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Sustainability from Farm to Cup: Consumer Perspectives on the Adoption of Blockchain Technology in the Coffee Supply Chain

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Department of Marketing, Strategy and Operations

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Resumo

Palavras-chave: *Blockchain*, cadeia de abastecimento, rastreabilidade, transparência, sustentabilidade, café

A indústria do café enfrenta desafios significativos de sustentabilidade que têm impacto em aspectos ambientais, sociais e económicos da sua cadeia de abastecimento. Este estudo explora essas preocupações e investiga o potencial da tecnologia *blockchain* como solução sob a perspetiva do consumidor.

Com a crescente consciencialização dos consumidores sobre fornecimento ético, impacto ambiental e práticas de comércio justo, a necessidade para a existência de transparência na indústria do café tem aumentado. A tecnologia *blockchain*, com a sua capacidade de fornecer rastreabilidade e segurança na partilha de dados, apresenta-se como uma ferramenta promissora para melhorar a sustentabilidade da cadeia de abastecimento.

Este estudo combina uma revisão da literatura sobre as preocupações com a sustentabilidade e as funcionalidades da tecnologia *blockchain*, com um inquérito aos consumidores para avaliar as suas perspetivas em relação à adoção desta tecnologia. O inquérito capta as atitudes dos consumidores em relação aos problemas existentes na cadeia de abastecimento do café e ao uso da tecnologia *blockchain*, destacando o seu potencial para melhorar a sustentabilidade, a rastreabilidade e a transparência ao longo da cadeia de abastecimento, enquanto aprimora a autenticidade e qualidade do café.

Os resultados indicam que, embora o conhecimento sobre a tecnologia *blockchain* ser relativamente baixo, os consumidores demonstram uma forte disposição para aderir a soluções baseadas nesta tecnologia. Além disso, o uso da tecnologia *blockchain* pode contribuir para fortalecer a confiança dos consumidores e alinhar a indústria do café com os Objetivos de Desenvolvimento Sustentável (ODS) das Nações Unidas.

JEL Códigos: Q01, O33

Abstract

Keywords: Blockchain, supply chain, traceability, transparency, sustainability, coffee

The coffee industry faces significant sustainability challenges that impact environmental, social, and economic aspects of its supply chain. This study explores these concerns and investigates the potential of blockchain technology as a solution from a consumer perspective.

With increasing consumer awareness of ethical sourcing, environmental impact, and fair trade practices, the demand for transparency in the coffee industry has grown. Blockchain technology, with its ability to provide traceability and secure data sharing, presents a promising tool to improve sustainability within the supply chain.

This research combines a comprehensive literature review on sustainability concerns and blockchain functionalities with a consumer survey to assess perspectives towards blockchain adoption. The survey captures consumer attitudes toward the concerns present in the coffee supply chain and the adoption of blockchain technology, highlighting its potential to improve sustainability, traceability and transparency, while also enhancing the authenticity and quality of coffee products.

The findings suggest that although knowledge of blockchain is relatively low, consumers demonstrate a strong willingness to adopt blockchain-based solutions. Furthermore, the use of blockchain can contribute to strengthening consumer trust and aligning the coffee industry with the United Nations' Sustainable Development Goals (SDGs).

JEL Codes: Q01, O33

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List of Abbreviations

DLT – Distributed Ledger Technology

PoW – Proof-of-Work

PoS – Proof-of-Stake

IoT – Internet of Things

RFID – Radio Frequency Identification

GPS – Global Positioning System

QR Code – Quick Response Code

UN – United Nations

SDGs – Sustainable Development Goals

1. Introduction

1.1. Research Problem

Coffee continues to thrive as one of the most consumed beverages worldwide, with global revenue reaching US\$468.2 billion in 2024 and projected annual growth of 4.37% through 2028 (Statista, 2024). A notable trend in the coffee market is the growing demand for unique and high-quality coffee experiences, alongside an increasing awareness of sustainability concerns and ethical sourcing practices in the coffee supply chain.

Despite the industry's growth, sustainability issues persist throughout the coffee supply chain, affecting various stakeholders differently. For coffee farmers, challenges include unstable incomes, poor working conditions, and exposure to child labour. These issues compromise their ability to sustain their livelihoods and invest in environmentally friendly practices. For retailers and consumers, there is an increasing demand for transparency regarding the origins and production methods of their coffee, driven by concerns over ethical sourcing and sustainability. Furthermore, the coffee supply chain's complexity, characterized by numerous stakeholders and varied data recording practices, limits collaboration and efficient communication. This lack of coordination leads to inefficiencies and missed opportunities for improving the overall system.

In response to these challenges, the integration of blockchain technology emerges as a promising solution. Blockchain can enhance transparency by providing a tamper-proof record of transactions and movements throughout the supply chain. This enables more accurate tracking of coffee from farm to cup, ensuring that sustainability claims can be verified and that ethical sourcing practices are adhered to. For farmers, blockchain can offer direct access to global markets and fairer pricing, reducing intermediaries and ensuring better returns. For retailers and consumers, it offers a transparent view of the supply chain, helping them make informed purchasing decisions aligned with their values. Moreover, blockchain can streamline data management and improve collaboration among stakeholders by creating a unified, transparent ledger that all parties can access. This can lead to more efficient operations, reduced fraud, and a better ability to address sustainability concerns across the supply chain.

This research will focus specifically on consumer perspectives regarding the adoption of blockchain technology in the coffee supply chain. By examining how consumers perceive the benefits and potential drawbacks of blockchain integration, this study aims to provide valuable insights into the viability of blockchain as a tool for enhancing sustainability and ethical practices in the coffee industry.

1.2. Research Questions

The research is guided by the following question designed to address the research problem:

- What is the consumer perspective on sustainability concerns in coffee supply chain, and their acceptance of blockchain technology to address these concerns?

1.3. Research Objectives

This work is expected to collect information regarding the sustainability concerns in the coffee supply chain processes and the blockchain technology functionalities through the study of existent literature to identify the benefits and challenges of implementing blockchain technology in the coffee supply chain.

Furthermore, it is also intended to investigate the factors that influence consumer acceptance for adopting blockchain technology in the coffee supply chain. Thus, a survey was conducted to collect the consumers' perspective about the research topic. Until the end of the dissertation, it is expected to identify trends and patterns in consumer perception and acceptance of blockchain technology in the coffee supply chain.

1.4. Research Approach

Research Question	What is the consumer perspective on sustainability concerns in coffee supply chain, and their acceptance of blockchain technology to address these concerns?	
Literature Review	Identify sustainability concerns in the coffee supply chain from existing research academic papers, industry reports, and sustainability assessments	Explore how blockchain technology can enhance sustainability, traceability, transparency, authenticity, and quality throughout the journey from farm to cup
Consumer Survey	Design a consumer survey to assess perception, awareness and acceptance of blockchain technology in the context of the coffee supply chain	Include questions on factors influencing acceptance, such as perceived benefits, trust in this technology, and willingness to pay a premium for blockchain-verified products
Data Analysis	Analyze survey data using descriptive and inferential statistics to identify trends and patterns in consumer perception and acceptance	

1.5. Relevance of the Topic

The integration of blockchain technology in the coffee supply chain is a highly relevant and timely research topic for several reasons. Firstly, there is an increasing awareness among consumers regarding the ethical and environmental implications of their purchasing decisions. This heightened awareness has led to a growing demand for sustainability and transparency in the products they consume, particularly in the coffee industry, where such concerns are becoming more pronounced.

Additionally, the rapid advancement of blockchain technology presents a unique opportunity to address longstanding challenges in the supply chain, such as traceability, fraud prevention, and data management. The implementation of blockchain can lead to more efficient and reliable systems that benefit all stakeholders involved, enhancing the overall functionality of the supply chain.

Moreover, the findings from this research can guide companies from the coffee industry in promoting more sustainable and ethical supply chain operations. This aligns with global sustainability goals and corporate social responsibility initiatives, reinforcing the relevance of this research.

1.6. Dissertation Structure

This dissertation comprises several sections: Section 1 introduces the research problem, followed by the formulation of research questions and research objectives; Section 2 provides a literature review on the implementation of blockchain technology within the coffee supply chain; Section 3 outlines the methodology employed in the research; Section 4 presents the results obtained and Section 5 draws conclusions based on the research outcomes.

2. Literature Review

2.1. Sustainability Concerns Encountered in the Coffee Supply Chain

The coffee supply chain is a complex network involving various stakeholders responsible for delivering the coffee from farm to cup. These stakeholders include farmers, processors, manufacturers, regulatory agencies, markets/retailers/cafes, and end consumers.

- 1. Farmers are responsible for cultivating and maintaining coffee plantations, while employing the best practices to ensure the quality of the coffee beans produced.
- 2. Processors handle the drying, roasting, and grinding of the green coffee beans into the final product to meet specific requirements.
- 3. Manufacturers are involved in scaling up the production and packaging of the coffee products for distribution.
- 4. Regulatory agencies oversee the certification of the coffee products, ensuring compliance with quality standards and fairtrade regulations.
- 5. Markets/Retailers/Cafes serve as the points of sale for coffee products, where these are bought and sold to consumers.
- 6. End Consumers are the individuals that ultimately enjoy coffee products and are responsible to make informed purchasing decisions.

In the long journey of coffee from farm to cup, several concerns are encountered in the supply chain that compromise the environmental, social, and economic sustainability of the coffee industry. The sustainability concerns found in the coffee supply chain are presented in Table 2.1.

Table 2.1. Sustainability concerns in the coffee supply chain.

Environmental concerns	▪ Deforestation: Expansion of coffee cultivation contributes to deforestation, particularly in tropical regions, leading to habitat loss and biodiversity depletion (IDH, 2020; Pendrill et al., 2019). In Peru, coffee production is estimated to contribute to
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approximately 25% of deforestation (Panhuysen & Pierrot, 2020). Similarly, in Uganda, it is reported that since 1990, around 55% of natural forests have been converted into agricultural land, which correlates with 50% expansion in coffee cultivation during this period (Bunn et al., 2019).

- Biodiversity loss: The shift from shade-grown coffee to sun-grown monocultures leads to both deforestation and biodiversity loss (Perfecto et al., 2005; Takahashi & Todo, 2017), impacting tree species, birds, and arthropods (Anil Kumar et al., 2019; Philpott et al., 2008).
- Climate Change Impact: Coffee cultivation is sensitive to climate change, leading to increased prevalence of diseases and pests (Sachs et al., 2019). Additionally, natural disasters like hurricanes, heavy rains, and droughts disrupt harvests, reduce yields, and impact coffee quality, leading to income losses for farmers (ICO, 2021a; International Trade Centre, 2021; Samper & Quiñones-Ruiz, 2017). Furthermore, heightened reliance on pesticides and fertilizers to combat these challenges contributes to soil and water degradation (Capa et al., 2015).
- Water Consumption: High water usage in coffee processing leads to wastewater generation, impacting water resources and ecosystems (Janissen & Huynh, 2018; Rattan et al., 2015). Also, the coffee industry has a significant water footprint, as it is estimated that producing a 125mL cup of coffee requires approximately 140L of water (Hoekstra, 2008).
- Carbon Emissions: The entire coffee chain is estimated to have a total carbon footprint of 4.82 kg CO₂ emissions per kilogram of green coffee (Killian et al., 2013).
- Waste Production: The coffee industry produces substantial waste, including byproducts from processing and packaging, such as the materials used in single-use coffee capsules. Additionally, the consumption of coffee in capsules requires the use of a capsule-based coffee machine, contributing to increased energy consumption (Brommer et al., 2011; Killian et al., 2013).

Social concerns

- **Poverty and Labor Conditions:** Coffee farmers often face poverty due to low and volatile incomes, leading to issues like seasonal hunger and limited access to healthcare and education (Sachs et al., 2019). It is estimated that around 50 to 100 million coffee farmworkers are living below the extreme poverty line (Browning & Moayyad, 2017).
- **Child Labor:** The prevalence of child labor in coffee-producing regions poses ethical and social challenges, depriving children of education and exposing them to hazardous working conditions (Panhuysen & Pierrot, 2020; Sachs et al., 2019).
- **Gender Inequality:** Female coffee farmers face unequal access to land and resources, limiting their empowerment and contribution to the coffee industry (ICO, 2018a; Yeo, 2020).

Economic concerns

- **Price Volatility:** Fluctuating coffee prices affect the livelihoods of farmers, leading to financial instability (Clay et al., 2018).
 - **Market Power Imbalance:** Limited participation of producers in value chain governance leads to unequal power dynamics, where influential actors control policies to maximize their benefits (Clay et al., 2018).
-

Each stakeholder in the coffee supply chain plays a crucial role in upholding environmental, social, and economic sustainability. For that, the 17 Sustainable Development Goals (SDGs) adopted by the United Nations encompass these interconnected foundations of sustainability to provide guidance for implementing sustainable strategies and practices in this supply chain.

Unfortunately, many of the SDGs, such as SDG 1 (No poverty), SDG 2 (Zero hunger), SDG 3 (Good health and well-being), SDG 4 (Quality education), SDG 5 (Gender equality), SDG 6 (Clean water and sanitation), and SDG 8 (Decent work and economic growth) have not been fully achieved in the coffee production sector (Peixoto et al., 2022). To address this, attention must be directed towards SDG 9 (Industry, innovation, and infrastructure), SDG 10 (Reduced inequalities), SDG 11 (Sustainable cities and communities), SDG 12 (Responsible consumption and production), SDG 13 (Climate action), SDG 14 (Life below

water), and SDG 15 (Life on land) to achieve sustainability within the coffee trade (Peixoto et al., 2022).

Therefore, effective collaboration and coordination among stakeholders are essential for optimizing operations in the coffee industry while addressing social, economic, and environmental challenges to achieve the UN SDGs (Marcus et al., 2022). Consequently, efforts to achieve sustainability must be integrated into all supply chain processes, and blockchain technology is increasingly seen as a viable solution for guaranteeing transparency and traceability throughout the entire coffee supply chain.

2.2. Core Concepts and Applications of Blockchain Technology

In 2009, blockchain technology was introduced in a whitepaper by the mysterious Satoshi Nakamoto. This technology, often referred to as distributed ledger technology (DLT) (Freni et al., 2022), facilitates the secure connection of data blocks within a decentralized network through encryption.

At its core, blockchain technology incorporates several key features (Nakamoto, 2009). Firstly, data is stored within blocks linked together in a chain. Each block contains a cryptographic hash, which is computed based on the data it contains and serves as a unique identifier. Even a small change in the data results in a completely different hash. This hash is stored not only in the current block but also in the subsequent block. Therefore, by storing the hash of the previous block in the current block, any alteration in the previous block would be immediately detected, ensuring data integrity. Additionally, consensus mechanisms such as proof-of-work (PoW) or proof-of-stake (PoS) are employed to validate and add new blocks to the chain. Moreover, blockchain networks may incorporate smart contracts, which are self-executing contracts with predefined conditions. These contracts automatically facilitate transactions when specific criteria are met, thereby streamlining processes, and enhancing efficiency within the blockchain ecosystem. These fundamental features give rise to the distinctive characteristics of blockchain, including immutability, resistance to tampering, traceability, cryptographic security, and decentralization (Wang et al., 2021). The data input in blockchain technology can vary widely, encompassing financial information, product characteristics, and multimedia content such as text, numbers, and pictures.

The attributes mentioned above collectively contribute to the robustness and reliability of blockchain networks, leading to its application across diverse sectors and industries. In finance, it streamlines cross-border payments and trade finance, reducing costs and mitigating fraud. Supply chain management benefits from its ability to track goods transparently, ensuring authenticity and ethical practices. In healthcare, it secures patient records and enables telemedicine. Governments use it for identity management and voting systems. Additionally, it enhances digital identity security and privacy in authentication processes and online transactions. These applications showcase blockchain's potential to revolutionize industries.

Blockchain technology is already making significant strides in coffee supply chains, with various multinational coffee companies embracing its potential. Farmer Connect, in collaboration with several industry leaders, has developed the "Thank My Farmer" app, built on IBM's blockchain infrastructure (IBM, 2020). This innovative platform aims to bridge the gap between coffee farmers and consumers by offering traceability and transparency throughout the supply chain. Consumers can track and trace their coffee, learn about the stakeholders involved, explore sustainability projects near or on the coffee farms, and even support these initiatives through in-app donations. Similarly, Starbucks has partnered with Microsoft on their 'Bean to Cup' project, which leverages blockchain technology to enhance traceability and showcase coffee producers. By implementing blockchain, Starbucks aims to empower consumers with detailed information about the journey of their coffee, from farm to cup (Starbucks, 2018; Microsoft, 2019). These projects underscore blockchain's potential to revolutionize supply chain management, providing stakeholders with valuable insights into sustainability impacts and outcomes.

2.3. Blockchain Technology Applied in the Coffee Supply Chain

Government regulations have compelled various sectors and industries to adopt traceability systems, including the food industry (Hader et al., 2022). Similar conditions apply to coffee enterprises, where traceability serves to enhance sustainability and transparency regarding processes throughout the supply chain, thereby empowering stakeholders with insights into every detail of the coffee's journey from farm to cup. Ensuring traceability is also imperative

for safeguarding product authenticity and quality throughout the supply chain (Tan & Ngan, 2020).

Blockchain technology offers the potential for fast and comprehensive traceability, allowing stakeholders to track the movement of coffee products by providing pertinent information such as origin, components, and journey through the supply chain (Lu & Xu, 2017). The implementation of blockchain technology in the coffee supply chain introduces a heightened level of transparency throughout business networks, enabling companies to seamlessly connect, transact, and collaborate with all their trading partners in real-time where the information is systematically recorded on the blockchain at each stage of the process (Alamsyah et al., 2023). The acquisition of traceability data is facilitated through business transactions and IoT-enabled devices like Radio Frequency Identification (RFID) (Feng et al., 2020).

When implementing blockchain, stakeholders within the supply chain are assigned specific roles, either allowing them to both write and read data or solely read information. The workflow for recording data among stakeholders' roles is as follows:

1. Farm data: farm name, farm address, GPS coordinates, types of coffee beans (species, variety), plantation data: seedling, age, batch, growth details and fertilization, harvesting data, other transaction details.
2. Processor data: farm address, processor name, batch, coffee bean grade, roasting method, other transaction details.
3. Manufacture data: manufacture name, manufacture address, process details, processing batch, coffee bean grades, volumes, production code.
4. Certification data: production code, certification number, manufacture name and location, date issued, coffee bean grades, certification agency name.
5. Market/Retailer/Cafe data: production code, certification number, market/retailer/café name and location, supply date, processing data, purchase order number including transaction details.
6. Consumer: tracing coffee process by scanning the QR code.

In 2023, Alamsyah et al. developed a model aimed at registering these records, intending to transform the business processes of the coffee supply chain into a blockchain-compatible workflow, as shown in Figure 2.1. Furthermore, they developed an application to facilitate participation from each stakeholder within the supply chain, allowing them to contribute to data collection and monitor the status of individual coffee batches. The prototype of this application was successfully implemented and assessed within the Indonesian coffee industry, with the potential to ensure fair pricing for farmers and provide quality assurance to end-consumers.

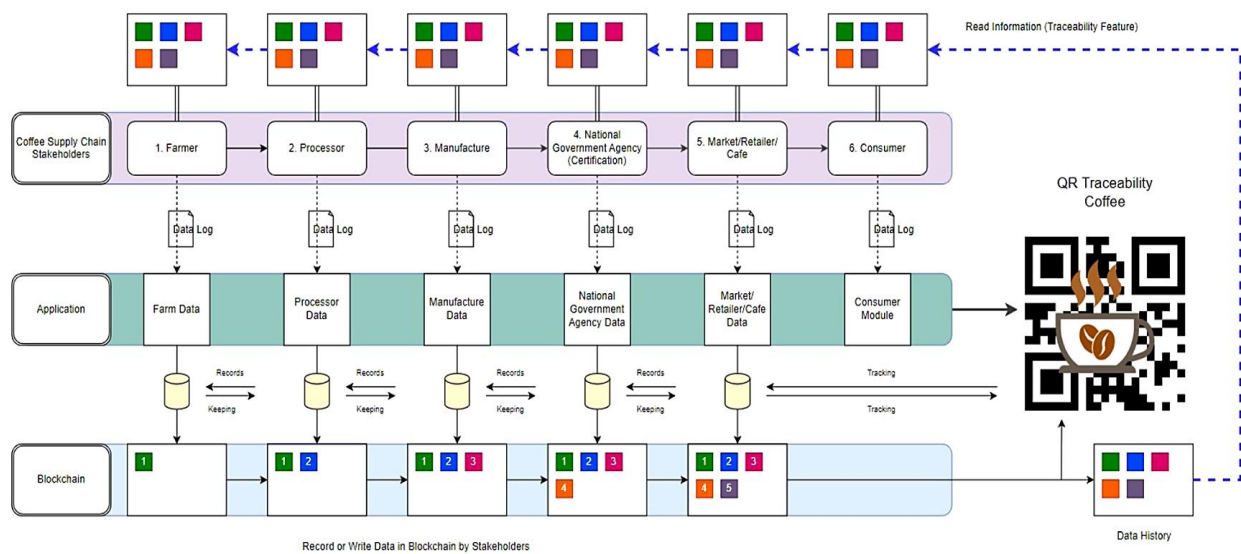


Figure 2.1. The coffee traceability design implemented in Indonesia by Alamsyah et al., 2023.

Nevertheless, while traceability is crucial for sustainability efforts, it is not sufficient on its own. To truly improve sustainability in coffee supply chains, stakeholders also need access to information about sustainability impacts and outcomes (Thakur et al., 2020). Table 2.2. below summarizes the linkages between sustainability challenges in coffee supply chain and the attributes of blockchain technology to deliver benefits across the supply chain management.

Table 2.2. Possibilities for blockchain technology to address sustainability challenges in the coffee supply chain.

Challenge	Possibilities of blockchain technology to address these challenges
Traceability and transparency	Blockchain enables the creation of an immutable and transparent ledger, allowing every participant in the supply chain to record and verify transactions (Kshetri, 2018). This transparency ensures that the entire journey of coffee beans, from farms to consumers, can be tracked in real-time, providing details about the origin, quality, certifications, and handling processes (FAO & IUT, 2019; Francisco & Swanson, 2018; IFAD, 2019).
Fair trade and ethical sourcing	Blockchain can facilitate the verification of fair-trade practices and ethical sourcing by tracking and confirming certifications (e.g., Fairtrade, Rainforest Alliance) attached to coffee beans (Kouhizadeh & Sarkis, 2018). It helps in ensuring that farmers are fairly compensated and that ethical standards are met throughout the supply chain (Saber et al., 2019).
Authenticity and quality assurance	Information about the quality and characteristics of coffee beans can be recorded at various stages (Tripoli & Schmidhuber, 2018). Smart contracts in blockchain can automatically execute actions or payments based on predefined conditions, such as the compliance of quality standards, ensuring consistent quality.
Reducing fraud and counterfeiting	Immutable records on blockchain prevent tampering or alteration of data, reducing the risks of counterfeit products entering the supply chain (Casado-Vara et al., 2018). Consumers and stakeholders can verify the authenticity and legitimacy of coffee products easily.
Efficient supply chain management	Blockchain's decentralized nature streamlines documentation and reduces paperwork. It facilitates smoother transactions, faster settlements, and minimizes errors in record-keeping across the supply chain, leading to cost savings and increased operational efficiency (Wang et al., 2021).

However, challenges associated with the implementation of the blockchain technology in the supply chain remain (Mohammed et al., 2017), including the cost of implementation (Li et al, 2021; Wang et al., 2019), interoperability between different systems (Liu et al., 2020; Nurgazina et al, 2021), and ensuring the participation and adoption of the technology by all stakeholders involved in the supply chain (Chang et al., 2020; Helo & Hao, 2019).

Despite these challenges, the integration of blockchain technology in the coffee supply chain holds significant promise in promoting sustainability from farm to cup. Furthermore, implementing blockchain in the coffee supply chain contributes to SDGs 8, 9, 10, and 12, which respectively focus on decent work and economic growth; industry, innovation, and infrastructure; reduced inequalities; and responsible consumption and production (Voshmgir et al., 2019; Aysan et al., 2021; de Villiers et al., 2021; Parmentola et al., 2022).

3. Methodology

3.1. Research Context

This research adopts a mixed-method methodology to address the research problem and objectives, so it combines both qualitative and quantitative approaches. The research encompasses a literature review about the research topic, and a survey to consumers to gather diverse perspectives into the adoption of blockchain technology in the coffee supply chain.

For this research, a comprehensive review of existing literature on this topic was conducted through an inspection of articles found in academic journals available on Scopus (<https://www.scopus.com/>) and Web of Science (<http://www.webofknowledge.com/>) as represented in Figure 3.1. To identify the most relevant literature for this research, recent articles were selected based on the following keywords: blockchain, supply chain, sustainability, traceability, coffee, and food. The search filters were restricted to articles published in English within journals holding a Q1 ranking, and since the earliest article pertinent to this research traces back to 2017 and remains recent, this date was taken as the starting point until the day of the search (January 31, 2024) on the selected online platforms.

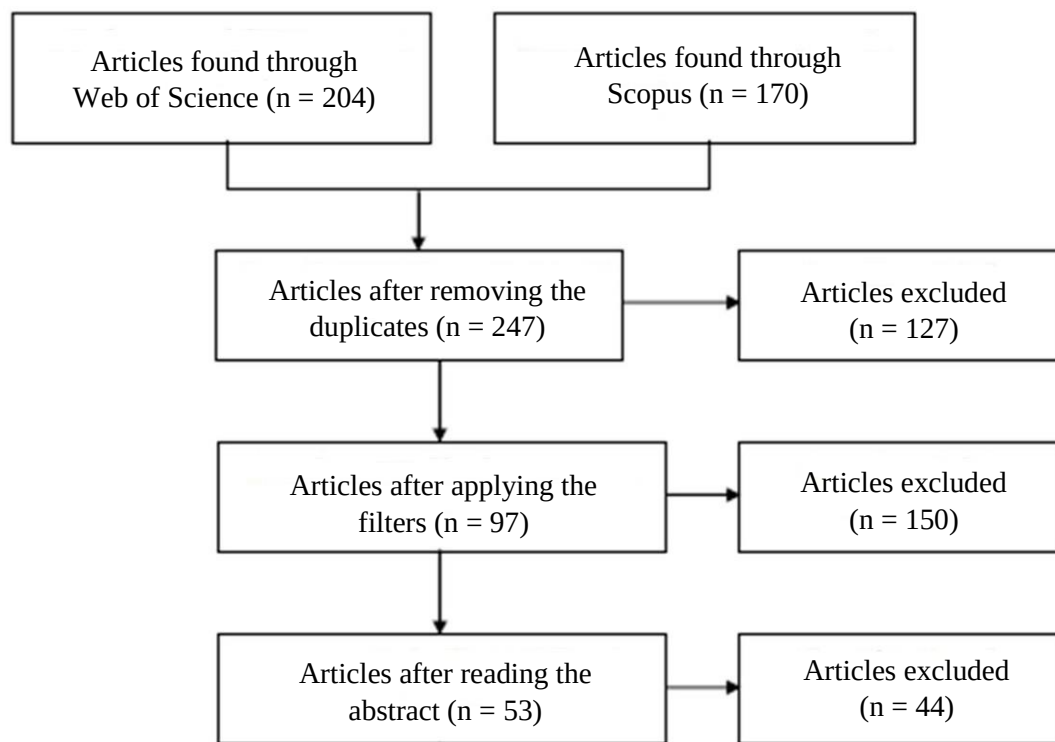


Figure 3.1. Article selection process by systematic literature review.

3.2. Research Design

The consumer survey will assess consumer perceptions regarding the implementation of blockchain technology in the coffee supply chain. A carefully crafted questionnaire will be distributed to a diverse sample of coffee consumers, encompassing various demographics and consumption patterns. The survey will gather data on consumers' awareness of blockchain technology and their concerns towards sustainability, traceability, transparency, authenticity, and quality in the coffee supply chain, as well as their willingness to use blockchain technology and whether it would enhance their trust in the coffee industry. Additionally, it will explore consumers' willingness to pay for blockchain-traced coffee products and recommend it to others. Through comprehensive analysis of the survey responses, the research aims to provide insights into consumer concerns that can inform the potential adoption of blockchain technology in the coffee industry.

Survey questions:

1. What is your age group?
(less than 18, 18-20, 21-25, 26-30, 31-35, 36-40, 41-45, 46-50, 51 and above)
2. What is your sex? (male, female, prefer not to say)
3. Where do you live in Portugal? (north, center, south, island, abroad)
4. How would you describe the environment where you live? (urban, suburban, rural)
5. What is your current occupation? (student, worker, student worker, unemployed, retired)
6. How would you rate your level of proficiency with technology (phone use)?
(1. very low, 2. low, 3. average, 4. high, 5. very high)
7. How many cups of coffee do you drink in a day? (rarely, 1, 2, 3, 4 or more)
8. Where do you consume your cup of coffee?
(at home, at office, at university, at coffee shop, at restaurant, at gas station, other)
9. How important is it for you to know the origin of the coffee beans you consume?
(1. very unimportant, 2. unimportant, 3. neutral, 4. important, 5. very important)
10. How concerned are you about the sustainability in the coffee supply chain?
(1. very unconcerned, 2. unconcerned, 3. neutral, 4. concerned, 5. very concerned)
11. How concerned are you about the traceability in the coffee supply chain?
(1. very unconcerned, 2. unconcerned, 3. neutral, 4. concerned, 5. very concerned)

12. How concerned are you about the transparency in the coffee supply chain?
(1. very unconcerned, 2. unconcerned, 3. neutral, 4. concerned, 5. very concerned)
13. How concerned are you about the authenticity of the coffee?
(1. very unconcerned, 2. unconcerned, 3. neutral, 4. concerned, 5. very concerned)
14. How concerned are you about the quality of the coffee?
(1. very unconcerned, 2. unconcerned, 3. neutral, 4. concerned, 5. very concerned)
15. Have you ever encountered issues related to the authenticity or quality of the coffee you purchased? (yes, no)
16. How often do you consider the environmental and social impact of the products you purchase, including coffee? (1. never, 2. rarely, 3. sometimes, 4. often, 5. always)
17. How likely are you to support initiatives aimed at promoting sustainability in the coffee industry? (1. very unlikely, 2. unlikely, 3. neutral, 4. likely, 5. very likely)
18. Do you know blockchain technology? (yes, no)
19. Blockchain is a technology that enables the recording of all information about a product until it reaches you and then you can access this information on the product packaging by scanning a QR code with your phone. This technology will enhance the sustainability, traceability and transparency of the supply chain while guaranteeing the authenticity and safety of the coffee. Would you use it? (yes, no, not sure)
20. Once the information is registered in the blockchain, it is not easily modified. Would blockchain technology enhance your trust in the coffee industry? (yes, no, not sure)
21. Do you think blockchain technology can help address issues related to fair trade and ethical sourcing in the coffee industry? (yes, no, not sure)
22. In your opinion, what are the key benefits of implementing blockchain technology in the coffee supply chain? (promoting sustainability, enhanced product traceability, improved transparency, ensuring authenticity, ensuring quality, other)
23. In your opinion, which Sustainable Development Goals (SDGs) do you believe blockchain technology will have an impact? (1 to 17, none, not sure)



24. How important is it for you to support environmentally and socially responsible coffee brands? (1. very unimportant, 2. unimportant, 3. neutral, 4. important, 5. very important)
25. Are you willing to pay more for coffee that is traced using blockchain technology? (yes, no, depends on the price increase)
26. How likely are you to recommend blockchain-traced coffee products to your friends and family? (1. very unlikely, 2. unlikely, 3. neutral, 4. likely, 5. very likely)
27. Comments (open-ended)

3.3. Data Collection

The survey was conducted using Google Forms, which provided an efficient and user-friendly platform for data collection. The survey link was shared online through social media platforms, and it was made available in both English and Portuguese languages to accommodate a diverse range of participants. Additionally, ethical considerations including informed consent and data privacy protections were carefully addressed in the survey to ensure transparency and compliance with research standards. The survey started on April 17th and concluded on May 17th, with a total of 72 responses collected during this period.

3.4. Data Analysis

After completing the data collection, a statistical analysis was performed using RStudio software, version 4.1.1. All variables in the survey are categorical, so counts and percentages were used to summarize them. The percentages were calculated using the number of participants with available data as the denominator. In this study, all participants answered all the questions, so the denominator was always the number of participants in the study ($N = 72$). For categorical variables with inherent order (ordinal categorical variables), where of interest, the following summary measures were calculated: mean, standard deviation, median, first quartile, third quartile, minimum, and maximum.

4. Results

To analyze the results of the survey, the responses were broken down into several key categories to explore trends and insights across demographics, lifestyle and habits, attitudes towards the coffee industry and its supply chain, knowledge and attitudes towards blockchain, perceptions of blockchain benefits and impact, and consumer preferences and behavior regarding sustainable initiatives.

The demographic data provides an overview of the participants, highlighting age and sex distribution, and regional representation (Table 4.1). Lifestyle and habits include environmental settings, occupation status, technology proficiency and coffee consumption, shedding light on the context in which the participants live and work (Table 4.2). Attitudes towards the coffee industry are examined through the importance placed on coffee origin, issues with coffee authenticity and quality, and concerns related to sustainability, traceability, transparency, authenticity and quality (Table 4.3). The study further investigates the awareness and willingness to adopt blockchain technology, evaluating its perceived benefits and impact on fair trade and ethical sourcing within the coffee industry to enhance trust in the sector (Table 4.4). Additionally, consumer preferences and behaviors are assessed, focusing on their consideration of environmental and social impacts when making purchases, their support for sustainable initiatives, their willingness to pay more for blockchain-traced coffee and recommend it to others (Table 4.5).

4.1. Consumer Demographics

- **Age group:** The largest group is 21-25 years (43.1%), followed by those over 50 years (19.4%). There is a relatively even distribution across other age groups.
- **Sex:** The sample is almost evenly split between males (50.0%) and females (48.6%), with a small percentage preferring not to say.
- **Region:** Most participants are from the center of Portugal (69.4%), with fewer from the north (11.1%) and south (18.1%). Only one participant is from abroad (1.4%) and there are no participants from the Portuguese islands.

Table 4.1. Consumer demographics.

Variable	Total (N = 72)
Age group (years), n (%)	
<18	1 (1.4%)
18-20	5 (6.9%)
21-25	31 (43.1%)
26-30	7 (9.7%)
31-35	3 (4.2%)
36-40	2 (2.8%)
41-45	5 (6.9%)
46-50	4 (5.6%)
>50	14 (19.4%)
Sex, n (%)	
Male	36 (50.0%)
Female	35 (48.6%)
Prefer not to say	1 (1.4%)
Region in Portugal, n (%)	
North	8 (11.1%)
Center	50 (69.4%)
South	13 (18.1%)
Island	0
Abroad	1 (1.4%)

4.2. Consumer Lifestyle and Habits

- **Environment:** Most participants live in urban areas (72.2%), with fewer in suburban (23.6%) and rural areas (4.2%).
- **Occupation:** The majority are workers (65.3%), followed by students (20.8%), student workers (11.1%), and a small percentage are unemployed (2.8%).
- **Technology proficiency:** A significant number report very high proficiency (59.7%), with a mean of 4.4, indicating a tech-savvy group.
- **Coffee consumption:** Most drink 1-2 cups per day (55.6%), with consumption primarily at home (88.9%), followed by office (47.2%) and coffee shops (38.9%).

Table 4.2. Consumer lifestyle and habits.

Variable	Total (N = 72)
Environment, n (%)	
Urban	52 (72.2%)
Suburban	17 (23.6%)
Rural	3 (4.2%)
Current occupation, n (%)	
Student	15 (20.8%)
Worker	47 (65.3%)
Student worker	8 (11.1%)
Unemployed	2 (2.8%)
Retired	0
Technology proficiency, n (%)	
1. Very low	1 (1.4%)
2. Low	0
3. Average	11 (15.3%)
4. High	17 (23.6%)
5. Very high	43 (59.7%)
Technology proficiency	
Mean (SD)	4.4 (0.85)
Median (Q1, Q3)	5.0 (4.00, 5.00)
Min, Max	1, 5
Number of coffees per day, n (%)	
Rarely	10 (13.9%)
1	18 (25.0%)
2	22 (30.6%)
3	16 (22.2%)
>4	6 (8.3%)
Local of coffee consumption, n (%) ^a	
Home	64 (88.9%)
Office	34 (47.2%)
University	11 (15.3%)
Coffee shop	28 (38.9%)
Restaurant	22 (30.6%)
Gas station	1 (1.4%)
Other	0

Min: Minimum. Max: Maximum. Q1: First quartile. Q3: Third quartile. SD: Standard deviation.

^a The percentages can sum up more than 100% as it is possible to answer more than one category.

4.3. Consumer Attitudes Towards the Coffee Industry and its Supply Chain

- **Importance of coffee origin:** Responses are mostly neutral (36.1%), with a mean of 2.6, indicating mixed feelings about the importance of coffee origin.
- **Concern for sustainability, traceability and transparency:** While there is some level of concern about sustainability (30.6%), traceability (25.0%), and transparency (38.9%) in the coffee supply chain, a significant portion of respondents remain neutral. The boxplot shows that these concerns have median scores around 3, aligning with the high proportion of neutral responses. The wide interquartile range, extending from approximately 2 to 4 across these concerns, indicates mixed feelings among respondents.
- **Concern for authenticity and quality:** There's a significant level of concern about the authenticity (59.7%) and quality (76.4%) of coffee, with many respondents being either concerned or very concerned. The boxplot reveals higher median of 4 for these concerns, and the narrower interquartile range indicates that most respondents are indeed placing higher importance on this factor, with less variability in responses compared to the other concerns.
- **Encountered issues:** 34.7% reported issues, while 65.3% did not, suggesting that authenticity and quality is a concern for a significant minority.

Table 4.3a. Consumer attitudes towards the coffee industry and its supply chain.

Variable	Total (N = 72)
Importance of coffee origin, n (%)	
Very unimportant	18 (25.0%)
Unimportant	13 (18.1%)
Neutral	26 (36.1%)
Important	13 (18.1%)
Very important	2 (2.8%)
Importance of coffee origin	
Mean (SD)	2.6 (1.14)
Median (Q1, Q3)	3.0 (1.75, 3.00)
Min, Max	1, 5
Any issue with the authenticity / quality of the coffee acquired, n (%)	
Yes	25 (34.7%)
No	47 (65.3%)

Min: Minimum. Max: Maximum. Q1: First quartile. Q3: Third quartile. SD: Standard deviation.

Table 4.3b. Consumer attitudes towards the coffee industry and its supply chain.

Response category	Total (N = 72)				
	Sustainability	Traceability	Transparency	Authenticity	Quality
1. Very unconcerned	14 (19.4%)	17 (23.6%)	10 (13.9%)	6 (8.3%)	4 (5.6%)
2. Unconcerned	10 (13.9%)	8 (11.1%)	5 (6.9%)	7 (9.7%)	7 (9.7%)
3. Neutral	26 (36.1%)	29 (40.3%)	29 (40.3%)	16 (22.2%)	6 (8.3%)
4. Concerned	19 (26.4%)	15 (20.8%)	19 (26.4%)	35 (48.6%)	29 (40.3%)
5. Very concerned	3 (4.2%)	3 (4.2%)	9 (12.5%)	8 (11.1%)	26 (36.1%)
Mean (SD)	2.8 (1.15)	2.7 (1.17)	3.2 (1.17)	3.4 (1.09)	3.9 (1.15)
Median	3.0	3.0	3.0	4.0	4.0
(Q1, Q3)	(2.00, 4.00)	(2.00, 3.25)	(3.00, 4.00)	(3.00, 4.00)	(4.00, 5.00)
Min, Max	1, 5	1, 5	1, 5	1, 5	1, 5

Min: Minimum. Max: Maximum. Q1: First quartile. Q3: Third quartile. SD: Standard deviation.

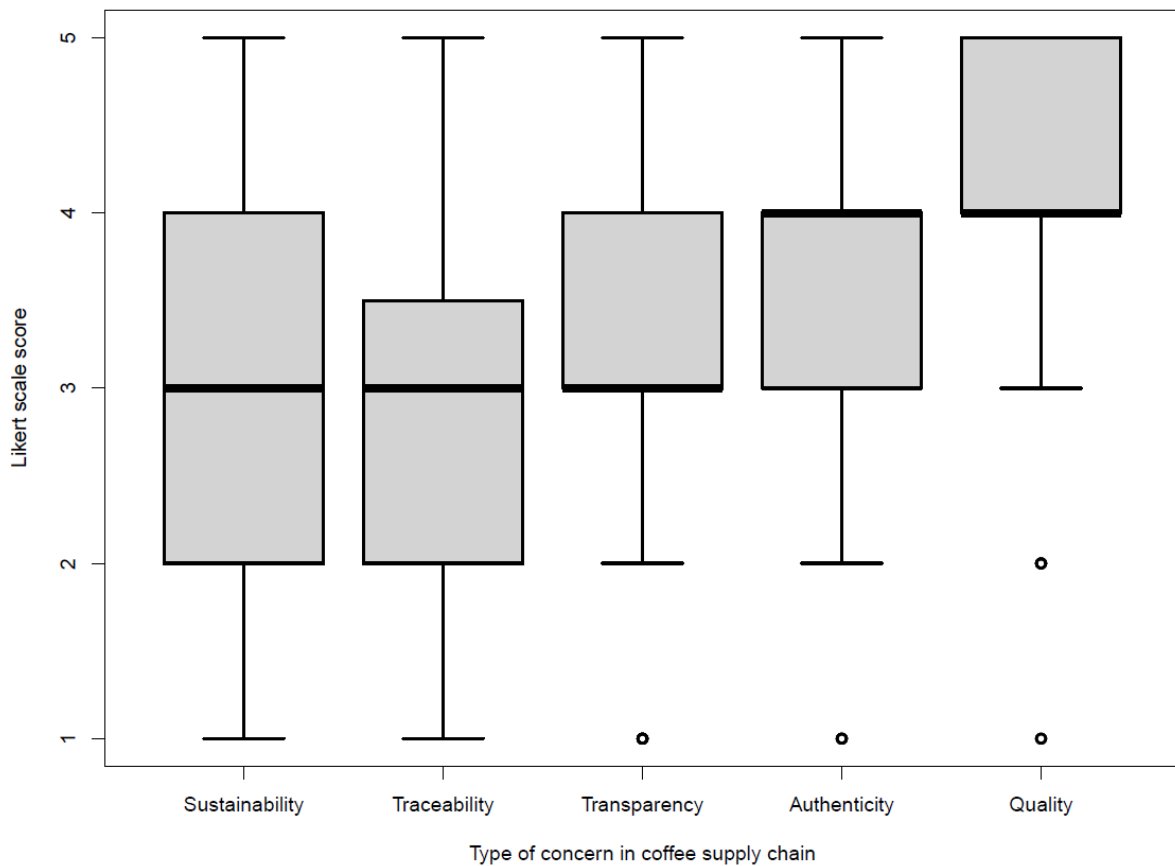


Figure 4.1. Boxplot of types of concerns in the coffee supply chain.

4.4. Consumer Knowledge and Attitudes Towards Blockchain Technology

- **Awareness of blockchain:** Only 34.7% are aware of blockchain technology, suggesting a need for greater education regarding this technology.
- **Willingness to use blockchain:** A large majority (75.0%) of respondents are willing to use blockchain, indicating openness to adopting new technology.
- **Trust in coffee industry with blockchain:** A significant majority (84.7%) believe that blockchain technology would enhance their trust in the coffee industry.
- **Impact of blockchain on fair trade and ethical sourcing:** Most respondents (81.9%) believe that blockchain technology can help address issues related to fair trade and ethical sourcing in the coffee industry.
- **Key benefits:** Respondents see the key benefits of implementing blockchain technology in the coffee supply chain where improved transparency (68.1%), authenticity (58.3%), traceability (54.2%), and sustainability (52.8%) are seen as major benefits.
- **Impact on SDGs:** The participants believe that blockchain technology will have a significant impact on various Sustainable Development Goals, particularly SDG8 (Decent Work and Economic Growth), SDG9 (Industry, Innovation, and Infrastructure), SDG 10 (Reduced Inequalities), and SDG12 (Responsible Consumption and Production).

Table 4.4. Consumer knowledge and attitudes towards blockchain technology.

Variable	Total (N = 72)
Blockchain awareness, n (%)	
Yes	25 (34.7%)
No	47 (65.3%)
Willingness to use blockchain, n (%)	
Yes	54 (75.0%)
No	5 (6.9%)
Don't know	13 (18.1%)
Enhanced trust in coffee industry, n (%)	
Yes	61 (84.7%)
No	5 (6.9%)
Don't know	6 (8.3%)
Impact of blockchain on fair trade and ethical sourcing, n (%)	
Yes	59 (81.9%)
No	3 (4.2%)
Don't know	10 (13.9%)
Key benefits, n (%) ^a	
Promoting sustainability	38 (52.8%)
Enhanced product traceability	39 (54.2%)
Improved transparency	49 (68.1%)
Ensuring authenticity	42 (58.3%)
Ensuring quality	29 (40.3%)
SDGs impact, n (%) ^a	
1 No poverty	14 (19.4%)
2 Zero hunger	4 (5.6%)
3 Good health and well-being	22 (30.6%)
4 Quality education	12 (16.7%)
5 Gender equality	3 (4.2%)
6 Clean water and sanitation	6 (8.3%)
7 Affordable and clean energy	11 (15.3%)
8 Decent work and economic growth	43 (59.7%)
9 Industry, innovation and infrastructure	35 (48.6%)
10 Reduced inequalities	33 (45.8%)
11 Sustainable cities and communities	18 (25.0%)
12 Responsible consumption and production	48 (66.7%)
13 Climate action	22 (30.6%)
14 Life below water	7 (9.7%)
15 Life on land	13 (18.1%)
16 Peace, justice and strong institutions	10 (13.9%)
17 Partnerships for the goals	22 (33.3%)
None	1 (1.4%)
Don't know	5 (6.9%)

Min: Minimum. Max: Maximum. Q1: First quartile. Q3: Third quartile. SD: Standard deviation.

^a The percentages can sum up more than 100% as it is possible to answer more than one category.

4.5. Consumer Preferences and Behavior

- **Consideration for environmental and social impact of the products purchased:**
There is a moderate level of consideration with a mean of 3.1, indicating that while some consider these impacts often, others do not.
- **Likeliness to support sustainable initiatives:** Majority are likely or very likely to support (58.3%), with a mean of 3.4.
- **Importance of supporting responsible coffee brands:** The mean is 3.5, with 59.7% rating it as important or very important to support environmentally and socially responsible coffee brands.
- **Willingness to pay more for blockchain-traced coffee:** 38.9% are willing to pay more, while 37.5% say it depends on the price increase.
- **Likelihood to recommend this technology:** 55.5% are likely or very likely to recommend it to friends and family, with a mean of 3.4.

Table 4.5. Consumer preferences and behavior.

Variable	Total (N = 72)
Consideration for environmental and social impact of the products purchased, n (%)	
1. Never	7 (9.7%)
2. Rarely	12 (16.7%)
3. Sometimes	24 (33.3%)
4. Often	24 (33.3%)
5. Always	5 (6.9%)
Consideration for environmental and social impact of the products purchased	
Mean (SD)	3.1 (1.08)
Median (Q1, Q3)	3.0 (2.00, 4.00)
Min, Max	1, 5
Consumer likeliness to support sustainable initiatives, n (%)	
1. Very unlikely	4 (5.6%)
2. Unlikely	10 (13.9%)
3. Neutral	16 (22.2%)
4. Likely	36 (50.0%)
5. Very likely	6 (8.3%)
Consumer likeliness to support sustainable initiatives	
Mean (SD)	3.4 (1.02)
Median (Q1, Q3)	4.0 (3.00, 4.00)
Min, Max	1, 5

Importance to support environmentally and socially responsible coffee brands, n (%)

1. Very unimportant	6 (8.3%)
2. Unimportant	6 (8.3%)
3. Neutral	17 (23.6%)
4. Important	32 (44.4%)
5. Very important	11 (15.3%)

Importance to support environmentally and socially responsible coffee brands

Mean (SD)	3.5 (1.11)
Median (Q1, Q3)	4.0 (3.00, 4.00)
Min, Max	1, 5

Consumer willingness to pay more for coffee that is traced using blockchain, n (%)

Yes	28 (38.9%)
No	17 (23.6%)
Depends on the price increase	27 (37.5%)

Likelihood to recommend to friends and family, n (%)

1. Very unlikely	4 (5.6%)
2. Unlikely	9 (12.5%)
3. Neutral	19 (26.4%)
4. Likely	34 (47.2%)
5. Very unlikely	6 (8.3%)

Likelihood to recommend to friends and family

Mean (SD)	3.4 (1.00)
Median (Q1, Q3)	4.0 (3.00, 4.00)
Min, Max	1, 5

Min: Minimum. Max: Maximum. Q1: First quartile. Q3: Third quartile. SD: Standard deviation.

5. Conclusion

The data collected from the survey provides a comprehensive understanding of the demographics, lifestyle, habits, attitudes, and preferences of the participants in relation to the coffee industry and blockchain technology.

The largest age group among participants is 21-25 years, indicating a young demographic, with significant representation from those over 50. The sample is evenly split between males and females, and most participants are from the center of Portugal, with minimal representation from other regions and abroad. Most participants reside in urban areas, and the majority are workers, followed by students and student workers. Participants generally have a high level of technology proficiency, and most consume 1-2 cups of coffee daily, primarily at home and at the office.

There are mixed feelings regarding the importance of coffee's origin. While some concerns exist about sustainability, traceability, and transparency in the coffee supply chain, many respondents are neutral on these issues. However, there is significant concern for authenticity and quality, with a notable portion of respondents having encountered related issues.

Awareness of blockchain technology is low, but there is a strong willingness to use it. A majority believe that blockchain can enhance trust in the coffee industry and positively impact fair trade and ethical sourcing. Improved sustainability, traceability, transparency, and authenticity are seen as major benefits of blockchain in the coffee supply chain. Participants believe blockchain technology can significantly impact several SDGs, particularly those related to SDG8 (Decent work and economic growth), SDG9 (Industry, innovation and infrastructure), SDG10 (Reduced inequalities), and SDG12 (Responsible consumption and production).

There is moderate consideration for the environmental and social impacts of products purchased among participants, but a majority are likely to support sustainable initiatives and believe it is important to support environmentally and socially responsible coffee brands. There is a mixed willingness to pay more for blockchain-traced coffee, with some participants indicating that their decision depends on the extent of the price increase. Additionally, most consumers are likely to recommend blockchain technology to others.

In conclusion, the data reveals a diverse demographic with a significant urban presence and high technology proficiency, showing a strong interest in coffee consumption and an openness to adopting blockchain technology. Despite mixed feelings on certain aspects like the importance of coffee origin and the environmental and social impact of products purchased, there is a notable inclination towards supporting responsible coffee brands and sustainable initiatives. The significant willingness to use and recommend blockchain technology suggests a promising future for its application in the coffee industry, not only enhancing consumer trust but also positively impacting fair trade and ethical sourcing. Consequently, it has the potential to contribute to various SDGs, further strengthening the industry's commitment to sustainability.

5.1. Research Limitations

This research has several limitations that should be acknowledged. Firstly, the sample size of 72 participants is relatively small, which may limit the generalizability of the findings to the broader population. The demographic composition of the sample, predominantly centered in the central region of Portugal and with a high proportion of young adults aged 21-25, may also influence the results and not fully represent the diversity of the general coffee consumer base. Additionally, the cross-sectional nature of the study provides a snapshot in time but does not allow for the assessment of changes in attitudes or behaviors over time. Lastly, the awareness and understanding of blockchain technology among participants were not deeply explored, which could affect their responses regarding its potential impact on the coffee industry.

5.2. Suggestions for Future Research

Future research should aim to address the limitations identified in this study and build upon its findings to provide a more comprehensive understanding of consumer attitudes towards blockchain in the coffee industry. Expanding the sample size and ensuring a more diverse demographic representation would enhance the generalizability of the results. Longitudinal studies could provide insights into how consumer attitudes and behaviors evolve over time, especially as blockchain technology becomes more prevalent and better understood. Additionally, qualitative research methods, such as interviews, could delve deeper into

consumers' perceptions and knowledge of blockchain technology, providing a richer context for understanding their responses. Exploring the impact of educational interventions on consumer attitudes towards blockchain could also be valuable, as increased awareness and understanding might influence their willingness to support and pay more for blockchain-traced coffee. Furthermore, future research should consider incorporating feedback from all relevant stakeholders, including farmers, processors, manufacturers, regulatory agencies, markets/retailers/cafes, who were not fully represented in this study.

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