International Journal of Information Management Data Insights 4 (2024) 100262

Contents lists available at ScienceDirect

International Journal of Information Management Data Insights

journal homepage: www.elsevier.com/locate/jjimei

Information needs for transparency in blockchain-enabled sustainable food supply chains

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ARTICLE INFO

Keywords:
Alternative food supply chain
Blockchain technology
Information needs
Transparency
Sustainable food supply chains

ABSTRACT

The growing demand for transparency in sustainable food production creates a challenge for supply chains to meet the diverse information needs of stakeholders. This research addresses this challenge by identifying and prioritising information needs within sustainable food supply chains. Employing a mixed-methods approach, the study identified 14 information needs, categorised them into three clusters: a) product and quality details information, b) production and processing information, and c) sustainability information, and prioritised the information needs. Experts highly prioritised information needs on quality and safety, followed by product origin and nutrition/ingredients. The research suggests that blockchain technology can play a role in supporting consumer decision-making. These findings can inform the development of information-sharing systems that enhance transparency and support consumer decision-making in sustainable food supply chains.

1. Introduction

The need for transparency in the food supply chain is rising as stakeholders from production to consumption demand higher levels of sustainability, food quality, and food safety (Beulens et al., 2005; Mol, 2014; Seminar, 2016). These trends result in real-world policy shifts; for example, the European Commission is pursuing directives on green claims and supply chain transparency in Europe, aiming for improved consumer decision-making and enhanced due diligence across supply chains. Such trends motivate a need to understand the information stakeholders require to make informed decisions across supply chains, i.e. information needs.

Supply chain transparency refers to sharing accurate data regarding operations, processes, and goods, including their sourcing and origin, processing methods, and logistics (Jiang & Zhang, 2022). It is the degree to which supply chain stakeholders share and have access to information related to the product, process, and monetary flows across the chain Beulens et al. (2005). Transparent, accessible, and end-to-end information can reinforce performance and stakeholder trust (Bastian & Zentes, 2013; Wognum et al., 2011). In global food supply chains, information is made transparent to consumers through information presented on labels based on institutional standards and quality management systems (Park, Kim, Hong, & Ghim, 2020; Renkema & Hilletofth, 2022). Information management systems are also being developed to uphold chain-wide transparency in food supply chains (Kassahun et al., 2016). Information sharing in food supply chains can help consumers make informed choices (Thøgersen et al., 2010). However, current forms of information sharing often lead to information overload (Horne, 2009). In addition, food fraud, scandals, and foodborne illnesses have impacted consumer trust in information, motivating a shift towards creating shorter supply chains (Ling & Wahab, 2020), where trust is based on direct lines of information sharing and strong relationships (Kneafsey et al., 2013).

Food supply chains that adopt short and direct supply chain strategies, like those in alternative food supply chains, assume a certain level of transparency and trust concerning the practices, processes, and products in the chain. Such trust may be unjustified, as consumers usually need help understanding the product, its origin, and supply chain processes (Wertheim-Heck et al., 2014). Supporting consumer's understanding of information is becoming critical as alternative food supply chains that use more extended channels are increasingly popular. To help consumers and other stakeholders make informed choices in alternative food supply chains, emerging digital technology can assist in communicating transparency criteria regarding, e.g., food production,

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https://doi.org/10.1016/j.jjimei.2024.100262

Available online 15 July 2024

processes, and origin. Successful development and integration of such technologies (i.e. blockchain technology) requires understanding the information needs within sustainable supply chain environments.

Blockchain technology is of growing interest for developing transparent supply chains. Blockchain applications in food supply chains show supporting factors like reduced supply chain disputes, efficiency, tamper-proof data, data quality, improved product quality, disintermediation, improved product lifecycle management, and enhanced trust and quality in the supply chain (Burgess et al., 2022; Hong et al., 2018; Tao et al., 2021). For blockchain-based platforms, information relating to product and process properties, quality requirements, standards, business requirements, transaction proprieties, and stakeholder reputation are known to play significant roles, particularly in support of traceability and trust in global chains (Malik et al., 2019; Samal & Pradhan, 2019; Yadav et al., 2020a). Blockchain infrastructures are also emerging to facilitate transparency in information systems within the food and agriculture sector (Yadav et al., 2020b). These developments are leading to the applicability of blockchain for transparency in food supply chains, building trust, and supporting quality, holding promise for sustainable food supply chains (Burgess et al., 2022).

Transparency is increasingly recognised as essential in food supply chains (Astill et al., 2019; Bastian & Zentes, 2013; Beulens et al., 2005; Trienekens et al., 2012; Wognum et al., 2011), and further research on transparency-enabling technologies such as blockchain has emerged, e.g. Montecchi et al. (2021). Studies have also shed light on how blockchain characteristics regarding transparency can help support food supply chains (Kamilaris et al., 2019; Shahid et al., 2020; Yadav et al., 2022). There is a lack of understanding of how such digital technologies can support sustainable supply chains (Deepu & Ravi, 2023). There is also a substantial research gap in understanding stakeholders' information needs for transparency in blockchain-enabled food supply chains, a vital aspect of the subject. The research gap motivates this study, which seeks to answer the following research questions.

RQ1: What are the information needs for transparency in sustainable food supply chains?

RQ2: How do sustainable food supply chain stakeholders prioritise the information needs?

RQ3: How can blockchain technology leverage the information needs for transparency in sustainable food supply chains?

This research draws from stakeholder theory and organisational information processing theory to contribute by identifying, validating, and categorising stakeholders' information needs for transparency in the sustainable food supply chains facilitated by blockchain technology and prioritising these needs from the perspective of industry experts and academics. The research focuses on the alternative food supply chain, a form of sustainable food supply chain.

The remainder of this report is in six sections. Section 2 contains a literature review on food supply chains, information needs for transparency in food supply chains, blockchain-based food supply chains, and theoretical underpinnings. Section 3 includes the research methodology adopted in this paper, and the results obtained are in Section 4. Section 5 discusses the results and their implications, while Section 6 is the conclusion and highlights areas of limitations and future work.

2. Literature review

2.1. Global and alternative food supply chains

A food supply chain is a series of actors, processes, and operational activities that transform food from a raw material state to a finished product to meet consumers' needs and wants (Dani, 2021). Typical actors in food supply chains include traders, distributors, food producers, food processors, retailers, wholesalers, and catering companies. The end customer is also an important actor and decision-maker in the supply chain.

In global food supply chains, significant amounts of producers and consumers and various other, often large entities that process, sell, trade, and distribute food between the point of production and consumption. Global chains are usually long in structure and have low levels of consumer awareness relating to sustainable production and consumption practices, requiring considerations towards enhanced information sharing (Govindan, 2018). The global food supply chain producers experience power imbalances compared to more powerful stakeholders further down the chain (e.g., supermarkets) (Rao et al., 2021). Large manufacturers regularly interact with large retailers and have a direct channel of information and product flow between each other (Rao et al., 2021). These supply chains typically depend on product characteristics, market power, and the size of entities within the supply chain. Globalisation, commoditisation, and consolidation impact transparency and traceability throughout the global food supply chain. Global food supply chains have been determined to increase the productivity of food production and provisioning systems, removing inefficiencies and reducing costs to support competitive advantage (Roth et al., 2008). A general structure of the global food supply chain is shown in Fig. 1 (Brinkley, 2018).

Within the global food supply chains, the importance of information sharing and information technology is widely acknowledged, and it is needed to support the management of sustainability, quality, safety, and logistics (Trienekens et al., 2014). To address the issues related to environmental sustainability, food waste, food safety, and food quality, global food supply chains are adopting international management standards and quality/safety management systems (Thomé et al., 2021). Food product, production, and processing standards are set under these systems and communicated to consumers through quality marks on labels. Although this type of communication has benefits, the information presented may need clarity, as the supply chain practices and processes behind such labels can be far away from the consumers. Although global food supply chains have been known to be traceable, current systems for information sharing, such as labelling, have pitfalls in guaranteeing aspects such as food quality, authenticity, and safety (Aung & Chang, 2014).

The alternative food supply chain is a sustainable food supply chain aimed at providing an alternative to the global chain (Kneafsey et al., 2013), and it often tries to reduce social and physical distances (Renting et al., 2003), and offer enhanced levels of sustainability to stakeholders. Alternative food supply chains focus on developing multi-actor and participatory strategies around quality and sustainability-related outcomes, aiming to create value, drive socio-technical innovations, and build producer associations (Sacchi et al., 2018). Consumers motivate these supply chains as they ardently desire to understand aspects such as the product's origin and provenance-related information. Processing and retailing are locally based, are diverse in size, scale, and offerings, and aim for quality products and information transparency. Institutional frameworks are more locally oriented, where the local authority is involved and has lower levels of bureaucracy. Associational frameworks are relational and trust-based, formulated regionally, and can also be collaborative (Sonnino & Marsden, 2006). Stakeholders in the alternative food supply chains have two distinct actors, namely producers and consumers; one intermediary in-between is also possible, i.e. small-scale processor. Other actors in the alternative food supply chains include logistic and transport actors and secondary actors, for example, universities, research institutes, and authoritative organisations (Burgess et al., 2022). Characteristics of alternative food supply chains include disintermediation, personalised relationships, direct interaction, and short distances. Another central trait of alternative food supply chains is to help consumers make informed choices. An example of an alternative food supply chain structure is shown in Fig. 2.

Information in the alternative food supply chains is communicated through three main channels: face-to-face, proximate, or extended (Kneafsey et al., 2013; Renting et al., 2003). Farmers and consumers interact directly in the face-to-face supply chain, and this approach develops trust through benevolence (Prigent-Simonin &

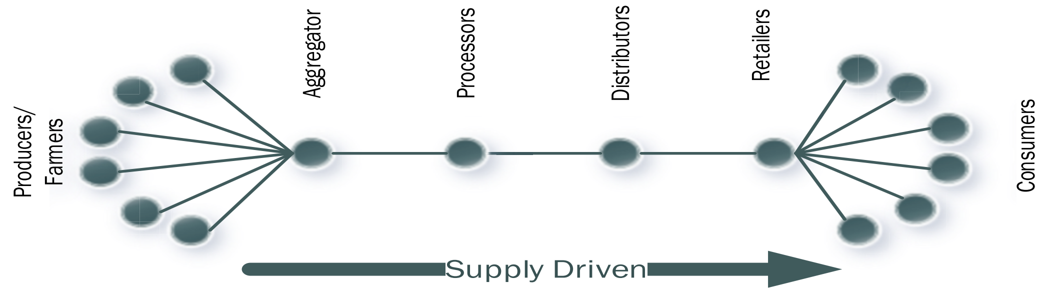

Fig. 1. Supply chain in global food systems.
Source (Brinkley, 2018).

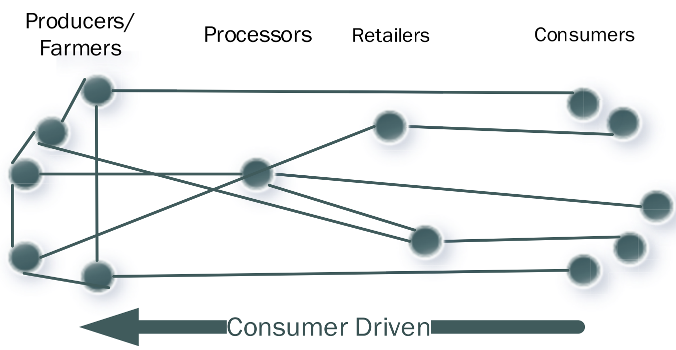

Fig. 2. Supply chain in alternative food networks.
Source (Brinkley, 2018).

Hérault-Fournier, 2005). Proximate, where a locally based company (intermediary) can give product information. Extended uses techniques such as labels to provide information, raising challenges like mistrust and misunderstanding of information. Trust in the proximate and extended channels has been developed through a certain level of credibility and integrity of supply chain stakeholders (Prigent-Simonin & Hérault-Fournier, 2005). Supply chains that do not use face-to-face channels, for example, catering companies (i.e. restaurants), e-commerce, and speciality retailers (Corsi & Mazzocchi, 2019; García et al., 2018; Ji et al., 2020), may benefit through emerging digital technologies (e.g. blockchain technology) to improve information flow and transparency within the supply chain, reinforcing credibility and integrity-based trust.

2.2. Transparency in digital food supply chains

2.2.1. Information needs

A drive to develop transparency within organisations and across supply chains is becoming increasingly apparent. Several definitions of transparency have been put forward, and some include the following:

Process transparency: Organisational policies to ensure that information is provided to all stakeholders and is accessible, usable, understandable, and presented (Sánchez-Hernández, 2019).
Business transparency: Complete, on-time, accurate information fosters honesty towards stakeholders, improves collaboration, and allows for collective decision-making (Sánchez-Hernández, 2019).
Supply chain transparency: Sharing accurate data regarding operations, processes, and goods, including their sourcing and origin, processing methods, and logistics (Jiang & Zhang, 2022).
Information Transparency: The ability of an organisation or a supply chain to make information available to stakeholders to support them in making informed decisions (Vallejo et al., 2019).

This research focuses on supply chain transparency. Transparency in supply chains is well-recognised for supporting performance and consumer demands in supply chains (Tao et al., 2020). Transparency in the food supply chain is critical to support areas like trust in food safety and quality (Wognum et al., 2011). In the food supply chain, transparency-enabling systems are often controlled by prominent, more powerful actors, such as those that use certifications and labels to communicate information. Micro-small-medium size stakeholders may face challenges in such supply chain transparency infrastructures (Mol, 2015). Therefore, defining and analysing the information needs in the alternative food supply chains is essential to support transparency and information sharing. Examples of information in food supply chains include product and supplier identification, quality and safety information, environmental monitoring, and production and cultivation-related information (Nakandala et al., 2017). Table 1 provides an overview of studies on the types of information shared in food supply chains.

The information types listed in Table 1 indicate information needs in food supply chains. Information needs describe the types of information an individual or group needs to perform a task or make decisions (Vuori, 2006). Within the field of information management, information needs studies cut across disciplines, such as healthcare, management strategy, and sustainable supply chains. Studying information needs is very important in the early stages of information management (Lueg, 2001). The ability to assess information needs is an essential attribute of supply chains and their managers within the field of information management (Willard & Mychalyn, 1998). For example, Foshay and Kuziemsky (2014) investigate the information needs from the perspective of managers and knowledge management within Malaysian firms. The information needs for managers reflect closely on the sources of information and the information itself, e.g. customer and competitor-related information. The results in Foshay and Kuziemsky (2014) highlight various managerial information needs, such as information on business trends, finance, markets, and industry. Based on the literature review, this paper presents fourteen identified information needs in food supply chains as described in Table 2.

Table 1
Examples of the types of information shared in food supply chains.

Source	Scope	Information types
(Evans & Redmond, 2017)	A study on the provision of food safety information to chemotherapy patients.	Information related to Food Safety and Hygiene. Cooking and preparation; Storage.
(Niederhauser et al., 2008)	A conceptual information system for the coffee industry.	Information related to product quality, farmer information (location, contact details), origin, production, and cultivation.
(Wang et al., 2017)	Wireless multi-sensor gas sensor systems in the grape supply chain.	Information related to quality, transport, and product freshness through the supply chain.
(Bager et al., 2022)	Blockchain-based food management system in the coffee supply chain.	Information regarding farm location, sustainability, processes, and price information.
(Gadema & Oglethorpe, 2011)	An investigation of carbon footprinting and how labelling can be used as a tool to guide consumer choices for more sustainable purchasing decisions.	Information regarding environmental sustainability.
(Trienekens & Wognum, 2013)	An analysis of information needs in the pork supply chain.	Information related to origin, product authenticity, social sustainability, quality management, nutrition and health, food safety, production processes, and supply chain processes.
(Hall & Johnson-Hall, 2021)	A study of recall effectiveness in the food industry.	Information related to food safety.
(Xiao et al., 2016)	A study on using compressed sending and wireless sensor networks (WSN) in fish supply chains.	Information relating to transport and storage-related (temperature), freshness information, and shelf-life information.
(Wang et al., 2018)	A multi-sensor traceability system for the honey peach supply chain.	Information on supply chain processes, safety, and quality information.
(Trienekens et al., 2012)	A paper that discusses the role of transparency in food supply chains.	Product information, process information, supplier information, information on taste, functional food information, freshness information, convenience information, environmental and social sustainability information, price and fair-trade information, distance information, natural production information, logistics and storage information.
(Woolley et al., 2016)	Food waste reduction through smartphone applications.	Use by date information, supply chain inventory stages information, and convenience information.
(Raab et al., 2011)	A temperature monitoring system in the meat supply chain.	Temperature history information of a product is available through processing, storage, transport, and quality information.
(Meulensteen et al., 2016)	The study on governance strategies used in large companies to create shared value between buyers and suppliers.	Supplier quality information.
(Arens et al., 2012)	Information exchange and sharing in the pig supply chain.	Food quality information.
(Althoff et al., 2005)	A reference model to support quality information needs within the pork supply chain,	Information regarding quality, Product information, health information, process information, safety, origin information, supply chain process, supplier information.
(Wowak et al., 2016)	A study that investigates the factors that hinder traceability in supply chains.	Origin information, information over consumption.
(Zhang et al., 2011)	Modelling functional and information needs in the fish supply chain.	Information regarding the supplier, input supply information, quality and safety information, process information, product information, information over taste, logistics and transportation information.
(Deimel et al., 2008)	A measurement model for transparency in food supply chains.	Information over supply chain processes.
(Raab et al., 2008)	A generic shelf-life model for cold chain management of pork and poultry supply chains.	Logistics and storage information, processing information.
(Brinkmann et al., 2011)	A supply chain quality coordination model in pork supply chains.	Information related to demand and inventory, market-related information, product quality information, supply chain-related information, cost and price information, and process information.
(Pinior et al., 2012)	The trade network structure for the dairy food chain.	Food safety information.
(Pulker et al., 2018b)	A study on the use and perspective of nutrition labelling on supermarket brand products.	Nutrition and health-related information.
(Wiedenroth & Otter, 2022)	The use of social media to communicate information on luxury short food supply chain products.	Product information.
(Pulker et al., 2018a)	A study on health and nutrition labelling regarding ultra-processed food products.	Nutritional and health-related information.

The information needs listed in Table 2 may reside in the food supply chain in general; however, it is essential to realise that such needs can change significantly amongst supply chain types. The research illustrated in this paper addresses this by evaluating the information needs from stakeholders' perspectives regarding sustainable food supply chains, particularly alternative food chains. Moreover, the information needs for blockchain-based alternative food supply chains is void, warranting the need for the research reported here.

2.2.2. Blockchain technology

A blockchain is a decentralised, immutable, transparent, and secure digital ledger technology. The blockchain stores transaction information, such as price, quantity, quality standards, product specifications, and other supply chain agreements. Blockchain participants can include standard organisations, certification providers, registers, business-level supply chain stakeholders, and consumers (Saberi et al., 2019). Blockchain technology has been reported to support sustainable performance throughout supply chains (Jasrotia et al., 2024). Blockchain-based supply chains are increasingly being researched in the agrifood sector and show the potential to influence consumer perceptions towards product quality positively (Treiblmaier & Garaus, 2023). Examples of literature regarding blockchain applications in food are blockchain-based traceability (Bumblauskas et al., 2020; Feng et al., 2020), blockchain to support food safety (Zhang et al., 2020), and blockchain-enabled food supply chain quality management in short food supply chains (Burgess et al., 2022). Burgess et al. (2022) highlight that blockchain should support alternative food supply chain stakeholders through fair prices, sustainability, health and safety, locality, freshness, origin, and quality. Real-life blockchain use cases and applications are also emerging.

Blockchain characteristics such as disintermediation, tamper-proof, trust-less, smart contracts, reliable and transparent information flow, immutable, and non-reputation can enable transparency in food supply chains (Feng et al., 2020; Peng et al., 2023). Blockchain-enabled

Table 2
An overview of information needs for transparency in food supply chains.

Source	Information need	Description
(Bager et al., 2022; Nakandala et al., 2017; Siddh et al., 2021)	Information related to quality and safety	This includes information on supply chain quality and safety management practices (e.g. supplier quality management), quality guarantee schemes (e.g. the product of designed origin), quality certifications, quality claims, auditing results, quality performance and outcomes, food inspection protocols, quality control, and quality governance.
(Grunert & Wills, 2007)	Information related to nutrition and ingredients	The information about the ingredients and nutritional content of products supports the consumer's ability to make informed choices.
(Zimmermann et al., 2021)	Information related to origin of product/ production (country and region)	This requirement includes the country of origin, exact place of origin, and origin of materials, input supplies, and final products for production, processing and consumption.
(Zimmermann et al., 2021)	Information related to product freshness	This information needs to communicate aspects such as the best-before date, the date of production, the date of processing, the date of packaging, and the best-before and use-by dates.
(Zimmermann et al., 2021)	Information related to cultivation and production methods	This information relates to the type of production (animal husbandry, crops, fish), organic/ conventional farming, type of farming/fishing methods, and production standards (e.g. GlobalGap)
(Bager et al., 2022; Nakandala et al., 2017; Trienekens et al., 2012)	Information related to environmental sustainability	This focuses on information relating to sustainable performance. For example, recycling, packing type, amount, use of ecolabels, Co2 impact, resources used, soil and water impact, and deforestation.
(Trienekens et al., 2012)	Information related to convenience (preparation, storage)	This information needs to inform the consumer about food preparation, use by/best before dates, and disposal methods.
(Cheftel, 2005)	Information on the names and addresses of manufacturers and producers	This information needs to inform the stakeholders about the names and addresses of food producers and manufacturers.
(Cheftel, 2005; Zhong et al., 2015)	Information related to production and processing dates	This information refers to date marketing and providing information on the production date or processing date.
(Zimmermann et al., 2021)	Information related to transportation modes.	This informs them about the type of information mode used to move product, as well as the distances (food miles), lead time, and tracking compliance, like temperature in the cold chain.
(Nakandala et al., 2017) (Zhong et al., 2015)	Information related to economic sustainability	This communicates information like cost of production, cost/price distribution throughout the supply chain, and contractual agreements in supply chains.
(Bager et al., 2022; J. H. Trienekens et al., 2012)	Information related to social sustainability	This information need is to provide information on labour conditions and safety, legal and civil rights, animal welfare, educational and rural support, and culture.
(Trienekens et al., 2012)	Information related to food sensory attributes	This information needs to inform the consumer of organoleptic characteristics like taste, texture, and smell.
(Zhong et al., 2015; Zimmermann et al., 2021)	Information related to supply chain network and processes	This information need is used to communicate information related to stakeholders' processes, a farm-to-fork overview of the supply chain, and existing supply chain structures. Information on process steps, recall information and inputs used are also provided.

transparency can support trust (Dey & Shekhawat, 2021), traceability and supplier engagement, sustainability (Saurabh & Dey, 2021), improved monitoring and control (Shivendra et al., 2021), and provenance and authentication (Lin et al., 2020). An overview of example blockchain characteristics for the supply chain is shown in Table 3 (Chen et al., 2017).

Table 4 shows an overview of blockchain applications in the food industry to support transparency. Other applications not identified in Table 4 include virtualisation, data integrity, time and cost saving, food fraud reduction, improved relationships, provenance, and trust (Arun & PrasannaVenkatesan, 2019; Baralla et al., 2019; Cao et al., 2021; Prashar et al., 2020; Rogerson & Parry, 2020).

Table 4 does not list non-food research on blockchain technology that is important for developing information needs. For example, Jain et al. (2021) reviewed the literature on blockchain in marketing and communication, showing a need for future work regarding blockchain's use in e-commerce and how it can improve data management and performance.

Blockchain technology challenges, including energy consumption, security concerns, legal issues, implementation costs, privacy, and scalability, cannot be ignored (Mbaidin et al., 2023; Peng et al., 2023). Therefore, the design of such technology must ensure the expected benefits (i.e. effecting, risk mitigation, and transparency (Mbaidin et al., 2023). A precise knowledge and understanding of the information needs would help.

2.3. Theoretical underpinnings

This research draws on existing theories to determine the information needs of stakeholders across a type of sustainable food supply chain (alternative food supply chains), including stakeholder theory and organisational information processing theory (OIPT). Stakeholder theory supports corporate strategy and decision-making by considering stakeholders' interests across a supply chain (Freeman, 1984, 2010; Qazi et al., 2022), including stakeholders within an organisation, such as employees and those outside an organisation, for example, suppliers, B2B customers, and the end consumer. It also considers the needs of a community external to the supply chain and the direct supply chain stakeholders involved (Damak-Ayadi & Pesqueux, 2005). About stakeholder theory, some emphasis should be placed on fair treatment and value creation for all supply chain stakeholders (Mahajan et al., 2023). Stakeholder theory motivates an understanding of the needs of stakeholders, encourages a holistic framework that extends beyond the needs of shareholders and promotes collaboration, value addition, and long-term growth for organisations and supply chains (Co & Barro, 2009; Daradkeh, 2023). In a recent review of stakeholder theory (Mahajan et al., 2023), future work areas highlight its use in understanding sustainability and digital technologies in organisations and their supply chains. Stakeholder theory has been applied to recent works on sustainable supply chain management, for example, in (Shah & Bookbinder, 2022), where the authors use stakeholder theory to study the drivers of sustainable circular supply chains and the relationships between the drivers. Sarkar et al. (2023) draw from stakeholder theory in prioritising critical success factors in agri-food supply chain waste minimisation, highlighting its applicability to considering the interest of stakeholders across the supply chain.

This research also draws on an information processing theory, organisational information processing theory (OIPT). OIPT has been used to support decision-making around information management and supply chain transparency (Zhu et al., 2018). OIPT characterises supply

Table 3
Blockchain Characteristics Relevant to Supply Chains.

Accessibility	Durability, reliability and longevity	Information flow and control	Security
Accounting	Ecosystem simplification	Integrity	Sharing demand in SCM
Anonymity and identity	Efficiency	Laws	Simplification of current paradigms
Audible	Energy	Near-impossible loss of data	Smart contracts and smart systems
Consensus mechanisms	Feedback	Non-repudiation	Social influence
Costs	Government policy	Permanence	Solving the double spend problem
Customer focus and satisfaction	High availability	Persistency	Speed
Data access and control in SCM	High-quality data	Private, public, and permissioned blockchain	Streamlined invoicing
Decentralisation	Identification of issues	Quality	Traceability and visibility
Disintermediation	Immutability and encryption	Reduction in administrative costs, transaction	Transaction approval
Documentation	Improvement in inventory	Removal of intermediaries	Transparency
		Scalability	Trust

Source: (Sunmola & Apeji, 2020; Yadav & Singh, 2020).

Table 4
Blockchain applications and benefits in food supply chain.

Source	Focus	Main blockchain application	Benefits
(Lucena et al., 2018)	A blockchain-based quality solution in a grain supply chain.	Smart contracts Quality Transparency	Reduced supply chain disputes; Efficiency
(Shivendra et al., 2021)	A blockchain-based price monitoring system in the agri-food supply chain.	Traceability	Improved control; disintermediation
(Tao et al., 2021)	A blockchain-based rice quality supply chain.	Traceability Transparency	Tamper-proof data; Transparency; Data Quality; Improved product quality; Disintermediation
(Hong et al., 2018)	Blockchain-based food provenance and traceability.	Smart contracts Traceability Transparency	Improved product lifecycle management

chain organisations and businesses as open social systems that seek to reduce uncertainties in the decision-making process. OIPT consists of three main aspects: a) information required to satisfy decision-making for specific objectives, b) information processing capability, which is the organisation's ability to gather, interpret, and synthesise information for meaningful decision-making and c) the alignment between information processing requirements and capabilities (Tushman & Nadler, 1978; Zhu et al., 2018). OIPT can inspire improved decision-making processes (Lai et al., 2020) and support information system development, including developing the system's information needs (Gupta et al., 2023). This paper uses OIPT to further the information needs of blockchain-based transparency within sustainable (e.g. alternative) food supply chains.

3. Methodology

This research applies three methods to identify, categorise, and prioritise information needs in alternative food supply chains. The methods used in the study are i) Traditional literature review, ii) Principal components analysis (PCA) method, and iii) Best-worst method. Fig. 3 shows an overview of the methodology. Within these is data collection, achieved through questionnaire surveys and semi-structured interviews.

3.1. Data collection

Data collection was facilitated through a living lab setting. The "living lab" approach is an open innovation ecosystem beneficial for studying system platforms and prototypes. It involves users who cooperate with developers and researchers in open, neutral research environments (Dell'Era & Landoni, 2014). Living labs help design, envision, develop, test, and validate supply chain models and tools. Living labs provide several benefits, including facilitating a participatory approach to research and innovation, bringing various stakeholder perspectives together, allowing users to experiment with novel systems, and providing feedback for co-creation and further development (Hossain et al., 2019). In this research, four main phases of the living lab approach were used: i) opportunity identification through literature review, ii) concept development through interviews with the case study companies regarding the information needs and use of blockchain for transparency in alternative food supply chains, iii) development and validation of the information needs for blockchain-based transparency platforms through survey approach and iv) expert feedback and prioritisation concerning the information needs. Personal identifiers were not captured in this study for all data collection with human participants to respect the ethical conditions set before undertaking the study.

In phase one, the primary method for data collection was a traditional literature review. Compared to the systematic literature review, a traditional literature review uses a more flexible way of searching for articles to identify and interpret current publications and documents relevant to a research area (Jesson et al., 2011). The traditional literature review uses seven steps. They are selecting, understanding, comprehending, interpreting, analysing, synthesising, and evaluating. The weakness of the traditional literature review is related to the difficulty in replicating the findings and highlighting questions relating to its rigour. To address this, we applied the following search strategy. The following keywords were used: "Information Need" and "Food Supply Chain" across Emerald Insight, Science Direct, and Scopus databases.

Phase two was the concept development phase, which followed the opportunity identification and aimed to define the proposed project boundaries. This stage involved a series of online interviews with Case Companies A and B (Described in Section 3.2) to validate the information needs from the literature review.

Phase three was to collect data on information needs in blockchain-based alternative food supply chains in a live location setting. The test

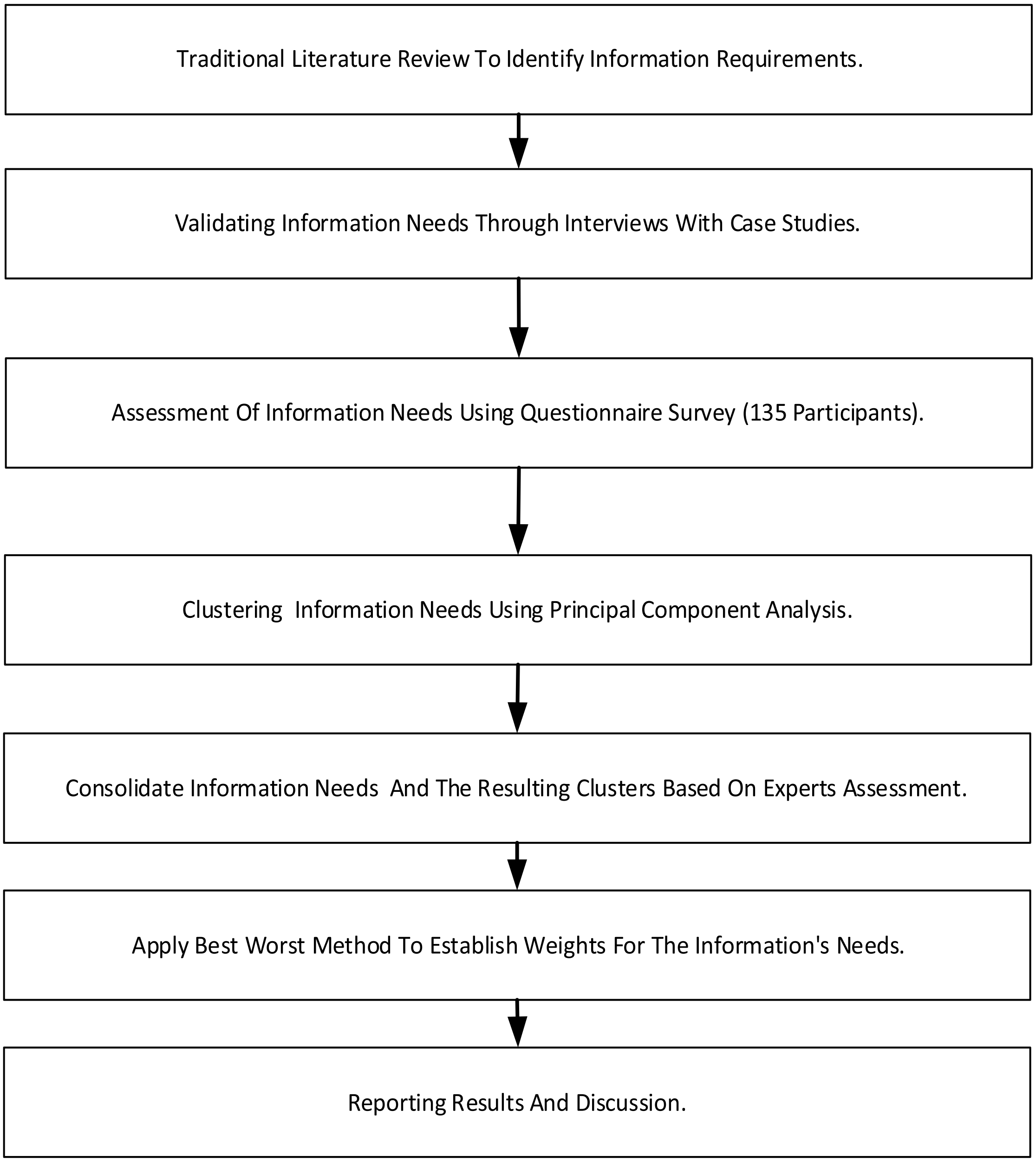

Fig. 3. Overall research approach.

location for the living lab was the Floriade Expo in Almere, the Netherlands, where an existing blockchain platform was demonstrated. The research design focused on the role of blockchain-based transparency in alternative food supply chains, emphasising those chains with short and local priorities. The Floriade hosted diverse stakeholders, from producers to consumers, including stakeholders actively engaged in sustainable food supply chains at local, sub-national, and national levels. The location proved suitable for collecting stakeholders' data and demonstrating blockchain-based transparency in alternative food supply chains throughout the field study at the Floriade exhibition.

The questionnaire survey used in phase three was divided into three parts. The first part of the questionnaire asked demographic questions. The participants were asked about their role in the supply chain (i.e. consumer or practitioner), the amount of time involved in such chains, and the number of times purchased per week. The type of supply chain actor (e.g., producer, retailer, processor) was asked for the supply chain practitioners. The second part of the questionnaire focused on information needs in the alternative food supply chain. The participants were asked about their perspective on the relevance of the fourteen information needs in alternative food supply chains using a 5-point Likert scale. The third part of the questionnaire asked two open-answer questions regarding a) their view on transparency and why it might be important in alternative food supply chains and b) how, from the respondent's perspective, blockchain technology could be used to support transparency. Inductive content analysis was used to identify patterns in the open-answer questions. Regarding non-response bias, statistical guidance papers state that this bias will likely occur when missingness is over 10 % (Dong & Peng, 2013), and in cases where missingness is less than 5 %, it has been suggested to be inconsequential (Schafer, 1999). Regarding the data presented in this paper, we observe missingness of <1 %, where the living lab approach and in-person data collection have mitigated the risk of non-response. The on-site paper-based surveys likely resulted in some items being left unanswered, possibly due to human error (such as missing a question). Despite the low proportion of missing data, we conducted Little's test for missing completely at random in SPSS (Li, 2013; Little, 1988), where the test results 0.087 (>

0.05) showed the values were missing completely at random (MCAR). Based on the low missingness, we proceeded with a sample size of 135 participants for analysis.

Phase four involved expert feedback to provide a final categorisation and designation of the information needs in the alternative food supply chain and to prioritise those needs. The part of the study involved a panel of nine experts. Among the industry experts were Expert 1, Expert 2, Expert 3, and Expert 5, who engaged in providing blockchain platforms for food and agriculture supply chains and are employees in the Case Companies. Expert 6 is involved in local and short food supply chains. Expert 7, on the other hand, was engaged in digital supply chain compliance software for the food industry. The remaining three experts, i.e., Experts 4, 8, and 9, were academics who focused on alternative, sustainable, and circular food supply chains. In Step 5, the Experts reviewed the categorisation of the information needs and provided feedback on any information needs that fell into more than one category. Also, the experts were asked to name the main categories of information needs. Following the final categorisation and naming of information needs, the experts were asked to prioritise the information needs for blockchain-based transparency in alternative food supply chains. The experts are summarised based on their role, the type of organisation, and the level of blockchain exposure In Table 5. All expert organisations are based in the Netherlands, with many having international activities.

The qualitative research steps, i.e. those involving the experts, run the risk of several limitations. For example, Browne et al. (2018) discuss the Abilene Paradox within the field of requirements determination, highlighting potential drawbacks resulting from the illusion of agreement. Other known limitations of such an approach are the results of biases related to organisational needs and functions.

3.1.1. Case study companies and platforms

The blockchain platform used for demonstration at the exposition is the development of a partnership between two companies. Case Company A is a small-scale blockchain solution developer and provider in the food industry whose platform can be customised for various food industry applications. The company offers several products and services, including blockchain solutions, blockchain labs, masterclasses, expert placement, SDG consultants and blockchain auditing services. Company B is a micro-size company that offers a blockchain-based service platform for the catering industry. Their blockchain platform, developed by Company A and Company B, is central to this research and is a blockchain-based hamburger. The blockchain acts as a transparency and traceability platform to communicate the story of a hamburger that uses only ingredients from local producers. The information provided is on the story of the producer, origin, nutrition, distance travelled, and nutritional and sustainability facts (e.g. Co2 emissions).

3.2. Data analysis

3.2.1. Content analysis

Content analysis was applied to the literature review to highlight aspects of food supply chains, information needs, and blockchain technology in supply chains. A structured approach summarised the literature to ensure consistent results. This approach can contribute to a robust understanding of the material and guide the research process from a scanning stage to a more substantial analysis stage (Lim & Kumar, 2023).

3.2.2. Principal component analysis

The Principal Component Analysis (PCA) is a mathematical approach towards gathering and grouping factors into components (Wold et al., 1987). PCA is a valuable tool for compressing and aligning factors into components, providing simplified data analysis and assisting in the analysis and observations of variables (Labrín & Urdinez, 2020). Although novel approaches for dimension reduction are emerging, Singh et al. (2022) discuss how the PCA approach performs well,

Table 5
Overview of experts participating in BWM.

ID	Role	Type of organisation	Years of experience	Blockchain exposure
1	Chief Operations Officer	Blockchain Services in Food Supply Chain	5–10 years	High
2	Product Owner	Blockchain Services in Food Supply Chain	0–3 years	High
3	Product Owner	Blockchain Services in Food Supply Chain	5–10 years	High
4	Lecturer Sustainable Food Supply Chains/ Senior Project Manager	Higher Education in Agriculture/ Innovation and Sustainable Food Systems	>15 years	Medium
5	Owner/Operator	Blockchain technology for the food catering industry (Events, restaurants)	>15 years	High
6	Board Member	Short Food Supply Chain Network	>15 years	Medium
7	Account Executive DACH market	Digital Compliance Management Platform in Food and Agriculture	0–3 years	Low
8	Researcher Sustainable Food Supply Chains	Higher Education Focused on Food and Agriculture	3–5 years	Low
9	Course Coordinator/ Lecturer Food Business	Higher Education Focused on Food and Agriculture	10–15 years	Low

especially when combined with other analysis types. PCA has been used in recent works such as (Rajput & Singh, 2019), which applies the approach to group the enabling and challenging factors for the circular economy and Industry 4.0. The current research uses PCA to cluster the information needs identified in the literature review, confirmed by the group of experts.

This research uses a 5-point Likert scale to collect data on information needs from respondents (supply chain stakeholders). The information needs in the questionnaire survey are the list of 14 information need items obtained from the literature and validated by the case study companies; they are listed in Table 6. PCA is used in this research to generate groups of information needs based on stakeholder responses from the questionnaire survey. The survey responses were imported into SPSS, checked, and verified for accuracy. A dimension reduction technique was applied using PCA. Direct Oblimin rotation was adopted, which is a popular approach in PCA when there are some assumptions that the variables may correlate. To reduce the number of times a factor fell under different components, the value of 0.38 was set as a limit to suppress factor loadings across multiple principal components. There were limited occurrences where an information need appeared under multiple components; these occurrences were resolved by experts used in the research. Based on the results of the PCA, the information needs are developed as a vital contribution to this research. The flow chart for the PCA adopted in this research is shown in Fig. 4.

The suitability of PCA was tested using KMO and Bartlett's test, where the KMO value should be above 0.500, and Bartlett's test of Sphericity P value should be below 0.05. As shown in Table 7, the values suggest that PCA is suitable. Information needs indicate that samples score adequately above 0.800, supporting PCA suitability as a factor reduction technique (Napitupulu et al., 2017).

3.2.3. Best worst method

Decision-making refers to the cognitive process of selecting alternatives from a set criterion. In supply chains, multi-criteria decision-making is often needed as there are usually various criteria and alternatives. There are several different MCDA approaches for ranking and

Table 6
List of factors.

Information needs	
Label	Name
IN1	Information related to product freshness
IN2	Information related to transportation modes
IN3	Information related to the origin of product/production (country and region)
IN4	Information related to quality and safety
IN5	Information related to food sensory attributes
IN6	Information related to supply chain network and processes
IN7	Information related to environmental sustainability
IN8	Information related to social sustainability
IN9	Information related to economic sustainability
IN10	Information related to cultivation and production methods
IN11	Information related to production and processing dates
IN12	Information on the names and addresses of manufacturers and producers
IN13	Information related to convenience (preparation, storage)
IN14	Information related to nutrition and ingredients

prioritising alternatives, for example, the Analytical Hierarchy Process (AHP), Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE), Generalised Regression with Intensities of Preference (GRIP), and the Best-Worst Method (BWM). The BWM has shown significant advantages over other MCDAs like AHP regarding statistical validations (Kusi-Sarpong et al., 2020; Wankhede & Vinodh, 2021). The benefits of BWM over AHP include improved consistency, conformity, total deviation and minimum violation (Rezaei, 2015). BWM and its variations have been applied by various supply chain and digital technology researchers, for example, to study Industry 4.0 Challenges (Wankhede & Vinodh, 2021), to prioritise transport flexibility measures (Shardeo et al., 2022), to examine the digitalisation enablers that can support supply chain management (Kusi-Sarpong et al., 2020), prioritising social sustainability criteria in supply chains, and evaluating external factors for sustainability in supply oil and gas supply chains

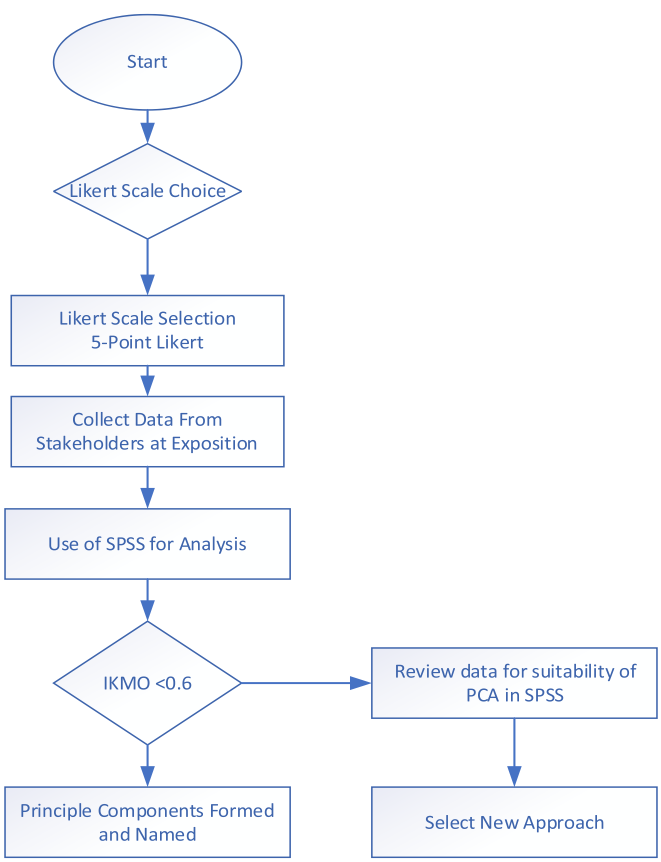

Fig. 4. PCA process.

Table 7
KMO and Bartlett's test of information needs.

Kaiser-Meyer-Olkin measure of sampling adequacy.		.891
Bartlett's test of sphericity	Approx. Chi-square	845.731
	Df	91
	Sig.	<0.001

(Ahmad et al., 2017). To summarise, the best-worst method has several advantages over other decision-making approaches, including its flexibility and ability to accommodate multiple decision-makers, its consistency compared to other tools, and its involvement of a limited number of comparisons compared to other decision-making methods, such as AHP. The demonstrated applicability of BWM in sustainable supply chain management and its advantages compared to other decision-making tools reinforce the choice for using BWM in this study.

The best-worst method can be broken into nine steps (Rezaei, 2015). This research adopts the following nine steps of the BMW method.

Step 1 is to determine the decision criteria. In this step, the decision maker (expert) decides on the criteria $\{c_1, c_2, c_3 \ldots c_n\}$. The decision criteria in this research represent the information needs (found in the literature, confirmed by experts, and validated by stakeholders in the survey and PCA). The criteria used in the current study are in Fig. 5.

Step 2 determines the best and the worst (most and least preferred) criteria. This step involves the decision maker identifying the best and worst criteria, but no comparison is made. This step is repeated four times in this research. First, each expert was asked to rank their preference for the best and worst clusters of information needs (Principal Components). The experts then ranked their preference for best and worst information needs (sub-cluster/local criteria) under each cluster of information needs (Principal Component).

Step 3 is to determine the most preferred (best) criteria over the other criteria. This study uses a 9-point Likert scale based on preference, where 1=Equally Preferred, 2= Slightly Preferred, 3=Moderately Preferred, 4= Somewhat Preferred, 5= Fairly Preferred, 6= Quite Preferred, 7= Very Preferred, 8= Highly Preferred, 9= Extremely Preferred. This is represented in Eq. (1), where a_{bj} is the identification of the preference of the best crieriation *B,* over criteritation *j:*

$$A = (a_{B1},\ a_{B2},\ a_{B3} \ldots a_{Bn}\} \tag{1}$$

Step 3 is repeated four times. To establish the weight of the information needs, the experts compared their best information needs to the other information needs "best to others." For example, the best against the best information is equally preferred (1). As in the previous step, the expert repeats this step in the three categories of information needs. This is illustrated in Table 8 for the three information needs.

Step 4 determines all other criteria over the least preferred one, "others to worst", using a 9-point Likert scale. This is represented in Eq. (2), where a_{jw} is the identification of the preference of the creation *j* over the worst criterion *W:*

$$A = (a_{1W},\ a_{2W},\ a_{3W} \ldots a_{nW}\} \tag{2}$$

Like Step 3, Step 4 is repeated four times. First, for the information needs, followed by the information needs under each information need (Principal Component); see Table 9 for an example.

Step 5 determines the optimal weights or $(w_1^*,\ w_2^*, \ldots w_n^*)$. The optimal weight for each pair's criteria is w_B/w_j And $w_j\ /w_W$, we have $w_B/w_{j=}a_{Bj}$ and $w_j/w_{W=}a_{jW}$. To satisfy the conditions for all *j,* we use a solution for the maximum absolute difference $|\frac{w_B}{w_j} - a_{Bj}|$ and $|\frac{w_j}{w_W} - a_{jW}|$ for all *j* is minimised. This condition can be formulated as shown in Eq. (3) (Rezaei, 2015):

$$\min_{j} max = \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|,\ \left| \frac{w_j}{w_W} - a_{jW} \right| \right\}$$

Subject to

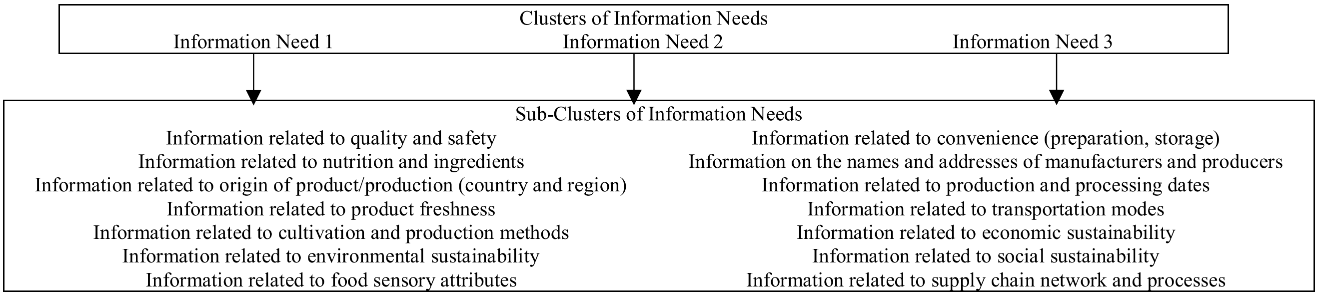

Fig. 5. Decision criteria.

Table 8
Example (best to others).

Best to others	Information need 1	Information need 2	Information need 3
Information need (Best)	1–9	1–9	1–9

$$\sum_j wj = 1 \tag{3}$$

$wj \geq 0$ for all j

In *Step 6*, we use the linear programming approach (Rezaei, 2015) to convert the Equation above, as shown in Eq. (4):

Min ξ

Subject to

$$\left|\frac{w_B}{w_j} - \text{vBj}\right| \geq \xi, \text{ for all j}$$

$$\left|\frac{w_j}{w_W} - \text{vjW}\right| \geq \xi, \text{ for all j}$$

$$\sum_j wj = 1 \tag{4}$$

$wj \geq 0$ for all j

For a linear model, like the current study on information needs in alternative food supply chains prioritisation, the value of ξ^L is directly considered as a measure for consistency check of the computed weights. ξ^L values close to 0 represent a high level of consistency.

Step 7 is the ranking of the weights. This is done for the clusters of information needs and the sub-cluster information need (local weight). This step takes the average weight based on the expert's response.

Step 8 involves calculating the global weight by multiplying the weight of a cluster of information needs by the sub-cluster of information needs (local weight).

Step 9 is to prioritise the information needs.

Section 4 reports the results of the questionnaire survey, the principal components analysis of the survey responses to generate the information needs clusters, and the best-worst method for prioritising the information needs clusters.

Table 9
Example (others to worst).

Others to the worst	Information need (worst)
Information need 1	1–9
Information need 2	1–9
Information need 3	1–9

4. Results

4.1. Survey participant's profile and perspectives

This section of the results illustrates the profiles of the participants and their views on transparency and blockchain in food supply chains. Descriptive statistics summarise the profile of the 135 participants who completed the questionnaire survey at the Floriade. As no personal identifiers, such as age, gender, or income, were collected, participants are profiled regarding involvement in the short and local alternative food supply chains. Figs. 6–8 summarise the profile of the survey respondents.

Participants were asked open questions regarding their perception of transparency in local and short food supply chains and how blockchain technology might support it. Fig. 9 illustrates why the participants view transparency as important in food supply chains, and Fig. 10 shows their views on how blockchain technology could support transparency in the food supply chain. Figs. 9 and 10 were based on the inductive content analysis performed on the survey data from the questionnaire.

Based on stakeholders' perspectives, summarised in Fig. 9, the importance of transparency in alternative food supply chains becomes more apparent, including a need to understand where food is coming from, how it is produced, and the steps it takes from production to consumption, reflecting the need for provenance and geographical indication of production. Health and nutrition, safe food production, fair trade, ethics, authenticity, supporting local producers, information availability, visibility of supply chain processes, freshness, awareness, and environmental sustainability were also identified in multiple

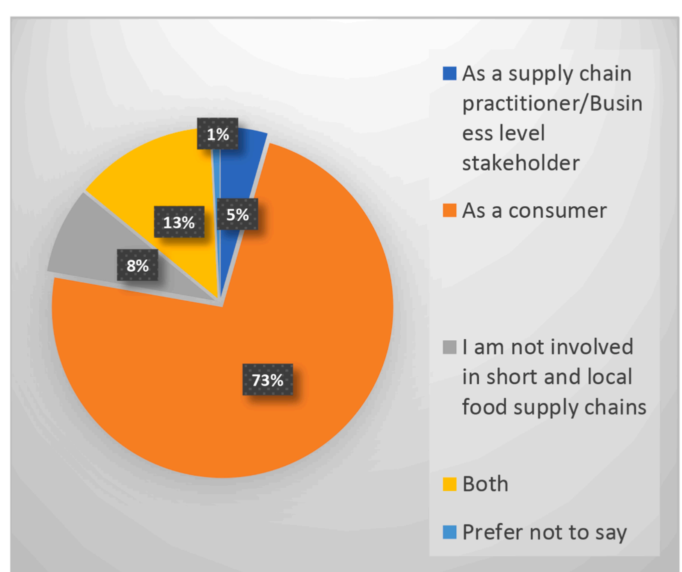

Fig. 6. Type of involvement (Actor Type).

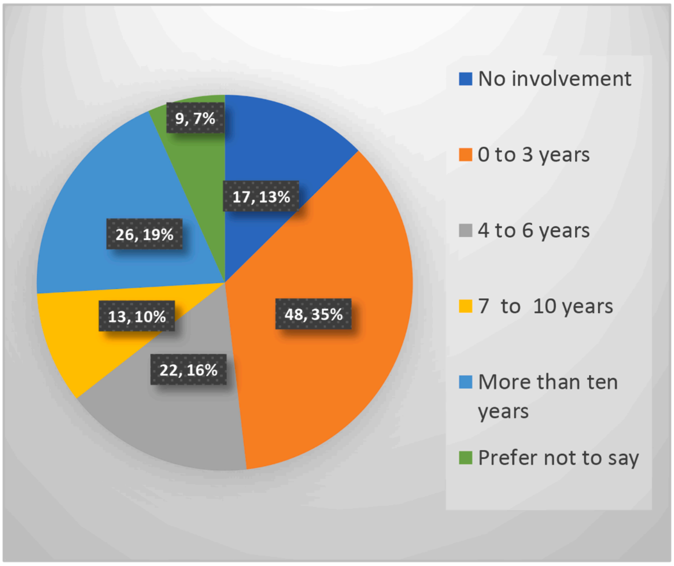

Fig. 7. Participation in AFSCs (length of time involved in AFNs).

responses.

As shown in Fig. 10, Stakeholders who participated in the study mentioned blockchain's ability to enhance end-to-end transparency as an overall support factor in the alternative food supply chain. Other factors mentioned reflected the ability to reinforce traceability and origin indications, support collaboration, reduce fraud and miscommunication, provide an overview of immutable supply chain and product information, support trust and honesty, reinforce responsible production, replace a need for labelling, improve storytelling, introduce rules and unity, validation of claims, and provide proof of origin.

4.2. Principal components of the identified information needs

The Kruskal–Wallis test was used to compare the variance between the groups regarding the questions on information needs. A significant difference occurs when the p-value > 0.05, and the results are shown in Table 10.

The PCA analysis resulted in three principal components (PCs), or clusters of information needs and showed significant and positive loading values. Table 11 shows the principal components (i.e. clusters of Information Needs). In PC 1 (45.15 % of the total explained variance) is information related to quality and safety, information related to nutrition and ingredients, information related to the origin of product/production, information related to product freshness, information related to cultivation methods, and information related to environmental sustainability. Information related to environmental sustainability also shows a correlation to PC 3; in PC 2 (9.03 % of the total explained variance) is information related to convenience, information on the name and address of manufacturers and producers, information related to production dates, information related to transportation modes, and information related to supply chain networks and processes. PC 3 contains information related to economic and social sustainability, food sensory and convenience information, supply chain networks and processes, and information related to environmental sustainability.

4.3. Priorities of the identified information needs

After conducting the questionnaire survey and analysing the results using Principal Component Analysis (PCA), the researchers recruited a group of experts to provide further input. The experts reviewed the PCA results to a) determine how to categorise sub-cluster information needs that had fallen under more than one information need cluster and b) assign names to each cluster. Collectively, the experts agreed on the names of each information need cluster based on the analysis results and

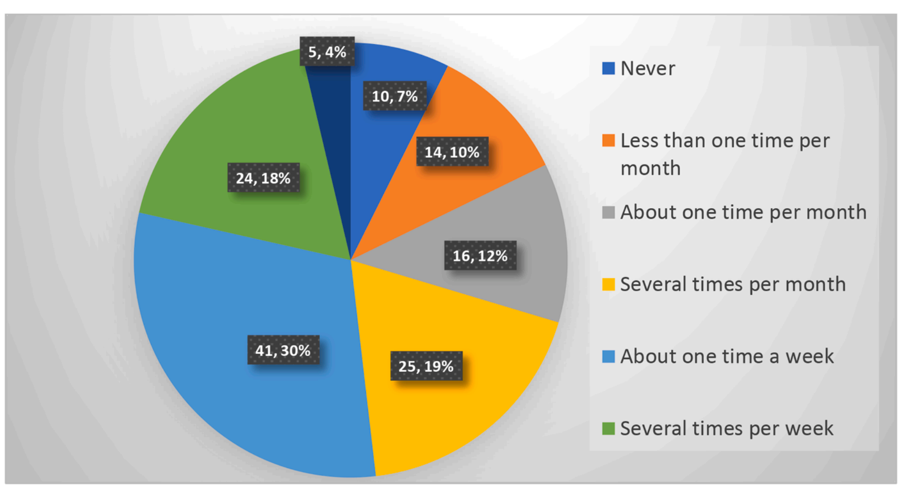

Fig. 8. Purchasing behaviour (amount of purchases per week).

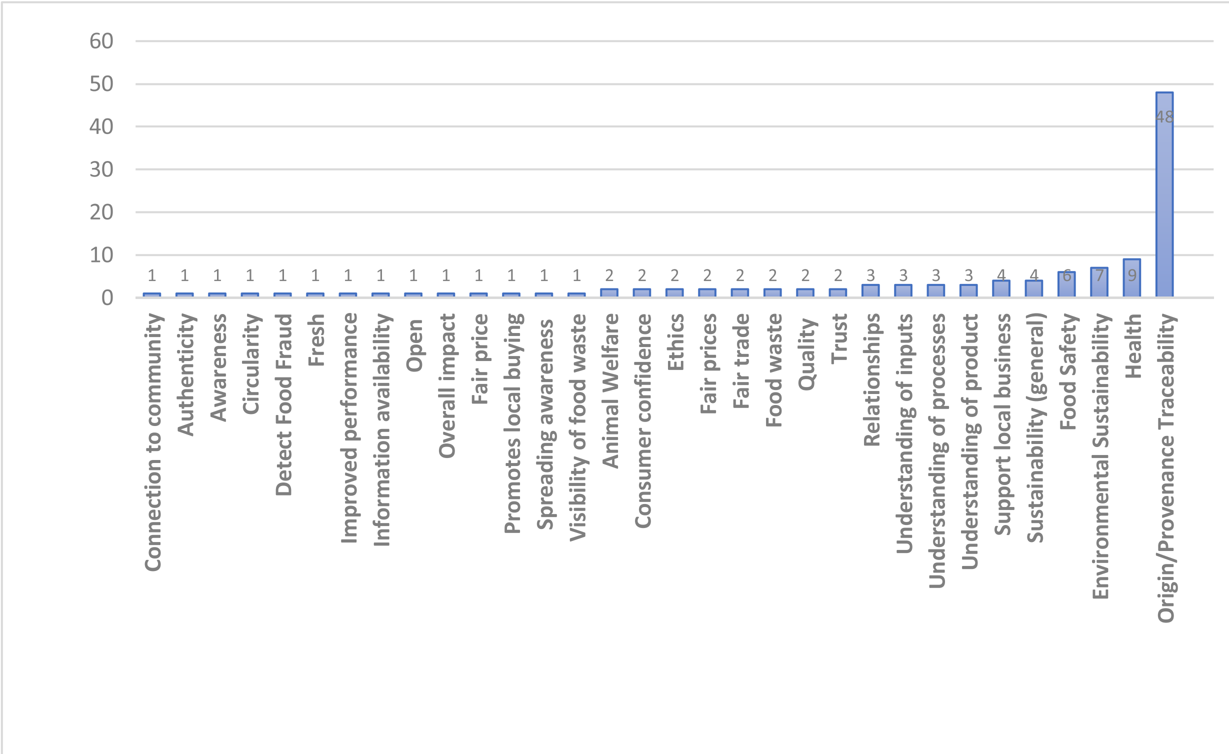

Fig. 9. Reasons why stakeholders believe transparency is important.

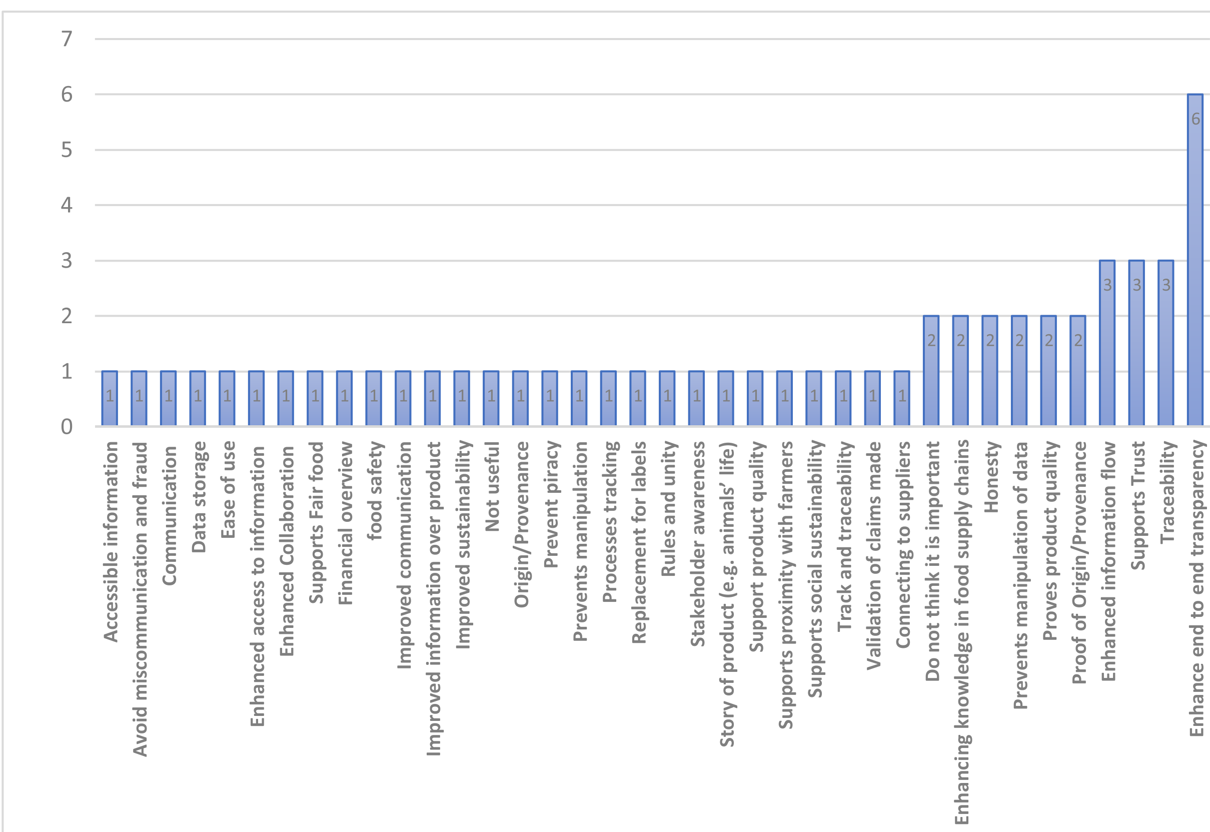

Fig. 10. Ways stakeholders believe blockchain can support transparency.

Table 10
Statistical significance test between participants' types and information needs.

	Group: participation type p-value	Duration of participation p-value	Buying behaviour p-value
Information needs			
Information related to quality and safety	**0.022**	**0.011**	0.069
Information related to nutrition and ingredients	0.37	0.241	0.679
Information related to origin of product/production (country and region)	**0.002**	0.78	0.567
Information related to product freshness	0.315	0.628	0.397
Information related to cultivation and production methods	0.221	0.962	0.642
Information related to environmental sustainability	0.139	0.468	0.817
Information related to convenience (preparation, storage)	0.053	0.342	0.209
Information on the names and addresses of manufacturers and producers	0.552	0.248	0.334
Information related to production and processing dates	0.747	0.399	0.401
Information related to transportation modes	0.246	**0.048**	0.146
Information related to economic sustainability	0.171	0.093	0.084
Information related to social sustainability	**0.009**	0.113	0.288
Information related to food sensory attributes	0.903	0.850	0.527
Information related to supply chain network and processes	0.837	0.968	0.192

Table 11
Principal components.

Information need	Components		
	PC1:	PC2:	PC3:
Information related to quality and safety	0.877		
Information related to nutrition and ingredients	0.805		
Information related to origin of product/production (country and region)	0.773		
Information related to product freshness	0.634		
Information related to cultivation and production methods	0.545		
Information related to environmental sustainability	0.524		0.504
Information related to convenience (preparation, storage)		0.778	
Information on the names and addresses of manufacturers and producers		0.690	
Information related to production and processing dates		0.568	
Information related to transportation modes		0.390	
Information related to economic sustainability			0.793
Information related to social sustainability			0.651
Information related to food sensory attributes			0.614
Information related to supply chain network and processes		0.491	0.560

allocation of the information needs into sub-clusters. They recommended the names "Product Details and Quality Information", "Production and Processes Information", and "Sustainability Information" for the information needs in PC1, PC2, and PC3 clusters, respectively. The experts also discussed allocating information needs under multiple categories, where "the categorisation appears consistent with the broad themes". There was some debate amongst the experts over allocating " Information related to food sensory attributes " to PC3, which dealt mainly with sustainability information needs. Ultimately, it was decided through majority voting that the information related to food sensory attributes should remain in the PC3 cluster. The expert review resulted in a more precise and concise breakdown of the clusters of information needs and their corresponding sub-clusters, as shown in Table 12.

Using the BWM method, the experts prioritised the three clusters of information needs against each other and then repeated the process to capture the local weights of the sub-cluster information needs; see Tables 13–15, for example, prioritisation results of the global weights. Eqs. (1)-4 were adopted to calculate the cluster and sub-cluster (local) weights; see Table 15 for the results of cluster weights per expert. This step is repeated for each of the sub-clusters of information needs to capture the "local weights". The cluster weight of an information need was multiplied by the local weight (sub-cluster information need) to

Table 12
Information needs in alternative food supply chains.

Product details and quality information	Production and processes information	Sustainability information
Information related to quality and safety	Information related to convenience (preparation, storage)	Information related to economic sustainability
Information related to nutrition and ingredients	Information on the names and addresses of manufacturers and producers	Information related to social sustainability
Information related to origin of product/ production (country and region)	Information related to production and processing dates	Information related to food sensory attributes
Information related to product freshness	Information related to transportation modes	Information related to environmental sustainability
Information related to cultivation and production methods	Information related to supply chain network and processes	

Table 13
Best to other information needs.

Expert	Best	Product detail and quality information	Manufacturing and process information	Sustainability information
1	Sustainability information	2	5	1
2	Product details and quality information	1	4	2
3	Sustainability information	3	5	1
4	Product details and quality information	1	7	9
5	Product details and quality information	1	7	9
6	Product details and quality information	1	4	6
7	Product details and quality information	1	2	4
8	Product details and quality information	1	3	4
9	Production and processes information	3	1	9

Table 14
Others to worst information needs.

Expert Worst	1 Production and processing information	2 Production and processing information	3 Production and processing information	4 Sustainability information	5 Sustainability information	6 Sustainability information	7 Sustainability information	8 Sustainability information	9 Sustainability Information
Product Detail and quality information	4	4	1	9	9	6	4	4	7
Manufacturing and process information	1	1	1	5	5	4	2	2	9
Sustainability information	5	3	5	1	1	1	1	1	1

Table 15
Expert weights of the information needs clusters.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Cluster weight
Product details and quality information	0.32500	0.56250	0.16667	0.79259	0.79259	0.69697	0.57143	0.62857	0.27059	0.56704
Production and processing information	0.10000	0.12500	0.16667	0.14074	0.14074	0.21212	0.28571	0.22857	0.67059	0.17494
Sustainability information	0.57500	0.31250	0.66667	0.06667	0.06667	0.09091	0.14286	0.14286	0.05882	0.25802
ξ^L	0.15000	0.16667	0.10000	0.36111	0.36111	0.33333	0.00000	0.11210	0.16667	0.19455

Table 16
Final ranking of information needs.

Cluster of information need	Cluster weight	Sub-cluster of information need	Local weight	Global weight
Product details and quality information	0.53410	Information related to quality and safety	0.30206	0.16133
		Information related to nutrition and ingredients.	0.21809	0.11648
		Information related to origin of product/production (country and region)	0.24149	0.12898
		Information related to product freshness	0.14931	0.07975
		Information related to cultivation and production methods	0.08904	0.04756
		ξL	0.33131	
Production and processing information	0.23002	Information related to convenience (preparation, storage)	0.33572	0.07722
		Information on the name and address of manufacturers and producers	0.17490	0.04023
		Information related to production and processing dates	0.22407	0.05154
		Information related to transportation modes	0.11249	0.02588
		Information related to supply chain network and processes	0.15281	0.03515
		ξL	0.31126	
Sustainability information	0.23588	Information related to economic sustainability	0.18972	0.04475
ξL	0.19455	Information related to social sustainability	0.28007	0.06606
		Information related to food sensory attributes	0.07825	0.01846
		Information related to environmental sustainability	0.45196	0.10661
		ξL	0.26098	

calculate the global weight. These are then calculated and ranked. The final ranking of information needs is in Table 16.

Fig. 11 shows the final prioritisation of information needs based on the global weights. Based on the Best-Worst Method, the results show that the experts prefer information related to quality and safety, followed by information related to the origin of product/production, nutrition and health, and environmental sustainability. The least preferred information is related to food sensory attributes and information pertaining to transportation modes.

5. Discussion and implications

5.1. Discussion of results

The PCA helped gain insight into alternative food supply chain stakeholders' perceptions of multiple information needs. The PCA helped identify the patterns between the information needs in alternative food supply chains. The validity of PCA scored highly in the Kaiser-Meyer-Olkin Measure of Sampling Adequacy. Reflecting on the Kruskal–Wallis Test, only a few variables showed significant statistical differences. Concerning actor type, information related to quality and safety, origin, and social sustainability resulted in some levels of difference. These differences may be attributed to the fact that those involved in the short and local alternative food supply chains can prioritise these aspects of variables differently than those not involved. There was also some evidence of a statistical difference between the groups with experience in the alternative food supply chain, specifically in the information needs relating to quality and safety and information related to transportation modes, potentially reflecting on the importance stakeholders give such information needs as their experience in alternative food supply chains advances.

Product Details and Quality Information (Information Need Cluster 1) is composed of requirements to support transparency around product detail and quality-related information, focusing on food quality and safety, freshness, nutrition and ingredients, the origin of the product and its production, and production and cultivation methods. These have been attributed as some of the norms, values and standards within more alternative food supply chains. Traceability is a crucial concept for

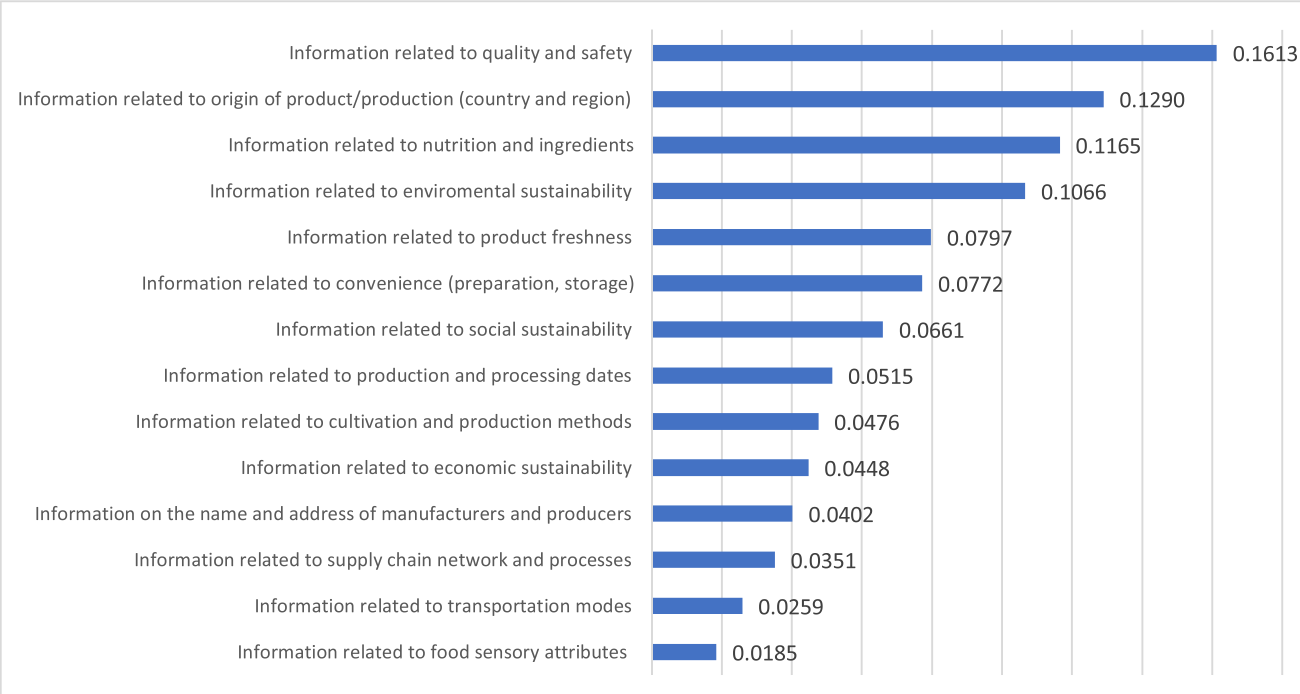

Fig. 11. Final ranking of the information needs.

quality and safety in food supply chains (Peng et al., 2020). Traceability in the food supply chain can support the need for information related to the origin and geographical indication (Barjolle et al., 2017) to improve monitoring of the whole supply chain, including aspects like production, product freshness, and support quality and safety in the supply chain (Pappa et al., 2018). Traceability can be supported through digital technologies, as discussed by Aung and Chang, (2014); Feng et al. (2020), 2013; Qian et al. (2020). In alternative food supply chains, proving the origin of food products and the processes before reaching consumers is important (Bryła, 2019; Sellitto et al., 2018). Traceability can, for example, further confirm information related to the ethnicity, authenticity, and locality of raw materials (Carzedda et al., 2018). Production and Processing Information (Information Need 2) encompasses production and supply chain processes, including sub-cluster information needs such as producer and processor information, information about the modes of transportation, convenience-related information, for example, how to prepare and store the food product, and information on the production and processing dates. There is also a need to map processes in the alternative food supply chain, considering the desire to create fairness between supply chain stakeholders (Demartini et al., 2017), where trust and a collaborative approach can be used to improve bargaining positions in the chain (van Tilburg et al., 2007). Relationships in the alternative food supply chains reflect the need for fair value and price across the supply chain (Lau & Nakandala, 2019). Therefore, knowing the producer and their processes becomes essential. In addition, as consumers become more convenience-oriented (Buckley et al., 2005), there is a need to provide information to help consumers understand how to prepare and store products properly. This can be done through upstream members sharing their knowledge through digital platforms. Sustainability Information (Information Need 3) represents a need for sustainability-related information (economic, social, and environmental). Information about food sensory attributes is in this information need, referring to how a product looks, tastes and smells or the organoleptic characteristics of a product. Sustainability means having reasonable economic, social, and environmental control (Michel-Villarreal et al., 2019). Consumer desire for sustainability-related information is critical and reflects on proper communication and embedded information about the product, place of production, and processes (Brunori, 2007).

The expert review of the PCA results provided valuable insights into allocating information needs across multiple PCs and naming the PCs. Experts determined the composition and structure of the three clusters of information needs. However, there was some disagreement regarding allocating the information need related to sensory aspects, as their relation to the overall information needs to be clarified. This raises an interesting discussion point about the importance of considering sensory aspects when designing information systems and the potential challenges of incorporating them into existing frameworks.

The Best-Worst method is valuable for understanding experts' preferences on information needs in blockchain-based supply chains. According to expert insight, the top three information needs related to quality and safety, proof of origin, and nutrition and ingredients, which are closely tied to the quality norms, values and standards in alternative food supply chains (Kneafsey et al., 2013; Renting et al., 2003). Information relating to quality and safety was regarded as the number one preferred information need amongst the experts. Quality and safety of food products are still deemed highly important across the supply chains, both alternative and global. A close second information need was about the origin of production and processes. The level of traceability and proof of origin are essential transparency drivers in alternative food supply chains (Sellitto et al., 2018). This finding also aligns with the open-answer questions shown in Figs. 9 and 10, as stakeholders strongly desire to understand the origin of their food in local and short food supply chains. Information about nutrition and ingredients ranked in the top three requirements, reflecting consumers' need to understand what they eat. The experts involved in this research who had adopted blockchain technology were already using the technology to communicate the nutritional value of the ingredients on the blockchain. The information on environmental sustainability ranked just outside the top three, highlighting a need to implement responsible production and processing practices across the supply chain. CO_2, resource usage, and other such data can be monitored when products and processes are within the control of firms; however, monitoring the sustainable practices of consumers remains a challenge. Other highly prioritised information needs included information relating to product freshness, convenience, and social sustainability.

Blockchain technology can enhance traceability and help create end-to-end, dynamic transparency in food supply chains (Lee et al., 2021), supporting more open and balanced information sharing. Blockchain can be used to reinforce information sharing, for example, to hold stakeholders accountable for the information being shared (Burgess et al., 2022; Yadav & Singh, 2020), potentially supporting a participatory approach to validating what is being communicated in the supply chain (Sacchi, 2019). Blockchain technology can enhance transparency and accountability in food supply chains, leading to a fairer value distribution among stakeholders. This technology can empower smaller players in the supply chain by enabling them to share information needs from the ground up and promote non-repudiation. It may also lead to a more open form of information sharing and stimulate dynamics in transparency. This research also acknowledges the drawbacks of blockchain technology, as the experts pointed out the difficulties in monitoring and capturing information related to specific needs, such as social sustainability. This makes it challenging to incorporate transparency-enabling technologies like blockchain. One of the participants mentioned that their platform allows supply chain stakeholders to communicate this information through an "off-chain" approach, meaning that there is a section on their platform that displays information not held on the blockchain. Another limitation relates to stakeholder knowledge of using blockchain technology to share and receive information in food supply chains, highlighting a need to develop stakeholders' understanding of such systems (Francisco & Swanson, 2018). Blockchain may not fit all types of alternative supply chains, especially face-to-face channels, where consumers can visit producers to be informed on supply chain practices.

5.2. Implications for practice

Information sharing in the food supply chain has often been addressed and developed from the top-down, where institutions decide what information is essential and should be shared. In the current research, information needs were tested from the perspectives of consumers, academics, and business-level stakeholders actively engaged in alternative food supply chains. Blockchain technology can support information sharing in these food supply chains, allowing for more dynamic (two-way) transparency and participatory information decisions. Defining information needs may help managers design and implement blockchain-based information transparency by offering insight into which areas of information to focus on. The practical implications of this research are as follows:

Stakeholder-Driven Information Sharing:

This research emphasises the importance of a participatory approach for identifying and prioritising information needs. By involving stakeholders in this process, practitioners can design information-sharing systems that optimise value strategically and align with what stakeholders consider valuable. This is particularly relevant for blockchain technology, where transparency can be enhanced by focusing on information needs deemed crucial by consumers, producers, and processors.

Prioritising Information for Blockchain Implementation:

Our findings highlight specific information needs that are essential for alternative food supply chains, such as product origin, quality, and safety. This can guide managers in blockchain-based technology companies to streamline information-sharing priorities on their platforms. Consumers can then access this prioritised information while also having the option to request additional details.

Blockchain's Potential Beyond Efficiency:

While blockchain has improved transparency and traceability in supply chains, this research suggests its potential for a broader role. The technology can facilitate the sharing of information beyond just economic performance, encompassing areas like environmental sustainability and even nutrient content. Further exploration is needed to exploit this potential and realise social and environmental benefits fully.

5.3. Implications for theory

Information sharing is essential in the food supply chain. Global food supply chains often share information that institutional directives and standards require. The communicated information may not represent the needs of all stakeholders, particularly in more alternative food supply chains. The current research contributes to the theoretical knowledge about information needs in alternative food supply chains and how blockchain-based transparency can support those needs. PCA was useful in categorising the sub-clusters of information needs into clusters of information needs and may be applied to future studies when analysing other types of information. The best-worst method was helpful in prioritising information needs, as its ability to offer less pairwise comparisons compared to different AHP approaches provided experts with the ability to critically assess the weights of information needs and requirements concerning blockchain-based transparency in alternative food supply chains. The consistency of the expert response was only reached by some experts. Inconsistency was alleviated by going back to the experts to validate their responses. A limitation highlighted by experts is that the initial criterion selected in a 'best to worst' ranking may differ from that in a 'worst to best' ranking due to the influence of evaluation direction on the decision-maker. This could lead to other criteria being given similar importance when comparing the other criteria against the chosen best and worst criteria. Nonetheless, the experts agreed with the prioritisation results, showing that information like food quality and safety extends from the global food supply chain to the alternative food supply chains. This can be supported through blockchain technology. Five key points of theoretical implications are shown, and they are listed below.

Information Needs in Sustainable Food Systems:

This research enhances our understanding of information needs in food supply chains, particularly those focused on sustainability. While some information needs, like origin tracking, overlap with conventional global chains, alternative food supply chains prioritise quality, nutrition, and environmental factors reflecting the values of their stakeholders (e.g., local consumers and organic producers). These differences might be driven by consumer preferences for local or ethically sourced products. Future research can further explore this area to pinpoint how consumer preferences influence information needs across various food supply chain models.

Principal Component Analysis (PCA) for Clustering:

This study utilises Principal Component Analysis (PCA) as a robust method for clustering stakeholders' information needs. By offering a clustering approach before prioritisation, PCA addresses limitations in traditional methods like the Best-Worst Method (BWM), which can struggle with many variables. PCA allows for identifying lower-level variables that can be used in Multi-Criteria Decision Making (MCDM) techniques among experts for prioritisation.

Drawing on Complementary Theories:

Drawing on complementary theories, such as organisational information processing theory and stakeholder theory, strengthens our understanding of information needs from various supply chain stakeholders' perspectives. This integrated approach can inform better information management and technology development decision-making within sustainable food supply chains. For instance, by understanding how information flows within the supply chain (Information Processing Theory) and the specific needs of stakeholders (Stakeholder Theory), managers can design information systems that are more efficient and meet stakeholder expectations.

Living Lab Environments:

This study introduces a pioneering approach to evaluating supply chain information needs using living lab environments. Living labs provide a well-suited setting for assessing information needs across diverse stakeholders within a supply chain. They facilitate in-person data collection, leading to a richer understanding of stakeholder perspectives and mitigating non-response risks. However, it is essential to acknowledge that findings from living labs might not be generalisable to a broader population, and future research might explore ways to enhance the generalisability of results obtained through this approach.

Best-Worst Method (BWM) for Prioritisation:

The Best-Worst Method (BWM) is a valuable tool for prioritising information needs and gaining insights into stakeholder preferences. This method allows respondents to reflect on the most and least preferred information needs, leading to a more critical assessment than traditional ranking methods. BWM offers advantages over other methods like the Analytical Hierarchy Process (AHP) by requiring fewer pairwise comparisons, making it more efficient for prioritising requirements and needs during system development.

6. Conclusion

This research has identified and prioritised the information needs for transparency in blockchain-enabled alternative food supply chains. The results show several key findings. First, the study's findings reveal three clusters of information needs in alternative food supply chains. The information needs for transparency in alternative food supply chains includes product details and quality information, production and processing information, and sustainability information. Second, the priorities of the information needs are shown, highlighting the importance of product detail and quality information. Third, the most expert-preferred information needs for transparency in blockchain-enabled alternative food supply chains are information related to quality and safety, information related to the origin of product/production (country and region), and information related to nutrition and ingredients. Information related to environmental sustainability, freshness, convenience, and social sustainability is also highly preferred. Fourth, the research highlights the potential of blockchain-based solutions to support information needs in alternative food supply chains by allowing dynamic transparency and the ability to facilitate bottom-up information needs across multiple alternative food supply chains. Fifth, the methodologies proved helpful, where the use of the PCA was beneficial in factor reduction of information needs to provide insight into the information needs in alternative food supply chains and could be applied in future work relating to other types of information and supply chain structures. The best-worst method was helpful in the expert prioritisation of the information needs in alternative food supply chains.

When interpreting the results of the study, it is crucial to recognise that there are limitations that must be considered. One of the most significant limitations is that although the study's selection was based on a literature review and validation of information needs, additional information may be needed in different food supply chains. Qualitative work on eliciting information needs across food supply chains would be beneficial. One limitation of the study is its narrow focus on alternative food supply chains and blockchain-based applications in the Netherlands. Therefore, the results may not be generalised to other countries, particularly those outside Europe. It is crucial to comprehend the information needs and utilisation of blockchain technology to aid in future situations. A third limitation that is significant is that although the research captured the views of stakeholders across the supply chain, it would be beneficial to conduct a further empirical investigation from the perspective of business-level stakeholders to gain further insight into how the information needs can be developed across the supply chain, and ultimately improve performance within the chain. Finally, the risk of an illusion of agreement is present in this research. The BWM was used to alleviate this in the prioritisation phase. However, this risk was more present in the final stages of agreeing on the final allocation of information needs to cluster and the naming of the clusters amongst the experts. Quantitative research through a survey approach may alleviate this bias and further develop the information needs.

CRediT authorship contribution statement

Patrick Burgess: Writing – original draft, Validation, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Funlade Sunmola:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Sigrid Wertheim-Heck:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

There is no conflict of interest regarding the research presented in this article.

Acknowledgements

The Public Institutions, The Ministry of Agriculture, Nature and Food Quality, and Regieorgaan SIA financially supported this work. Funding was allocated to hours and materials related to the preparation and conducting of the research. In addition to financial support, Innofest, a Dutch-based organisation dedicated to stimulating innovation at festivals, supported the research by organising aspects around the living lab, such as location.

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