Enhancing olive oil communication through blockchain agri-food traceability

DAVIDE MARIA CONSOLARO*, DOMINGO FERNÁNDEZ UCLÉS**, JULIO VENA OYA**

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Abstract

A large part of society remains unaware of agri-food blockchain traceability's value as an additional certification for ensuring the authenticity, safety and quality of several food products through their life cycle processes. Consequently, communication can help consumers by informing them about blockchain advantages orienting their trust, acceptance and purchase intentions. Communication of blockchain traceability can also help the agri-food sectors to differentiate their food products in their supply chain and consumer markets by mitigating the existing information asymmetry. Identifying the blockchain attributes communicated by olive oil organizations' websites, this study aims to analyze specific profiles of these agri-food operators who adopt this technology. Through a fuzzy set Qualitative Comparative Analysis (fsQCA) we analyze the blockchain attributes in order to determine the business drivers that influence the extent to which food traceability communication is associated with the corresponding strategic and business profile of olive oil organizations. Being that olive oil is one of the most counterfeited Mediterranean foods in global trade with a recent boost in global demand, our findings can help orient the management of the olive oil sector towards setting up a business and communication strategy with adoption of blockchain traceability system, thus capitalizing the added value of its certification. Filling a lack of literature in olive oil blockchain communication, this study offers an extended framework of blockchain attributes that can be applied to other agri-food sectors, thus opening up a new line of research.

Keywords*: Blockchain, Traceability, Communication, Websites, Olive oil, FsQCA.*

1. Introduction

Olive oil is one of the most counterfeited foods in global trade (Alkhudary *et al*., 2022). Repeated cases of fraud regarding the origin of olive oil by misleading and false labeling claims (Gentile *et al*., 2020; Rifna *et al*., 2022), adulteration and misconduct, or incidents in compliance with safety and hygiene regulations have generated five global consequences: lack of consumer trust (Rainero and Modarelli, 2021), reduction in consumption (Meerza and Gustafson, 2019), transmission of diseases in the population with social costs (Di Girolamo *et al*., 2015), reputational damage and losses in the agri-food sector and supply chains (Yan *et al*., 2020). Even if there

* Department of Business Organization, Marketing and Sociology, University of Jaén, Spain; Faculty of Social and Law Sciences, Jaén, Spain.
** Department of Business Organization, Marketing and Sociology, University of Jaén, Spain.
Corresponding author: dmconsol@ujaen.es

are multiple sources of information, consumers are often scared of food knowledge and wary of certified-labeled foods without understanding their concept (Borda *et al*., 2021). Moreover, consumers are unable to control the transparency of food-labeling information (Zhang, 2023).

From the offer side, olive oil organizations are facing the following global challenges (Informe Annual de Conjuntura del Sector Oleícola 2022, Caja Rural Jaén - España): super-intensive plantations that assure low prices altering the markets' competition; the environmental impact in terms of sustainability, extended to social and economic issues; asymmetrical information in the global trade supply chains; a more administrative complexity due the increasing data requirements imposed by several controls from multiples nationals and international public bodies and certification authorities; healthier lifestyle habits of consumers with an increasingly demand of organic food products; large request of more information and transparency about food origin, quality and safety from supply chain operators and society; misinformation on the Internet media that devalues the healthy olive oil value.

Therefore, in this context agri-food traceability has become one of the most strategic societal concerns and challenges worldwide, particularly for olive oil (Tseng *et al*., 2022) and the adoption of blockchain TS in the area of agri-food traceability can solve the previously indicated problems (European Commission, 2021; Castañeda and Fejo, 2023; Chiaraluce *et al*., 2024). This innovation allows consumers, farmers, supply chain operators and public authorities to connect directly in real time and to monitor food and information regarding its life cycle process in a public, transparent, and auditable digital register, eliminating the need for third-party certification and avoiding the risk of fraud, counterfeiting and negligent behavior (Tiscini *et al*., 2020).

However, most global consumers remain unaware of the concept of food Blockchain Traceability System (Blockchain TS hereinafter) and its digital tools for accessing traceability information (FMCG-GURUS, 2020). On the offer side, 58% of agri-food companies worldwide declare marketing and commercial objectives as their main priorities in the adoption of a blockchain Traceability System (TS) (Aparicio-Ruiz *et al*., 2022; Politecnico di Milano, 2023). Only two surveys of European olive oil producers and operators have revealed different results regarding the adoption of innovative TS and related objectives (Guido *et al*., 2020; Corallo *et al*., 2020). Effective communication is crucial to addressing global information asymmetry and promoting blockchain traceability in the olive oil sector (Muñiz-Gonzáles and Muñiz de la Torre, 2018). This helps to convey the blockchain's unique value to consumers, thereby improving their understanding, acceptance, and purchasing decisions (Cozzio *et al*., 2023).

In the context of blockchain communication, the website is an essential tool to consider. Websites play a crucial role in bridging the information gap between organizations and consumers, particularly in the context of emerging technologies (Chaffey and Ellis-Chadwick, 2019). By serving as centralized platforms for information, they enable organizations to control the narrative surrounding their technologies, ensuring that accurate and relevant information reaches potential users (Kumar and Reinartz, 2016; Shahid *et al*., 2020). This controlled environment is especially important for technologies that require consumer trust and understanding, such as artificial intelligence and blockchain (Zarbà *et al*., 2024). Focusing on communication through websites allows for a nuanced analysis of how organizations strategically position themselves in relation to these innovations, providing valuable insights into their marketing approaches and priorities (Kingsnorth, 2022). This multifaceted perspective underscores the importance of website analysis in understanding the dynamics of communication surrounding blockchain in the agri-food sector, offering essential insights for fostering adoption and trust in these technologies (Ferreira da Silva and Moro, 2021).

In this study we have focused the blockchain communication on websites of agri-food organizations to consumers due to the current lack of literature (WOS and Scopus, 2016-2024) and fragmented and scarce communication on different web channels (FB, YouTube, Instagram, TikTok and others) (Ancín *et al*., 2022). Sec-

ondly, most of the agri-food organizations market their products as traced through blockchain on the e-commerce webpage as on a traditional retail channel (Zen *et al*., 2017). In this dimension the website page can help the consumers to understand how to use blockchain tools (QR code, batch code, applications, etc.) and explain to them the value of blockchain traceability adoption, supporting the differentiation marketing strategy to promote and sell these foods whatever the sale channel is (Borsellino *et al*., 2018; Violino *et al*., 2019; Reitano *et al*., 2024). To address this gap, our study explores the following questions: Which profile variables and key business factors of olive oil organizations influence their website communication regarding blockchain traceability systems? To answer this, we first consolidated the communication attributes from the existing literature and then applied fuzzy set qualitative comparative analysis (fsQCA) to organizations identified as using this technology. Consequently, this study identifies the profiles of olive oil organizations to understand whether blockchain technology (TS) is adopted solely to reduce costs in the supply chain and agri-food processes, or whether it is also used to gain a competitive advantage in the consumer market with appropriate strategies (e.g. to trace by blockchain TS organic Extra Virgin Olive Oil (EVOO hereinafter) or premium – PDO – olive oils).

This research is particularly relevant in today's market, where transparency and traceability are essential to building consumer trust (Dionysis *et al*., 2022). By identifying the profile variables and key business factors that influence website communication, we provide insights that can help organizations tailor their messaging in order to better engage consumers. Additionally, this study offers a framework of blockchain TS attributes for evaluating the effectiveness of communication strategies, which is crucial for companies looking to differentiate themselves in a competitive agri-food landscape. Ultimately, our findings contribute to the broader discourse on how digital communication can enhance the adoption of innovative technologies in the sector.

The remainder of this paper is organized as follows. After the introduction, we present the contextual framework, detailing the propositions of the study. The material and methods section outlines the technical aspects of our research. Subsequently, we present the results and conclude the study with a discussion of the findings and their limitations.

2. Theoretical background

2.1. *Agri-food traceability concept and challenges*

The concept of agri-food traceability encompasses the ability to record and control five key historical dimensions: identifying the animal, agricultural, or food product and its corresponding owner; ensuring safety at each stage of the process to prevent contamination or disease risks for both the population and animals; guaranteeing product quality for stable business relations; and preventing adulteration, fraud, and theft (Martínez, 2022). Technically, the identification of a unit method known as the Traceable Resource Unit (TRU) (Moe, 1998) has been extensively discussed in the literature to elucidate the traceability concept, involving three factors: the object of measurement and a mechanism for identifying, documenting, and recording agricultural food attributes. In the olive oil sector, EU traceability regulations and much of the international legislation are grounded in policies and standards established by the International Olive Council (IOC).

Currently, agri-food traceability presents a significant global challenge, particularly in sectors such as olive oil, meat, fish, and wine, because these foods are the most unsafe and counterfeited in the global supply chains with a significant % of uncertainty and not declared origin (Yan *et al*., 2020). To prevent these concerns there are a wide range of agri-food certification authorities from public regulations (e.g., PDO - Protect Designation of Origin or PGI -Protect Geographical Indication of European Union, EC Reg. 510/2006), private bodies (e.g., ISO), and other international food council bodies (e.g., IOC for olive oils), and others. This poses various questions within global agri-food supply chains, including compatibility issues with standards and

legal requirements, data inconsistency, trustworthiness concerns, security vulnerabilities, diminished effectiveness, interoperability, scalability issues, and increased certification costs (Hassoun *et al*., 2020; KPMG, 2022).

Consequently, public authorities have difficulty controlling the food origin, safety, and quality traceability from different countries (von Ruth *et al*., 2018; Rocchi *et al*., 2020). On the other hand, the limitations placed on labelling by current regulations limit consumers' ability to verify the authenticity of food information provided by external intermediaries or central authorities using traditional third-party certification systems, reducing food risk perception (Montecchi *et al*., 2019). To maintain transparency information and trust through the value chain operators, consumers and central certification authorities the adoption of blockchain technology for agri-food traceability can resolve these issues by enabling tracking of the origin, its history in transformation and logistic processes, ensuring the quality of food product (Yele *et al*., 2024).

2.2. *Blockchain traceability system in the agri-food sector*

Blockchain responds to visionary research and human aspirations to communicate and conduct transactions without intermediaries and central authorities (Tang *et al*., 2019).

Technically, blockchain is a technology composed of both digital and physical components, serving as an open-source dataset or a digital, shared, distributed, and decentralized network of ledger systems (blocks) (Ben Ayed *et al*., 2022; Gligor *et al.*, 2022). It facilitates various transactions, including assets, money, intellectual property, contracts and data management (Clohessy and Acton, 2019). Developed to tackle historical algorithmic challenges in digital environments, blockchain operates within peer-to-peer web-based systems, enabling the real-time recording and verification of each transaction. This system maintains an immutable and reliable database without relying on central authority (Dujak and Sajter, 2019). Every participant in the network bears the responsibility of disseminating accurate information (Chen *et al*., 2018).

Because of the attributes of blockchain, including transparency, data integrity, and immutability, coupled with the absence of central controls or intermediaries, this technology was initially proposed for integration into the agri-food supply chain in 2016 (Demestichas *et al*., 2020; Tessitore *et al*., 2021; Politecnico di Milano, 2023). Blockchain technology applied to agri-food sector, by a new traceability certification system, can revolutionize and contribute to solving and contrasting the problems of fraud and adulteration, misconduct in the production and distribution processes, and recalls for damaged stocks that negatively influence the operators of the supply chain and customers´ trust and their relationship with the product (Sestino *et al*., 2022; Martínez-Castañeda and Fejioo, 2023; Chiaraluce *et al*., 2024). Consumers who buy food products with this traceability certification will know that they are not only consuming a product that complies with food safety and quality regulations, but that the farmers and mills are operating with good farming and production practices in line with the SDGs (Sgroi, 2022). Consequently, this innovation responds to society's considerable interest in obtaining more transparent traceability information, reducing the perception of food risk (Montecchi *et al*., 2019) and encouraging a new customer relationship (Rainero and Modarelli, 2021) in order to reassure consumers and protect them from possible counterfeits and fraud (Bandinelli *et al*., 2023).

One of the key topics associated with blockchain TS is its potential to promote sustainability (Friedman and Ormiston, 2022). In particular, the growing demand for organic products has highlighted the need for more transparent and reliable systems that ensure the authenticity of these products. In a globalized market, where organic products are sold on a large scale, consumers require assurances that what they are purchasing truly meets the environmental and health standards that define such products (Sahoo *et al*., 2024). In this context, blockchain technology emerges as a crucial tool for ensuring traceability and compliance with the standards established by organic certifications

On the other hand, blockchain TS provides a significant boost to Protected Designations of Origin (PDOs), which serve as a certification

mechanism ensuring that certain products originate from a specific geographic region and adhere to traditional production methods characteristic of that area (Scuderi *et al*., 2019; Vasileiou *et al*., 2024). This type of certification is commonly associated with food products and holds immense value for both producers and consumers, as it is closely linked to cultural identity and product quality. Blockchain offers an innovative solution to enhance consumer confidence by guaranteeing the authenticity and provenance of these products (Tran *et al*., 2024).

Furthermore, a considerable increase in food and agricultural products including traceability is expected in the coming years, as stated by all public and private international sources (FAO, OECD and others). In the supply chain, in the agri-food industry, blockchain traceability applications are providing new models for improvement and automation (Kramer *et al*., 2021). This allows easy and direct identification and generation of the certificate of origin of organic foodstuffs in international maritime transports and all stages of processing and distribution (Bettin-Díaz *et al*., 2018) In this line, some studies point out how traceability can increase the intrinsic value of the product (quality and profitability), establishing a new relationship of trust with the consumer (Lezoche *et al*., 2020; Boschi *et al*., 2021; Yadav *et al*., 2022). For these reasons blockchain TS redefines the trust paradigms into operators of agri-food supply chain and in consumer markets developing new business models (Galanakis *et al*., 2021).

Presently, eighty-five percent of the existing blockchain platforms are deployed for traceability solutions, with 40% dedicated to the agri-food sector (KPMG, 2022). According to the data of the WOS platform, approximately 2,673 studies on blockchain traceability systems applied to the agri-food sector have been published between 2015 and 2024. Computer technology and various supply chain applications have been the most researched topics, comprising 65% of all studies, owing to the versatility of blockchain traceability systems with different configurations (Köhler and Pizzol, 2020). This keen interest stems from researchers, companies, and organizations seeking novel alternatives and opportunities offered by blockchain TS across various agri-food sectors.

As the costs of management control, information systems, waste, and food recalls continue to increase, compliance with regulations and standards for traditional agri-food traceability has become increasingly complex throughout the supply chain (Bumblauskas *et al*., 2020). Consequently, agri-food and olive oil companies seek to minimize intermediary costs and certifications by transitioning to a new business model based on trust relationships (Zhang, 2023). Blockchain traceability systems have gained traction in the agri-food supply chain owing to their ability to provide full transparency in food products and processes, reduce information asymmetry (Sestino *et al*., 2022) and ensuring data privacy and safety for operators and consumers (Ghose, 2009), as well as facilitating regulatory oversight (Martínez-Castañeda and Fejioo, 2023).

2.3. *Blockchain traceability system in the olive oil sector*

As stated by WOS and Scopus data, there are only 20 publications on olive oil blockchain traceability, with a broader range of 231 studies in related areas. Most studies on the olive oil sector have focused on technical aspects (Marchesi *et al*., 2021; Bistarelli *et al*., 2022) and in the supply chain management (Caro *et al*., 2018; Guido *et al*., 2020; Fricka *et al*., 2023) with limited research exploring marketing dimensions (Bonetti *et al*., 2023; Treiblmaier and Petrozhitskaya, 2023).

In general terms, the blockchain traceability certification system applied to the olive oil sector allows the following advantages: 1) It disseminates good practices in the cultivation and extraction processes of EVOO by identifying technical quality standards, and consequently of the product (Stranieri *et al*., 2021); 2) It favors environmental sustainability and the circular economy, with good practices that respect and preserve the environment (Dal Mas *et al*., 2023); 3) It achieves cost savings throughout the value chain by reducing areas of risk and inefficiency (Caro *et al*., 2018); 4) It qualifies the differential value of indigenous EVOO, premium and organic pro-

duction, with fair and appropriate trade (Elfkih *et al*., 2021; Chiaraluce *et al*., 2024); 5) It favors the adhesion of distribution agents in the platform, who also benefit compared to large supermarkets (Antonucci *et al*., 2019; Shahid *et al*., 2020).

From a market perspective, blockchain TS can contribute to building loyalty among current consumers and conquers new consumer groups: 'Millennials', organic, online shoppers, and others (Bonetti *et al*., 2023). In this context, the blockchain has developed as a changeover value in the existing social, economic and governance models, (Zutshi *et al*., 2021) as well as in the sustainability area (Dal Mas *et al*., 2022), moving from the traditional controlled value-chain orientation to a network orientation based on participation, interaction and a trusting relationship with customers (Sahut *et al*., 2019).

Considering that olive groves are one of the most important plantations throughout the EU and in other emerging countries, the correct implementation of an adequate traceability system in the olive oil field that respects the environment contributes to soil sustainability and to counteracting greenhouse gases and optimizing the water regime (Tripoli *et al*., 2018; Ben Ayed *et al*., 2022). It is an aligned green forest that if properly cared for would lead to the conservation of biodiversity at soil and landscape scale. In addition, research has shown that olive groves act as a sink for CO2, one of the main greenhouse gases (Kamilaris *et al*., 2019; Lezoche *et al*., 2020).

3. Propositions

There is a lack of studies on the communication and marketing of blockchain traceability websites in the olive oil and agri-food sectors. The scarcity of studies in these areas also concerns olive oils and foods traced by traditional third-party certifications (Rossi, 2017; Mascio *et al*., 2024). These studies confirm the relevance of European PDOs and PGIs olive oil certification against frauds and safety concerns and a favorable consumers purchase orientation. However, there are some interesting points that can be applied to this emerging technology in olive oil website communication. Websites are among the most common online references for brands and image companies and are among one of the first contact channels for consumers and Internet users (Garaus *et al*., 2022). This medium allows a strong online position to be achieved by combining the informative, community, relational, and transactional functions associated with social media and e-commerce (Galati *et al*., 2016).

In the olive oil sector with traditional third-party certification, only a low percentage of online organizations exploited the opportunities offered by Web 2.0 (Fransi *et al*., 2020; Fernandez-Uclés *et al*., 2023). These website functions facilitate purchase orientation and the purchase process of olive oil consumers on e-commerce pages (Borsellino *et al*., 2018; Elfkih *et al*., 2021). Considering the consumer interaction, participation, involvement, and brand experience provided by blockchain TS, website communication functions can also develop Strategic Experiential Modules (SEM) for brand-land olive oil (Iaia *et al*., 2018).

However, the literature reveals a limited number of studies analyzing agri-food blockchain topics within the realm of business strategy and communication dimensions for agri-food organizations (Bonetti *et al*., 2023; Treiblmaier and Petrozhitskaya, 2023). Using a configurational approach (Fiss, 2011), we aim to identify the combinations of organizational characteristics related to blockchain traceability systems associated with increased information dissemination on an organization's website.

A quality website helps reinforce consumer trust (De Vries *et al*., 2022) and transfers the perceived value of a product to the market (Muñiz-Gonzales and Muñiz De La Torre, 2018; Landeta-Echeberría, 2021). According to Resources and Capabilities Theory (Barney and Mackey, 2005), intangible resources such as having a website with useful and abundant information can lead to a competitive advantage. A successful commercial strategy in the online channel is to be present on different platforms with a close relationship with the consumer; this is known as inbound marketing (Patrutiu-Baltes, 2016). Having a website reinforced by social networks, chats, blogs, or other types of platforms facilitates information and communication with consumers, and increases trust (Zeng

et al., 2017). Companies with a stronger focus on online channels tend to offer more information through these platforms, which enhances their relationships with consumers and fosters customer loyalty (Fernández-Uclés *et al*., 2023)

Similarly, agri-food companies operating online are expected to provide a significant amount of information, as digital platforms reduce transaction costs and consumers increasingly rely on this information to make informed purchasing decisions (Caiazza and Bigliardi, 2020). According to Kaplan and Haenlein (2010), as organizations expand their presence across diverse digital platforms, they create more opportunities to share not only product-related information but also details about emerging technologies. In this context, organizations with a stronger online presence are expected to offer more comprehensive communication about both their products and technological innovations, including advancements in blockchain. Based on this, the following proposition can be made:

Proposition 1. *Organizations with a more prominent presence across diverse online platforms are expected to provide greater communication about blockchain (TS).*

Although digital technologies have increased tools for improving their commercial position in the market, company size remains a relevant attribute associated with greater performance and impact in this medium (Kiang and Chi, 2001). There is a clear consensus that small companies benefit from operating in an online environment, but large organizations still have a greater capacity for investment, both human and technological, to strengthen their positioning on the internet (Wang, 2020; Fernández-Uclés *et al*., 2023). However, in the agri-food sector, small organizations are increasingly active in providing transparency and data, and larger companies have more possibilities and lower costs for managing the collection, processing, and communication of information (Bernal-Jurado *et al*., 2018). With this in mind, we make the following assertions:

Proposition 2. *Increased communication on blockchain TS is linked to the size of the company*

Technological development positively influences the competitive, differential, advantageous, and structural aspects of the sector in which it operates. Consequently, the communication and marketing areas in the adoption of innovative technology are central to the market strategy of organizations, especially in a digitization context (Kotler *et al*., 2016), which produces strong digital interaction with consumers and society (Marlene, 2019). Consistent with Hobbs *et al*. (2005), consumers show a strong interest in food traceability when the perceived transferred added value is associated with this communication content (Rainero and Modarelli, 2021). Communication in blockchain technology can also contribute to solving information asymmetry with consumers through QR or batch codes on food packaging or olive oil labeling (Mohammed *et al*., 2023). This information is provided to consumers to improve their trust, perceptions of quality, and purchase intentions (Liu *et al*., 2022; Treiblmaier and Garaus, 2022). This makes it necessary to implement blockchain TS, because key strategic communications and information commitments on digital platforms are relevant (Huijbregts-Jaén, 2021). However, it is expected that, in this process of technological integration, as this innovation develops the communication and information provided by the company to the consumer will be strengthened. Thus, we propose the following hypothesis:

Proposition 3. *Further communication on blockchain TS is determined by the degree of technological development within a company.*

Consumers of organic products need more information to purchase this type of product, partly because of a lack of knowledge about its characteristics and compensation for its higher price (Marozzo *et al*., 2023). Vega-Zamora *et al*. (2016) demonstrates that consumers have more positive attitudes and purchase intentions toward organic olive oil in the presence of adequate communication. In the case of olive oil, with cheaper substitute products, its marketing benefits from online communication, which opens doors to international markets and provides a greater amount of information about the

company, products, and production (Carzedda *et al*., 2021). Thus, organizations offer organic products that present a greater amount of information on digital platforms (Fernández-Uclés *et al*., 2020). The above arguments lead us to propose the following hypothesis:

Proposition 4. *The increased communication about blockchain TS is explained by the offer of organic products to the company.*

As with the organic attribute, the Protected Designation of Origin (PDO) has been widely used in the agri-food sector as a differentiation strategy, adding value to certified products by highlighting their quality and authenticity (Lajara *et al*., 2022). This label influences consumer satisfaction, loyalty, and purchase intentions, underscoring the importance of effectively communicating these attributes through digital channels (Violino *et al*., 2019). Proper communication of information about PDO products strengthens companies' reputations and builds consumer trust, making digital communication a key tool for commercial success (Scuderi *et al*., 2019). In this context, particularly for products with a PDO, where there is an expectation for greater transparency and detailed information about product traceability (Fotopoulos and Krystallis, 2003), the communication regarding blockchain is expected to be more extensive.

Proposition 5. *Increased communication on blockchain is associated with the presence of products with a designation of origin.*

4. Material and methods

4.1. *Population*

We compiled a comprehensive list of international olive oil companies that have developed blockchain traceability technology, or are in the process of doing so, identifying a total of 38 companies. This figure aligns with data from prominent Blockchain Distributed Ledger Technology Working Groups, including those in Italy, which hold particular significance in the olive sector. Table 1 captures the information from these companies.

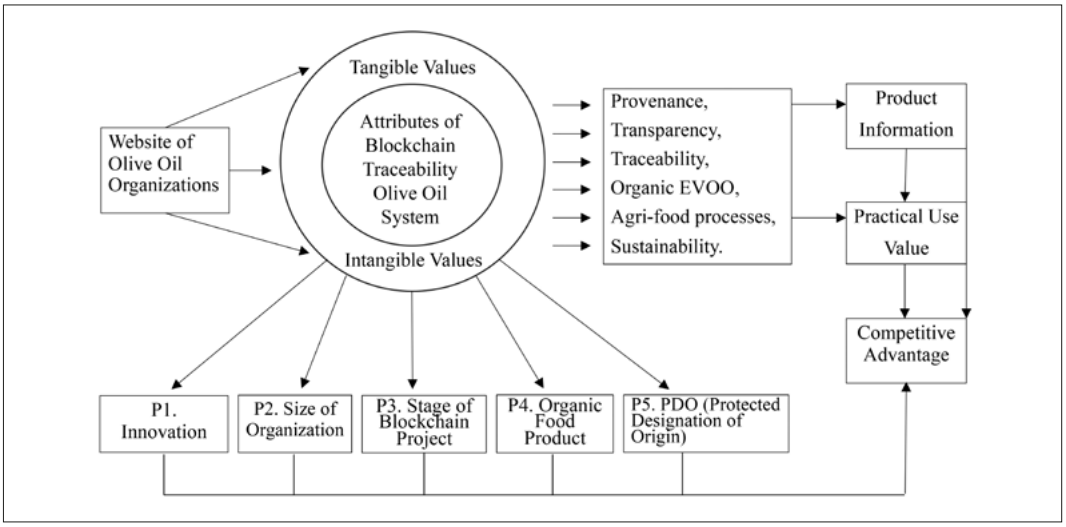
The data were gathered through an exhaustive review of the information available on leading Internet search engines, such as Google, reports from esteemed university centers, digital blockchain observatories (e.g., Politecnico di Milano, University of Federico II of Napoli, and Wageningen University), and scientific and popular articles in the specialized press dedicated to innovation and olive oil. Upon reviewing the liter-

Table 1 - Descriptive statistics of the olive oil organizations analyzed.

Profile of olive oil organizations	*Italy*	*Spain*	*E.U.*	*Non E.U.*
Country of origin	25	8	33	5
Other private certifications	19	7	26	4
Social media blockchain TS communication	24	9	33	5
Olive oils sold through e-commerce	2	1	3	2
Sustainability	10	3	13	2
Integration by other digital technologies 4.0.	7	2	9	2
Company profile: private	24	4	28	5
Company profile: cooperative	0	2	2	0
Company profile: consortium	1	2	3	0
Producer	20	6	26	2
Distributor	4	0	4	3
Consortium, European P.D.O. (Protected Designation of Origin) and G.I. (Geographical Indication) bodies	1	2	3	0

Source: own compilation.

Figure 1 - Blockchain traceability attributes framework.



Source: own compilation.

ature on the agri-food and olive oil sectors, we identified several attributes of blockchain TS I, along with their respective justifications (references and concepts). Figure 1 synthesizes information from the research study by referencing initial propositions.

4.2. *Method*

Qualitative comparative analysis (QCA), based on Boolean algebra, uses verbal, conceptual, and mathematical language to make it a simultaneously qualitative and quantitative approach, combining the main advantages of both (Ragin, 2014). Specifically, QCA allows a systematic analysis of a set of cases in order to determine causal patterns between a set of conditions and a given outcome in the form of necessity and sufficiency relationships (Schneider and Wagemann, 2010). Unlike conventional (symmetric) statistical approaches such as multiple regression and structural equation modeling, QCA has greater explanatory power and can be used on its own to provide rich insights into the relationships of interest (Gligor and Bozkurt, 2020). This is because QCA assumes that asymmetry, equifinality, and causal complexity may exist, mitigating some of the limitations of multiple regressions (Ragin, 2006).

QCA is a highly objective technique for deriving predictive conclusions, assuming the application of the complexity theory to scientific research (Kumar *et al*., 2022). QCA provides one or more antecedent combinations sufficient for the attainment of a particular outcome, such as X1*–X2*X3, which is sufficient for an outcome (Y). Using the symbology of this technique (X1*~X2*X3→Y) and X1, X2 and X3 are antecedents; Y, the result; * is the union, and ~ is the absence or negation, in this case the opposite value to X2 (1- X2).

The development of fuzzy sets (fsQCA) is one of the most widely used QCA variants, because it resolves one of the main drawbacks and criticisms of the initial csQCA approach, its strictly dichotomous approach (Sehring *et al*., 2013). It is a valid and reliable method that has the advantage of being developed for small samples or population settings, unlike other traditional quantitative methods (Pappas and Woodside, 2021), (Rihoux and Ragin, 2008).

4.3. *Outcome and conditions*

The outcome of this research represents the amount of information that organizations provide about the traceability of products linked to blockchain and traceability. Reviewing the liter-

Table 2 - Variables used in the fsQCA.

Outcome	*Description*	*Type of variable*
Blockchain TS communicated	Number of attributes reported in the digital environment linked to blockchain TS.	Continuous
Antecedents	Description	Type of variable
Innov	Digital platforms on which the company operates	Categorical*
Size	Company size according to EU Legislation	Categorical**
Stage of Project	Level of development of blockchain TS	Categorical***
Organic olive oil	The company markets organic products	Dichotomous****
PDO	The company offers products with designation of origin	Dichotomous****

Notes: Continuous variables were calibrated using fsQCA 4.1 software, according to the recommended thresholds. Although the literature recommends avoiding automatic calibration, it is most appropriate when there are no previous references to the variable (Pappas and Woodside, 2021).
** Categorical variable with four levels according to the number of digital platforms on which the company operates (website, blog, social media and mobile app).*
*** Categorical variable with four levels according to the size of the organization: micro, small, medium and large enterprises. Calibrated from Rihoux and Ragin, (2008).*
**** Categorical variable with three levels according to the status of development of the blockchain dlt technology (Companies that have announced the implementation of this technology, companies that are currently developing it and companies that have this traceability system already running).*
***** Dichotomous variables indicate the presence of the condition with a value of 1 and 0 its absence.*
Source: own compilation.

ature, we identified several blockchain attributes of olive oil on the different digital platforms of the companies analyzed. This outcome measures the amount of traceability information linked to traceability attributes and values according to the corresponding literature and to the laws of food safety, quality, and origin requirements valued by the consumer. The main value attributes cited in the literature are transparency and consumer trust (Reieb *et al*., 2020; Rana *et al*., 2021), safety, origin authentication, quality, sustainability and supply chain efficiency (Thompson and Rust, 2023).

Five conditions have been established that allow us to delimit the profile of an organization that performs more complete communication about attributes by integrating blockchain traceability into the olive sector. Table 2 lists all the variables considered in this study.

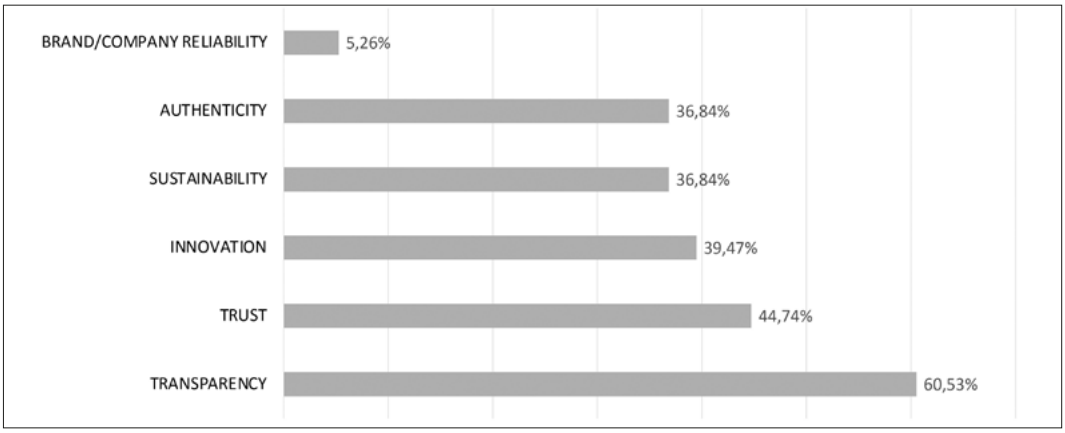
5. Results

In an initial approach to the study's results, the averages of the values and attributes communicated on the websites of the companies analyzed are presented (Figure 2). These attributes, serving as the foundation for the study's outcomes, indicate that the current total quantity of website communication, provided by 81.8% of olive organizations, falls short of encompassing even 50% of the blockchain TS attributes.

Regarding fsQCA, necessity tests were performed in which the necessary conditions were detected if they exceeded the consistency threshold of 0.9 (Pappas and Woodside, 2021). Simultaneously, we conducted the same analysis for non-occurrence of the detected phenomenon. It should be noted that the fsQCA technique is not symmetrical, and it is convenient to study which combinations (or configurations) of factors lead to a low level of reported information. An assessment of the triviality of conditions was also conducted using the Relevance of Necessity (RoN) indicator (Schneider and Wagemann, 2010). The literature advises checking for RoN values below 0.5, because they are the cause of concern. In none of the cases was the consistency equal to or above the recommended limit of 0.9, and no coverage was too low (<0.5) (Ragin, 2006) (Table 3).

The next part of the study required the use of fsQCA software 4.1. The truth table is calculated by considering these variables. The main findings of this analysis are presented in Table 4, which shows the various combinations that lead

Figure 2 - The most communicated attributes of blockchain TS.



Source: own compilation.

Table 3 - Analysis of necessary conditions.

	Blockchain communicated		*~ blockchain communicated*		*RoN*
	Consistency	*Coverage*	*Consistency*	*Coverage*	
Innov	0.7390	0.5935	0.7006	0.7475	0,6816
~innov	0.6857	0.6329	0.6190	0.7591	
Size	0.6183	0.7387	0.2454	0.3895	0,8381
~size	0.4890	0.3279	0.8353	0.7440	
Progress	0.6863	0.5333	0.4871	0.5029	0,6333
~progress	0.3603	0.3459	0.5480	0.6988	
Eco	0.6134	0.5561	0.3685	0.4439	0,7145
~eco	0.3866	0.3155	0.6315	0.6845	
Pdo	0.3977	0.4056	0.4387	0.5944	0,6982
~Pdo	0.6023	0.4468	0.5613	0.5532	

Source: own compilation.

Table 4 - Analysis of sufficiency results.

Configurations	*1*	*2*	*3*	*4*	*5*
Innov	●		⊗	⊗	⊗
Size		•	●	●	●
Progress	●	•	•		•
Eco	●	•		⊗	⊗
Pdo		⊗	⊗	⊗	
Raw coverage	0.3879	0.2022	0.1942	0.1795	0.1127
Unique coverage	0.2469	0.0196	0.0000	0.1078	0.0411
Consistency	0.9738	0.8616	0.9031	0.8772	0.9154
Model coverage	0.6697				
Model consistency	0.9093				

Source: own compilation.

to greater communication regarding traceability of a company's products. Specifically, four solutions were identified and presented in order from highest to lowest gross coverage. Using the usual terminology in this type of study, black circles (●) denote the presence of a condition, while crossed-out circles (⊗) indicate its absence. A blank indicates that the condition is irrelevant. The distinction between central and peripheral conditions is denoted by large and small circles, respectively (Fiss, 2011). The following table includes the set-theoretic consistency values for each configuration and the overall model solution.

The results show that, considering the proposed variables, different combinations lead to a greater amount of information on the traceability of the products offered by the company. Table II includes the set-theoretic consistency values for each configuration, as well as the global solution of the model. The global solution exceeds the recommended threshold of 0.80 (Pappas and Woodside, 2021). The global model obtained from this analysis reflected a total coverage of 0.6697. Thus, in 66.97% of the olive oil organizations analyzed, this set of causal configurations explains the amount of information. The core conditions of the model obtained are two: innov*progress*eco and size*~innov. The first configuration, with a gross coverage of 0.3879, establishes that the combination of innovation, state of progress, and offering organic products explains 38.79% of the cases with a greater amount of information. The corresponding consistency shows that 97.38% of the cases presented results of interest.

6. Discussion

Analyzing the communication of blockchain TS attributes in the olive oil sector, this study tries to identify the profile of olive oil organizations that adopt this certification technology and to understand the key drivers that move the business strategy. To achieve this objective, we have focused on the website communication channel for the following reasons: expands two foundations of the value of blockchain traceability transparency: visibility and disclosure (Duan *et al*., 2017; Köhler and Pizzol, 2020); explains to consumers how to use blockchain labelling tools (QR or batch code) to obtain a value information about the olive oil food product and processes (Violino *et al*., 2019; Liu *et al*., 2022); helps consumers to develop their decision-making abilities, engagement, and physical product experience (Iaia *et al*., 2018); build a direct trust-customer relationship with an olive oil brand company improving a competitive advantage (Singh and Sharma, 2022; Bonetti *et al*., 2023). Moreover, this blockchain TS attributes communication analysis allows us to understand if the adoption of this traceability technology is only a cost-saving on processes objective in their supply chain (Zheng *et al*., 2023) or hides an effective market strategy responding to global consumers' concerns about sustainability, trust and health (Dal Mas *et al*., 2022; Treiblmaier and Garaus, 2023; Giganti *et al*., 2024). Regarding the profile of olive oil organizations that trace their food products by blockchain TS we have found the following dimensions and corresponding strategies.

The size of the company influences the level of blockchain TS communication on the websites of olive oil organizations. Companies with larger dimensions can absorb rising communication costs because their operational and organizational structures can communicate more on the websites to thus achieve commercial and marketing objectives focused on consumers (Caiazza *et al*., 2020; Sgroi, 2022). This relevance has been confirmed in other traditional traceability certification systems used in the olive oil sector (Fernández-Uclés *et al*., 2023). Through the digital communication of blockchain technology the biggest companies of olive oil sector can develop a corporate and territorial competitiveness allowing a greater efficiency in management of agri-food supply chain (Antonucci *et al*., 2019; Zhao *et al*., 2019).

The blockchain technology project progress status at the announcement, ongoing development, and operation stages in the adoption of agri-food blockchain TS are also related to the level of blockchain TS communication on the websites of olive oil organizations. On the other hand, olive oil organizations that have completed the blockchain TS project are more sensitive

to communicate their results into a Corporate Social Responsibility (CSR) website content (Rainero and Modarelli, 2021) and to a consumer values and attributes when differentiating their brands and products traced by this technology to achieve a competitive advantage (Gazzola *et al*., 2023).

Organic olive oil is another relevant variable that impacts blockchain TS website communication and plays a significant role in the business strategy of olive oil sector. Producers of organic olive oil are highly oriented toward using Internet channels to promote and sell their products, maximize their economic performance, and obtain positive interest, acceptance, and purchase orientation from consumers (Carzedda *et al*., 2021; Pérez-Pérez and Gracia, 2023). This study confirms that olive oil organizations, especially those from Italy and Spain, trace their organic olive oils by blockchain TS adding an additional certification value to their premium olive oil productions (EVOO and or PDO) The corresponding website communication content aims to achieve the following business objectives: to reinforce the value labelling information of a previously organic traceability certification from European Union (Polenzani *et al*., 2020; van Hilten *et al*., 2020); to assure more familiarity with blockchain TS labelling tools (QR and batch code) and its usefulness to consumers (Georgescu *et al*., 2022); increasing a willingness to pay a premium price offering an extensive range of information about quality, safety and origin of organic olive oils because consumers of organic olive oil need more information than consumers of conventional olive oil products and need to be assured of the higher price of organic olive oils (Borsellino *et al*., 2019; Fernández-Uclés *et al*., 2020; Brusset *et al*., 2024). Organic olive oil communication is also associated with the social environmental sustainability concern. Consumers show a favorable purchase intention for olive oil organizations that certify their sustainability in the cultivating and mill processes by blockchain TS (Violino *et al*., 2019; Fernandes *et al*., 2022; Zhang, 2023).

Even if PDO and PGI offer to the agri-food and olive oil organizations a distinctive protection of origin, quality and practices of local production methods in the global supply chain trade on meet repeated cases of fraudulent activities that can damage the reliability of these entities and sectors (Scuderi *et al*., 2019; Vasileiou *et al*., 2024). In our study we have observed that several organizations that trace olive oil (especially the organic EVOO) via blockchain TSs are PDO and PGI entities, and this variable greatly influences the level of website communication because it has a positive impact on the consumer preferences (Violino *et al*., 2019; Contini *et al*., 2023). Consequently, this communication reinforces the value that PDO and GI olive oil offer to consumers: additional certification through blockchain regarding origin, safety, quality, and process compliance (Aparicio-Ruiz *et al*., 2022). Blockchain TS communication could be also a further asset for small-to-middle-size local organizations that belong to PDO and PGI olive oils entities in the consumer market, increasing company reliability to achieve a differential competitive advantage (Sanjuán-Lopez and Resano-Ezcaray, 2020).

7. Conclusions

The aim of this study has been to conduct an exploratory investigation of olive oil organizations that have implemented the new 4.0 digital blockchain traceability system (TS) and evaluate its impact on online communication using this innovative technology. This study addresses a gap in the literature and contributes to the consolidation of knowledge concerning blockchain within organizational profiles and communication attributes in the olive oil sector. Specifically, it investigates how the profile variables of olive oil organizations influence blockchain TS communication, and examines how and to what extent olive oil organizations communicate the values and benefits of blockchain on their websites. This analysis has aimed to determine the corresponding correlations and key business factors that impact the consumer market.

The results of this study reveal that communication of olive oils traced through blockchain TS is not perceived as a priority in olive oil organizations, contradicting their declarations, where the commercial objective was the main goal

in the adoption of blockchain technology. Our findings identify two different profiles of olive oil organizations: those with a larger dimension and those with an advanced blockchain TS project. These organizations are present on several digital platforms selling organic olive oils, and belong to a PDO organization that enforces the authenticity of the origin and quality of olive oil with a focus on sustainability. To be effective, the blockchain TS communication of organic olive oil should consider and be aligned with different consumer profiles in different countries and continents, such as "organic seekers," expanding web content to other groups, such as "organic indifferent," "quality and origin lovers," and "local consumers."

The organic food strategy in olive oil profile organizations is a key factor in explaining the adoption of blockchain as a strategy product and agri-food production process. This evidence indicates a clear strategic choice by olive oil companies to coherently develop this market channel with sustainability trends and consumers' expectations in order to achieve a competitive advantage.

However, current website content communication remains inadequate for mitigating the information asymmetry in the olive oil market traced by blockchain. The lack of clear and concise information explaining blockchain concepts and tools to consumers and online users impedes their perception and acceptance of this innovation, thereby limiting their purchase intentions and sustained usage. This communication gap hinders consumer awareness and familiarity with the newly-labeled blockchain TS tools. Additionally, the absence of differentiation, both visually and in content, as well as in price and sustainability attributes, between olive oils traced by blockchain TS and those traced by other certification systems sold via e-commerce channels, may negate the potential competitive advantages generated by blockchain TS adoption, particularly for premium olive oil categories.

Furthermore, our study highlights that this communication gap extends to professional clients and supply chain operators, potentially impacting olive oil-producing countries and organizations focused on bulk production, such as Spain and other emerging countries, where business clients represent a significant market value in global trade.

7.1. *Practical implications*

This study offers a complementary and enriching perspective for interpreting data from agri-food organizations that adopt blockchain traceability systems. Specifically, website communication about blockchain traceability systems (TS) for olive oil organizations can be extended in three dimensions:

First, supply chain operators can mitigate information asymmetry in global trade.

Second, transparency is a key factor in developing consumer trust.

Finally, a social dimension aligned with the Principles of Digital Development promoted by international entities (e.g., UNICEF, FAO, WHO, and the World Bank) and foundations (e.g., the Bill and Melinda Gates Foundation) can be integrated, contributing to the development of a local sustainability production, better farmer inclusion, shared values, health disease prevention, and development goals. For these reasons, some governments have invested extensively in agri-food blockchains as consumers are increasingly concerned about their health and product quality.

This study also addresses the management of olive oil organizations to support their website communication strategies in the blockchain TS area. These findings provide valuable information for managers emphasizing blockchain adoption to enhance consumer issues and requirements and help them establish a competitive advantage. Our work encourages organizations to align their blockchain agri-food traceability objectives with their communication strategies, especially for the European Protected Designation of Origin (PDO) and Geographical Indication (GI) or consortium associations in other countries.

From a business perspective, the study's findings highlight the strategic role that effective blockchain communication can play in helping agri-food operators differentiate their products within both the supply chain and the broader

market. Clear communication about blockchain traceability can mitigate information asymmetry, a persistent issue in food markets, particularly for products prone to fraud, such as olive oil. Ultimately, the study provides a valuable framework for agri-food businesses to assess the effectiveness of their communication strategies. This solution will also enable the use of key performance indicators (KPIs) in commercial, marketing, and digital web metrics to benchmark other olive oil categories.

The results of this study underscore its usefulness and need for significant investments in IT technical areas, organizational processes in the supply chain, and consumer communication. The framework of values and attributes identified in this study can be used to implement the information that the blockchain distributed ledger technology (DLT) platform needs to trace in the cultivation and mill production processes, integrating machinery and sensors.

7.2. *Limitations and future directions*

Although our findings address this study's research question, certain limitations should be acknowledged. First, the blockchain traceability system examined is specific to the olive oil sector rather than the entire agri-food sector. Due the difficulty of accessing the entire agri-food blockchain data, the focus was on analyzing the olive oil sector for its economic significance in several emerging countries, its recognized value food impact on health and nutrition for consumers, and the sustainable productions offering ecological premium olive oils coherently to the market trends and society concerns. Second, the study sample is confined to the offer side, analyzing the profiles of olive oil organizations rather than consumer behavior in order to understand the objectives and strategies behind the adoption of blockchain traceability systems.

As an exploratory study, our results were derived from a literature review and data compiled from various sources. This was necessitated by the lack of a pre-existing common model to serve as a guideline for this nascent research area. These limitations highlight areas for future research, particularly the need to examine consumer behavior to better understand market interactions in blockchain-based agri-food traceability.

Future research should include an analysis of the organizational profiles and website communication indices of agri-food organizations that have adopted blockchain technology. This finding can be used to compare the impacts and relationships between the supply and market sides. Further studies should develop and test comprehensive models in order to facilitate a holistic understanding of blockchain adoption in the agri-food sector.

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