy concerns, gradual implementation strategies to ease the transition, and improved interoperability solutions to ensure compatibility with existing systems. While BCT presents a promising opportunity for enhancing traceability and transparency, overcoming industry skepticism and fostering collaboration will be critical for its successful adoption in the meat sector.

5.5. Limitations and future research

As for all research, our study suffers from several limitations. An important limitation is related to our research design. Our study is based on qualitative interviews with actors in the pork and broiler chains of three European countries (Denmark, the Netherlands, and Spain). Comparing value chains in low- and middle-income countries may reveal different roles and adoption barriers for BCT. The study focuses on actors who are already formalized and integrated into regulated value chains. Very small producers (outside certification schemes) were underrepresented.

The proposed typology based on vertical integration and standardization yields four conditions, of which only three were observed in our data. Fragmented but highly standardized chains were not represented in our sample, and future research should examine BCT adoption in this context to further validate and refine the typology.

The final sample of 28 interviews was determined by both theoretical considerations and practical constraints. In both Denmark and the Netherlands, the main value chain actors were interviewed, and responses became increasingly consistent towards the end of data collection. This suggests that data saturation was largely achieved for these two countries. In Spain, recruitment difficulties limited the sample size, meaning that saturation could not be fully assessed for that context.

Few of the actors in our study have implemented BCT at scale. Since few informants had direct experience with BCT, their expectations and concerns were speculative. This limits the extent to which adoption barriers and benefits can be generalized to real-world implementation. The actual implementation of BCT in the meat chain remains largely untested (van Hoek, 2019). Further research should include pilot projects to assess BCT's effectiveness in improving traceability in relation to food fraud (Kamath, 2018).

A further limitation is that the study does not systematically specify the type of BCT architecture under consideration across all countries. In the Netherlands, informants primarily referred to permissioned BCT systems, in which access is restricted to authorized participants. However, for Denmark and Spain, the type of architecture was not explicitly discussed in the interviews. Future research should more systematically address the type of BCT architecture when studying adoption in agrifood value chains.

The study does not include direct observation of data systems or digital infrastructures. As a result, conclusions about data accuracy, interoperability, or BCT readiness rely on reported, not empirical, technical evaluation. BCT is unlikely to succeed as a stand-alone technological solution, as it requires several enabling conditions. These include a clear added value proposition for supply chain actors, interoperability with existing traceability and quality management systems, reliable data input and verification procedures, clear governance of data access, privacy, and ownership, and inclusive participation across the supply chain. Therefore, BCT may be particularly useful in cases where transparent, multi-actor documentation is urgently needed, for instance, to support a product's origin, quality, sustainability, or certification claims. There is a need for studies that combine interviews with technical audits of existing data systems. Such work could identify where BCT could genuinely add value.

6. Conclusion

This paper explored the potential adoption of BCT in pork and broiler value chains. From the results, it is evident that BCT currently is no panacea for documenting meat quality and traceability. Existing quality documentation and traceability systems are generally considered reliable and sufficient, although not without shortcomings due to administrative burdens and lack of real-time data. Although informants see some potential benefits of BCT adoption, there is considerable skepticism and numerous barriers to overcome.

The strengths of this study include its multi-country empirical design covering three European countries with different value chain structures, and its multi-actor perspective covering the entire value chain from farmers to retailers. By grounding the BCT discussion in real-world operational contexts rather than theoretical optimism, the study provides insights that go beyond existing conceptual frameworks. A key theoretical contribution of this study is the "enforced adoption paradox" — the finding that the actors with sufficient power to drive BCT adoption are simultaneously the actors whose use of that power undermines the trust and collaboration BCT depends upon. BCT's potential varies fundamentally across different chain contexts and cannot be assessed independently of governance structures. BCT adoption will require substantial re-organization of existing value chains and systems. Actors have little imperative to adopt BCT as they do not believe they will benefit sufficiently from the investment required, particularly given the costs and benefits are not shared equally across the chain (Lumineau et al., 2021).

The organization and governance of pork and broiler value chains play a key role in BCT adoption. For BCT to be scalable, it requires a well-organized chain with shared data standards, reliable input and clear agreements. BCT is a potentially transformative technology; however, it has not reached its full potential principally due to existing barriers. Strategies to overcome the four main barriers to BCT adoption were proposed, including improving training, awareness, cost, privacy concerns, and technological limitations.

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CRediT authorship contribution statement

Lars Esbjerg: Conceptualization, Data curation, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Farah Aisyah Sukmawati:** Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Linh Pham:** Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Sara Wilhelmina Erasmus:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodcont.2026.112474.

Data availability

The authors do not have permission to share data.

References

Akella, G. K., Wibowo, S., Grandhi, S., & Mubarak, S. (2023). A systematic review of blockchain technology adoption barriers and enablers for smart and sustainable agriculture. *Big Data and Cognitive Computing, 7*(2), 86. Retrieved from https://www.mdpi.com/2504-2289/7/2/86.

Akter, S., Michael, K., Uddin, M. R., McCarthy, G., & Rahman, M. (2022). Transforming business using digital innovations: The application of AI, blockchain, cloud and data analytics. *Annals of Operations Research, 308*(1), 7–39. https://doi.org/10.1007/s10479-020-03620-w

Astill, J., Dara, R. A., Campbell, M., Farber, J. M., Fraser, E. D. G., Sharif, S., & Yada, R. Y. (2019). Transparency in food supply chains: A review of enabling technology solutions. *Trends in Food Science & Technology, 91*, 240–247. https://doi.org/10.1016/j.tifs.2019.07.024

Bagraff, H. A., Kholis, N., Mugiyati, & Nabila, F. G. (2024). Implementing blockchain technology for optimized supply chain and enhanced sustainability. *International Journal of Innovative Science and Research Technology, 9*(8), 1697–1702. https://doi.org/10.38124/ijisrt/IJISRT24AUG1218

Behnke, K., & Janssen, M. F. W. H. A. (2020). Boundary conditions for traceability in food supply chains using blockchain technology. *International Journal of Information Management, 52*. https://doi.org/10.1016/j.ijinfomgt.2019.05.025, 101969–101910.

Blois, K. (2010). The legitimacy of power in business-to-business relationships. *Marketing Theory, 10*(2), 161–172. https://doi.org/10.1177/1470593110366676

Bonardi, S., Blagojevic, B., Belluco, S., Roasto, M., Gomes-Neves, E., & Vågsholm, I. (2021). Food chain information in the European pork industry: Where are we? *Trends in Food Science & Technology, 118*, 833–839. https://doi.org/10.1016/j.tifs.2021.10.030

Bosona, T., & Gebresenbet, G. (2023). The role of blockchain technology in promoting traceability systems in agri-food production and supply chains. *Sensors, 23*(11), 5342. Retrieved from https://www.mdpi.com/1424-8220/23/11/5342.

Burda, M. C., & Dluhosch, B. (2002). Cost competition, fragmentation, and globalization. *Review of International Economics, 10*(3), 424–441. https://doi.org/10.1111/1467-9396.00341

Cai, Y. J., Choi, T. M., & Zhang, J. (2021). Platform supported supply chain pperations in the blockchain era: Supply contracting and moral hzards. *Decision Sciences, 52*(4), 866–892. https://doi.org/10.1111/deci.12475

Caro, M. P., Salek Ali, M., Vecchio, M., & Giaffreda, R. (2018). Blockchain-based traceability in agri-food supply chain management: A practical implementation. *Paper presented at the IoT vertical and topical summit on agriculture - Tuscany (IOT tuscany)*.

Casino, F., Dasaklis, T. K., & Patsakis, C. (2019). A systematic literature review of blockchain-based applications: Current status, classification and open issues. *Telematics and Informatics, 36*, 55–81. https://doi.org/10.1016/j.tele.2018.11.006

Chang, Y., Iakovou, E., & Shi, W. (2020). Blockchain in global supply chains and cross border trade: A critical synthesis of the state-of-the-art, challenges and opportunities. *International Journal of Production Research, 58*(7), 2082–2099. https://doi.org/10.1080/00207543.2019.1651946

Collart, Alba J., & Canales, Elizabeth (2021). How might broad adoption of blockchain-based traceability impact the U.S. fresh produce supply chain? *Applied Economic Perspectives and Policy, 44*(1), 219–236. https://doi.org/10.1002/aepp.13134. https://onlinelibrary.wiley.com/doi/10.1002/aepp.13134. (Accessed 14 January 2021)

Dasaklis, T. K., Voutsinas, T. G., Tsoulfas, G. T., & Casino, F. (2022). A systematic literature review of blockchain-enabled supply chain traceability implementations. *Sustainability, 14*(4), 2439. Retrieved from https://www.mdpi.com/2071-1050/14/4/2439.

Delgado, P., Pinilla, V., & Belloc, I. (2025). From net importer to global leader: Understanding the drivers of Spain's meat export growth since the 1960s. *Cliometrica, 19*(2), 487–519. https://doi.org/10.1007/s11698-024-00292-5
Demestichas, K., Peppes, N., Alexakis, T., & Adamopoulou, E. (2020). Blockchain in agriculture traceability systems: A review. *Applied Sciences, 10*(12), 4113. Retrieved from https://www.mdpi.com/2076-3417/10/12/4113.
Doshi, S., Jangir, S., & Gohil, P. (2024). Role of blockchain technology in enhancing supplychain traceability, transparency and efficiency. *Journal of Experimental Agriculture International, 46*(5), 636–653. https://doi.org/10.9734/jeai/2024/v46i52419
Dwyer, F. R., Schurr, P. H., & Oh, S. (1987). Developing buyer-seller relationship. *Journal of Marketing, 51*(April), 11–27.
Ellwood, P., Williams, C., & Egan, J. (2022). Crossing the valley of death: Five underlying innovation processes. *Technovation, 109*, Article 102162. https://doi.org/10.1016/j.technovation.2020.102162
Esbjerg, L. (2020). To the market and back? A study of the interplay between public policy and market-driven initiatives to improve farm animal welfare in the Danish pork sector. *Agriculture and Human Values, 37*(4), 963–981. https://doi.org/10.1007/s10460-020-10023-x
Esbjerg, L., Laursen, K. B., & Olsen, J. V. (2024). Great expectations: Intersecting markets, conflicting temporalities and the difficulty of shaping markets. *Journal of Marketing Management, 40*(17–18), 1740–1770. https://doi.org/10.1080/0267257X.2024.2435473
Feng, H., Wang, X., Duan, Y., Zhang, J., & Zhang, X. (2020). Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges. *Journal of Cleaner Production, 260*, Article 121031. https://doi.org/10.1016/j.jclepro.2020.121031
Galvez, J. F., Mejuto, J. C., & Simal-Gandara, J. (2018). Future challenges on the use of blockchain for food traceability analysis. *TrAC, Trends in analytical chemistry (Regular ed.), 107*, 222–232. https://doi.org/10.1016/j.trac.2018.08.011
Gereffi, G., Humphry, J., & Sturgeon, J. (2005). The governance of global value chains. *Review of International Political Economy, 12*(1), 78–104.
Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the gioia methodology. *Organizational Research Methods, 16*(1), 15–31. https://doi.org/10.1177/1094428112452151
Goduscheit, R. C., Matos, S., Holm, K., Parry, G., & Xiong, Y. (2026). Blockchain technology through a paradox lens: Bridging the gap between promise and reality? *Technovation, 150*, Article 103384. https://doi.org/10.1016/j.technovation.2025.103384
Hacker, J., Miscione, G., Felder, T., & Schwabe, G. (2023). Commit or not? How blockchain consortia form and develop. *California Management Review, 65*(3), 110–131. https://doi.org/10.1177/00081256231175530
Hald, K. S., & Kinra, A. (2019). How the blockchain enables traceability in complex supply chains: A review of the literature. *Supply Chain Forum: International Journal, 20*(2), 119–131. https://doi.org/10.1108/IJPDLM-02-2019-0063
Hastig, G. M., & Sodhi, M. S. (2020). Blockchain for supply chain traceability: Business requirements and critical success factors. *Production and Operations Management, 29*(4), 935–954. https://doi.org/10.1111/poms.13147
Hingley, M. K. (2005). Power to all our friends? Living with imbalance in supplier–retailer relationships. *Industrial Marketing Management, 34*(8), 848–858. https://doi.org/10.1016/j.indmarman.2005.03.008
Iansiti, M., & Lakhani, K. R. (2017). The truth about blockchain. *Harvard Business Review, 95*(1), 119–127.
Iyengar, G., Saleh, F., Sethuraman, J., & Wang, W. (2024). Blockchain adoption in a supply chain with manufacturer market power. *Management Science, 70*(9), 6158–6178. https://doi.org/10.1287/mnsc.2022.02505
Jabbar, S., Lloyd, H., Hammoudeh, M., Adebisi, B., & Raza, U. (2021). Blockchain-enabled supply chain: Analysis, challenges, and future directions. *Multimedia Systems, 27*(4), 787–806. https://doi.org/10.1007/s00530-020-00687-0
Kamath, R. (2018). Food traceability on blockchain: Walmart's pork and mango pilots with IBM. *Journal of The British Blockchain Association, 1*(1), 1–12. https://doi.org/10.31585/jbba-1-1-(10)2018
Kamble, S. S., Gunasekaran, A., & Sharma, R. (2020). Modeling the blockchain enabled traceability in agriculture supply chain. *International Journal of Information Management, 52*. https://doi.org/10.1016/j.ijinfomgt.2019.05.023, 101967–101916.
Kamilaris, A., Fonts, A., & Prenafeta-Boldú, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology, 91*, 640–652. https://doi.org/10.1016/j.tifs.2019.07.034
Kietzmann, J., & Archer-Brown, C. (2019). From hype to reality: Blockchain grows up. *Business Horizons, 62*(3), 269–271. https://doi.org/10.1016/j.bushor.2019.01.001
Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics, 231*, Article 107831. https://doi.org/10.1016/j.ijpe.2020.107831
Kshetri, N. (2018). Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management, 39*, 80–89. https://doi.org/10.1016/j.ijinfomgt.2017.12.005
Kshetri, N. (2021). Blockchain and sustainable supply chain management in developing countries. *International Journal of Information Management, 60*, Article 102376. https://doi.org/10.1016/j.ijinfomgt.2021.102376
Kshetri, N., & DeFranco, J. F. (2020). The economics behind food supply blockchains. *Computer, 53*(12), 106–110. https://doi.org/10.1109/MC.2020.3021549
Lambert, D. M., & Enz, M. G. (2017). Issues in supply chain management: Progress and potential. *Industrial Marketing Management, 62*, 1–16. https://doi.org/10.1016/j.indmarman.2016.12.002
Langforth, S., Oswaldi, V., Isbrandt, R., Sotiraki, S., Anastasiadou, S., Nesbakken, T., … Langkabel, N. (2023). Food chain information for broilers: Results of a Europe-wide survey on status quo, usability and suggestions for improvement. *Food Control, 152*, Article 109844. https://doi.org/10.1016/j.foodcont.2023.109844
Li, P., Yang, J., Jiménez-Carvelo, A. M., & Erasmus, S. W. (2024). Applications of food packaging quick response codes in information transmission toward food supply chain integrity. *Trends in Food Science & Technology, 146*, Article 104384. https://doi.org/10.1016/j.tifs.2024.104384
Lin, W., Ortega, D. L., Ufer, D., Caputo, V., & Awokuse, T. (2022). Blockchain-based traceability and demand for U.S. beef in China. *Applied Economic Perspectives and Policy, 44*(1), 253–272. https://doi.org/10.1002/aepp.13135
Lumineau, F., Wang, W., & Schilke, O. (2021). Blockchain governance—A new way of organizing collaborations? *Organization Science, 32*(2), 500–521. https://doi.org/10.1287/orsc.2020.1379
Lustenberger, M., & Spychiger, F. (2025). Blockchain in supply chains: An unfulfilled promise. *Supply Chain Management, 30*(2), 178–194. https://doi.org/10.1108/SCM-03-2024-0192
Maglaras, G., Bourlakis, M., & Fotopoulos, C. (2015). Power-imbalanced relationships in the dyadic food chain: An empirical investigation of retailers' commercial practices with suppliers. *Industrial Marketing Management, 48*, 187–201. https://doi.org/10.1016/j.indmarman.2015.03.014
Magnani, G., & Gioia, D. (2023). Using the gioia methodology in international business and entrepreneurship research. *International Business Review, 32*(2), Article 102097. https://doi.org/10.1016/j.ibusrev.2022.102097
Manning, L., & Soon, J. M. (2014). Developing systems to control food adulteration. *Food Policy, 49*, 23–32. https://doi.org/10.1016/j.foodpol.2014.06.005
Michelman, P., & Catalini, C. (2017). Seeing beyond the blockchain hype. *MIT Sloan Management Review, 58*(4), 17–22.
Müßigmann, B., von der Gracht, H., & Hartmann, E. (2020). Blockchain technology in logistics and supply chain management—A bibliometric literature review from 2016 to January 2020. *IEEE Transactions on Engineering Management, 67*(4), 988–1007. https://doi.org/10.1109/TEM.2020.2980733
Montecchi, M., Plangger, K., & Etter, M. (2019). It's real, trust me! establishing supply chain provenance using blockchain. *Business Horizons, 62*(3), 283–293. https://doi.org/10.1016/j.bushor.2019.01.008
Patel, A. S., Brahmbhatt, M. N., Bariya, A. R., Nayak, J. B., & Singh, V. K. (2023). Blockchain technology in food safety and traceability concern to livestock products. *Heliyon, 9*(6), Article e16526. https://doi.org/10.1016/j.heliyon.2023.e16526
Pedersen, A. B., Risius, M., & Beck, R. (2019). A ten-step decision path to DetermineWhen to use blockchain technologie. *MIS Quarterly Executive, 18*(2), 99–115.
Petersen, D. (2022). Automating governance: Blockchain delivered governance for business networks. *Industrial Marketing Management, 102*, 177–189. https://doi.org/10.1016/j.indmarman.2022.01.017
Pongnumkul, S., Ittipornpaisarn, P., & Pongnumkul, S. (2025). Comparison of blockchain vs. centralised IT infrastructure costs for food traceability: A Thai broiler supply chain case study. *Journal of Innovation and Entrepreneurship, 14*(1), 13–22. https://doi.org/10.1186/s13731-025-00465-0
Ponte, S., & Gibbon, P. (2005). Quality standards, conventions and the governance of global value chains. *Economy and Society, 34*(1), 1–31. https://doi.org/10.1080/0308514042000329315
Rejeb, A., Keogh, J. G., Zailani, S., Treiblmaier, H., & Rejeb, K. (2020). Blockchain technology in the food industry: A review of potentials, challenges and future research directions. *Logistics, 4*(4), 27. Retrieved from https://www.mdpi.com/2305-6290/4/4/27.
Samaha, S. A., Palmatier, R. W., & Dant, R. P. (2011). Poisoning relationships: Perceived unfairness in channels of distribution. *Journal of Marketing, 75*(3), 99–117. Retrieved from http://www.jstor.org/stable/41228599.
Sri Vigna Hema, V., & Manickavasagan, A. (2024). Blockchain implementation for food safety in supply chain: A review. *Comprehensive Reviews in Food Science and Food Safety, 23*(5), Article e70002. https://doi.org/10.1111/1541-4337.70002
Sunny, J., Undralla, N., & Madhusudanan Pillai, V. (2020). Supply chain transparency through blockchain-based traceability: An overview with demonstration. *Computers & Industrial Engineering, 150*, Article 106895. https://doi.org/10.1016/j.cie.2020.106895
Sutton-Brady, C., Kamvounias, P., & Taylor, T. (2015). A model of supplier–retailer power asymmetry in the Australian retail industry. *Industrial Marketing Management, 51*, 122–130. https://doi.org/10.1016/j.indmarman.2015.05.008
Tan, T. M., & Saraniemi, S. (2023). Trust in blockchain-enabled exchanges: Future directions in blockchain marketing. *Journal of the Academy of Marketing Science, 51*(4), 914–939. https://doi.org/10.1007/s11747-022-00889-0
Trienekens, J. H., Wognum, P. M., Beulens, A. J. M., & van der Vorst, J. G. A. J. (2012). Transparency in complex dynamic food supply chains. *Advanced Engineering Informatics, 26*(1), 55–65. https://doi.org/10.1016/j.aei.2011.07.007
van Hilten, M., Ongena, G., & Ravesteijn, P. (2020). Blockchain for organic food traceability: Case studies on drivers and challenges. *Frontiers in Blockchain, 3*. https://doi.org/10.3389/fbloc.2020.567175
van Hoek, R. (2019). Exploring blockchain implementation in the supply chain: Learning from pioneers and RFID research. *International Journal of Operations & Production Management, 39*(6–7-8), 829–859. https://doi.org/10.1108/ijopm-01-2019-0022
Vasileiou, M., Kyrgiakos, L. S., Kleisiari, C., Lappas, P. Z., Tsinopoulos, C., Kleftodimos, G., … Vlontzos, G. (2025). Digital transformation of food supply chain management using blockchain: A systematic literature review towards food safety and traceability. *Business & Information Systems Engineering*. https://doi.org/10.1007/s12599-025-00948-0

Vern, P., Panghal, A., Mor, R. S., & Kamble, S. S. (2025). Blockchain technology in the agri-food supply chain: A systematic literature review of opportunities and challenges. *Management Review Quarterly, 75*(1), 643–675. https://doi.org/10.1007/s11301-023-00390-0

Villena, V. H., & Gioia, D. A. (2018). On the riskiness of lower-tier suppliers: Managing sustainability in supply networks. *Journal of Operations Management, 64*(1), 65–87. https://doi.org/10.1016/j.jom.2018.09.004

Wilkinson, I. F. (1990). Toward a theory of structural change and evolution in marketing channels. *Journal of Macromarketing, 10*(Fall), 18–46.

Yen-Ting, L., Pyke, D. F., & Swaminathan, J. M. (2022). Identifying and overcoming barriers to implementing blockchain in supply chains. *Management and Business Review, 2*(4), 56–63. https://doi.org/10.1177/2694105820220204006

Yogarajan, L., Masukujjaman, M., Ali, M. H., Khalid, N., Osman, L. H., & Alam, S. S. (2023). Exploring the hype of blockchain adoption in agri-food supply chain: A systematic literature review. *Agriculture, 13*(6), 1173. Retrieved from https://www.mdpi.com/2077-0472/13/6/1173.

Zhang, X., & Ling, L. (2023). A review of blockchain solutions in supply chain traceability. *Tsinghua Science and Technology, 28*(3), 500–510. https://doi.org/10.26599/TST.2022.9010030