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ALLIANCE

A hoListic framework in the quality Labelled food supply chain systems' management towards enhanced data Integrity and verAcity, interoperability, traNsparenCy, and tracEability

DELIVERABLE 2.1- Food Fraud Landscape, Strategic Gap Analysis, User Needs & Requirements

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List of Abbreviations

Abbreviation	Description

AI	Artificial Intelligence
ALPP	Association of Lika Potato Producers
API	Application Programming Interface
BC	Blockchain
BD	Big Data
BMS	Building Management System
CAC	Codex Alimentarius Commission
CCP	Critical Control Point
CoA	Certificate of Analysis
CSV	Comma-Separated Values
DApps	Decentralized Applications
DC	Distribution Centres
EFSA	European Food Safety Authority
ERP	Enterprise Resource Planning
EU	European Union
EVOO	Extra Virgin Olive Oil
FSC	Food Supply Chain
FSCM	Food Supply Chain Management
FT-NIR	Fourier Transform Near Infrared Spectroscopy Technology
GC	Gas Chromatography
GFSI	Global Food Safety Initiative
GI	Geographical Indication
GMP	Hazard Analysis And Critical Control Point
GPS	Global Positioning System
HACCP	Hazard Analysis and Critical Control Points
HBM	Health Belief Model
HBM	Health Belief Model
HIS	Hyperspectral Imaging
HRM	High-Resolution Melting
ICT	Information and Communications Technology
IF	Impact factor
IFS	International Featured Standard
IoT	Internet of Things
LC	Liquid Chromatography
MCA	Multiple Corresponding Analysis
MIR	Mid-Infrared
MS	Mass Spectrometry
NIR	Near Infrared Spectroscopy
PDA	Personal Digital Assistant
PDF	Portable Document Format
PDO	Protected Designation Of Origin
PGI	Protected Geographical Indication
PLS-DA	Partial Least Squares Discriminant Analysis
PLSR	Partial Least Squares Regression
PoW	Proof Of Work
PUC	Pilot Use Case
qPCR	quantitative Polymerase Chain Reaction
QR code	Quick Response code
QuEChERS	Quick Easy Cheap Effective Rugged Safe
SC	Supply Chain
SCM	Supply Chain Management
SOTA	State-Of-The-Art
TACCP	Threat Assessment And Critical Control Point
TPB	Theory of Planned Behaviour
TPB	Planned Behaviour
TRU	Traceable Resource Units
VACCP	Vulnerability Assessment And Critical Control Points
Vis-NIR	Visible And Near-Infrared Spectroscopy
WMS	Warehouse Management System

Executive Summary

This deliverable presents the Food Fraud Landscape, Gap and User Needs & Requirements Analysis. It explores the recent development and ongoing research in the field of Food Traceability, Safety and Authenticity. It describes an overview of the food fraud, current challenges, and vulnerabilities of the food supply chain systems. Moreover, it presents the current state-of-the- art (SOTA) analysis on the offered technologies and solutions within ALLIANCE that aim to improve Food Traceability, Safety and Authenticity, it conducts a gap analysis and identifies per Pilot Use Case (PUC)-Demonstrator the user needs and requirements for adopting the offered solutions and outlines how ALLIANCE will innovate to move beyond the current SOTA.

The primary objective of the deliverable is to discuss the business value of the technologies intended to be incorporated in ALLIANCE platform and identify the means those technologies will be addressing the issues of Food Fraud and Food Traceability and Food Authenticity in novel ways. This has been accomplished by conducting a GAP analysis on various technologies and then mapping to different pilot cases. Moreover, D2.1 identifies the User Needs and Requirements of the identified stakeholders in the different Food Supply Chains (FSCs) that the project considers. The deliverable is a result of the task *T2.1-The Food Fraud Landscape & Gap Analysis for Food Traceability* and the task *T3.1-The Food Fraud Landscape & Gap Analysis for Food Safety and Authenticity* and provides the foundation for the development of the technology offerings (WP2, WP3) and for the organization and planning of the Pilot Use Case (PUC) Demonstrators (WP4).

Upon reading this document, the reader will develop an understanding of relevant technologies enabling traceability in food systems, and allowing the provision of services and solutions that can guarantee safety and authenticity in food products. Distributed ledger technologies, (e.g. Blockchain supporting tamper-proof data protection models), AI-based analytics for Early Warning and Decision Support Systems, online monitoring and vulnerability risk assessment, advanced spectroscopy mechanisms and next-generation DNA sequencing mechanisms for food analysis are some of the technologies which will be described in this deliverable. The reader will also gain an understanding of the current gaps and room for improvement, that has been derived by applying each technology to at least one of the considered Pilot Use Cases (PUCs).

In ALLIANCE, seven PUCs demonstrate and validate the proposed solutions in their respective Food Supply Chains (FSCs). The *first* one is a Blockchain platform aiming at the PDO/PGI Extra Virgin Olive Oil Authenticity Validation. The *second* demonstrator is about safeguarding PDO Feta Cheese, while the *third* pilot is about fighting Fraud and Adulteration and Preserving Authenticity in organic Honey. Furthermore, pilot *four* is about AI-assisted Near-Infrared (NIR) and Hyperspectral Imaging (HSI) Rapid Testing for On-Site Verification of Authenticity of PGI Faba Beans. Pilot *five* is about improving traceability and minimize the risk of Food Fraud in PGI Lika Potato supply chains. Pilot *six* deals with the detection of pesticides' residues and metabolites on Organic Pasta products. Finally, Pilot *seven* aims to provide improved means of traceability for the PDO Arilje Raspberries Food Supply Chain. This deliverable briefly introduces each pilot use case, along with the potential technologies to be applied in each pilot and analysis of the users' needs and requirements for tackling the problems and weaknesses that they face. This deliverable will serve as a basis for the specification of the Use Case Scenarios and the KPIs definition.

In summary, the contributions of this deliverable are twofold and will serve as the foundation for future work and deliverables of ALLIANCE. The first contribution is a thorough analysis of the gaps for a variety of technologies for Food Traceability, Safety and Authenticity. The second contribution is the identification of the user needs, translated into functional and non-functional requirements for the technological solutions of the platform and the mapping of the specific technologies offered by ALLIANCE with those requirements.

1 INTRODUCTION

1.1 Purpose of this document

This document is the first technical deliverable of ALLIANCE. The main goal of the document is to lay out a solid technical foundation on which the project will continue to develop. In addition, this document aims to align the ALLIANCE consortium by providing a comprehensive description of available technologies on Food Traceability, Food Safety and Authenticity. It also includes analysis of user needs and requirements and an initial mapping of the offering technologies to ALLIANCE PUC-demonstrators, to facilitate collaboration and joint exploitation among the consortium members. To achieve this, first, the document includes an extensive literature review and then presents a state-of-the-art analysis for each technology offering to be used in the project. In total, the ALLIANCE consortium considers eight different technical offerings, which fall into two broad categories, mainly: Food Traceability (WP3) and Food Safety and Authenticity (WP4). Based on this, the document outlines the technological offerings of ALLIANCE compared to the highest level of development that has been achieved to date.

Moreover, this document presents the elicitation process and the methodology followed for the gathering of user needs and requirements. It is an essential step towards the development of ALLIANCE technical solutions with an aim to meet the specific needs and demands of the users in terms of functional or non-functional requirements into the system design. Those requirements describe features that the technologies should/must/will (or not) have according to the users' expectations and they will be translated later into detailed technical requirements and will be incorporated into the ALLIANCE architecture design. Particularly, an initial attempt to translate the user requirements into functional and non-functional requirements has been made. With the definition of the KPIs and the specification of the scenarios per PUC, those requirements will be elaborated and will be formalized later (in the next deliverable) during the design of the Architecture of the ALLIANCE platform into a unified and detailed system/technical requirements specification (traceability matrix), that they will contain descriptions of functionalities, services, software and hardware capabilities that the ALLIANCE platform must support and provide, specifying and quantifying also possible constraints, limitations or dependencies.

In a nutshell, the purpose of this document is to define how the ALLIANCE can push existing technologies beyond the state-of-the-art and how the innovations will be applied to real world use cases as these are considered in the Description of Action.

1.2 Relation to other's project work

As this document provides a state-of-the-art analysis for each technology belonging to the ALLIANCE platform, this document can be viewed as the foundation on which the platform is built upon. As ALLIANCE aims to deliver a trust management Blockchain-enabled platform, that will integrate all the different technologies that ALLIANCE brings and will be utilised in the fight against food fraud, this deliverable will serve as the basis for other deliverables in the project, specifically: D2.2 - D2.4, D3.2 – D3.3 and D4.1 - D4.3. To move forward, this document establishes the initial framework for potential innovations and limitations that should be considered in the future when making important management decisions.

1.3 Structure of the document

The document is organised as follows:

- Section 1 initiates with the project's introduction.
- Section 2 presents a thorough analysis and literature review of the Food Fraud Landscape in modern Food Supply Chains.
- Section 3 presents the SOTA of the technologies that are used to enable Food Traceability. The emphasis is placed on Blockchain Technologies that are used for Resilient Food Supply Systems, IoT technologies, AI and ML -based mechanisms for Vulnerability Risk Assessment of the Critical Control Points in the FSCs, Early Warning & Decision Support Systems and Interoperability Mechanisms for Complex Food Systems. Section 3 structure follows the Technical Offerings of WP2, and apart from the SOTA, it describes also how ALLIANCE innovates leveraging latest technology to move beyond the current SOTA.
- Section 4 presents the SOTA of the technologies for Food Safety & Authenticity and discusses the innovations in next generation portable DNA Sequencing, Food Fraud detection with advanced spectroscopy, Digital Knowledge Database and Management Systems, and use of predictive analytics and relevant technologies for the prevention of Food Fraud. Similar to Section 3, Section 4 structure follows the Technical Offerings of WP3 and describes also the way that ALLIANCE innovates on these technology fields moving beyond the current SOTA.
- Section 5 describes analytically the methodology followed for the gathering of the user needs and requirements. For each of the PUC-demonstrators, we have gathered, assessed and prioritized the requirements of the users per Technology Offering. As Section 3 and 4, introduce the technology offerings with a SOTA and beyond SOTA analysis, Section 5 describes how these technology offerings can be applied effectively to tackle problems and weaknesses pertaining to Food Fraud (Authenticity, Safety and Traceability). It also establishes the foundation for the definition of the Pilot Use Case Demonstrators Planning in WP4. Through this analysis, a mapping of the offered technologies to each PUCs is provided aiming to associate the problems (weaknesses, impediments, or barriers) of each FSC with the suitable ALLIANCE technology solution.
- Finally, Section 6 concludes, also presenting the next steps.

2 FOOF FRAUD IN FSC: LITERATURE REVIEW

Over the last decade, Food Supply chain has been facing one of the most emerging challenges and issues on a global scale, specifically "Food Fraud". As an already persistent issue for food fraud there has not been a widely accepted definition so far, but it is considered as an intentional act of misrepresentation of food for economic gain, which is intended to remain undetected by the consumer and often includes food modification or false documentation (Visciano & Schirone, 2021). Food products are heterogeneous as they come in various proportions from different geographical sources and comply with different legislation and norms depending on their origin, destination, and manufacturing (Brooks et al., 2021). That is the reason why food commodities are prone to fraudulent acts. The Food Supply Chains (FSCs) have several interconnected and intercorrelated elements and phases that should be considered for assuring elimination of food fraud all along the supply chain. Aspects include safety and authenticity up to the final product from the consumer side. Therefore, the gaps and inconsistencies regarding safety and authenticity, as well as the technological impediments that create low-performance efficiency in the FSCs are the subject of a large part of this deliverable.

For this reason, a literature review of the current state-of-the-art was conducted, considering technologies and equipment used across the divisions involved in food safety and food authenticity activities. The expected outcome is to identify gaps and needs providing the directions and strategic actions for a more oriented technology solution upgrade. Moreover, the reorganization and digital transformation of the FSCs to ensure authentic and safe products along the FSCs as well as to prevent and limit food fraud is examined. In the light of this, the insufficient digital literacy is also taken into consideration. The intended meaning of the statement is to refer to the identified barriers, such as the lack of means and tools to transfer knowledge and accelerate the transition to technology acceptance and adoption and the lack of funding opportunities (Gerard, 2019), that keep small- and medium-sized stakeholders (farmers, producers, processors, and retailers) in an inert condition.

Another aspect of paramount importance is the relevant previous projects or activities, connected to the subject of ALLIANCE. To begin with, the objective of the ETAPAS project is to establish a pragmatic framework, reinforced by a prototype software system, that can provide an initial evaluation approach with the ability to gauge and alleviate ethical, societal, and legal hazards (EU-ETAPAS, 2023). This project aims to collaboratively develop a comprehensive framework with Public Bodies, comprising of a set of ethical principles, quantifiable indicators, and a legal structure to facilitate the responsible integration of Digital Technologies. Furthermore, DECIDO aims to offer a comprehensive interface to Policy Analysts (PAs) for the purpose of defining policy-making workflows (EU-DECIDO, 2023). This interface will enable the orchestration and integration of various tools and services provided by EOSC, customized tools offered by DECIDO partners, and pertinent data (including big data) from public, academic, and private data providers. The workflow will encompass the entire process of policy-making, from evidence gathering to policy definition and evaluation. In addition, ACROSS seeks to promote the interconnection of private sector services while safeguarding the data sovereignty of citizens (EU-ACROSS, 2023). The ACROSS project is set to undergo development and testing in three distinct countries, each at varying stages of their respective digital transformation trajectories. Moreover, the objective of Data4Food2030 is to expand the knowledge base and understanding of the Data Economy for Food Systems (DE4FS) (EU - Data4Food2030, n.d.). This involves the creation of a monitoring and evaluation system to assess the development, performance, and impact of DE4FS on pertinent EU policies. Additionally, the project aims to identify the factors that facilitate or hinder the implementation of DE4FS and convert them into opportunities, recommendations, and solutions. The proposed solutions will be tested and evaluated through case studies and stakeholder dialogues. The project also intends to provide future scenarios and a roadmap for the DE4FS and sustain the monitoring system to support policy development and expedite the desired future state of the DE4FS.

The subsections that follow incorporate the literature review results in an illustrative way, presenting the main affiliations, contributors, and keywords connections regarding the food fraud issue.

2.1 Literature review

This literature review is mainly focused on the assessment of Web of Science database results, regarding the term "food fraud" in abstracts, titles and keywords, leading to the extraction of the factors influencing this specific field. More precisely, partnerships and trending topics were assessed, focusing on the technological, social and economic dimensions(Figure 1). **Error! Reference source not found.** displays that 2,331 results have been collected through the Web of Science data base and have been transformed into a unified Bibtex file, since this data base permits the extraction of only 500 results at a time. The unification process has been achieved through the R studio program and the use of R version 4.2.2. Moreover, the Bibliometrix library was used to extract the figures and data presented in the following section (*Bibliometrix*, 2023).

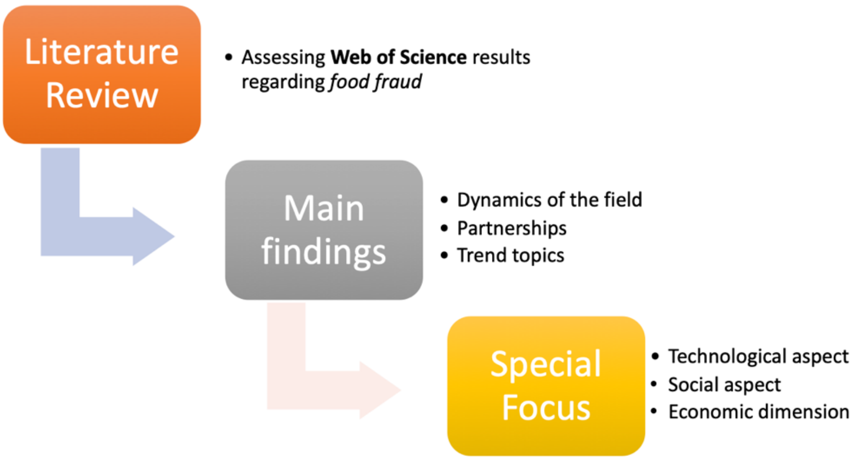

Figure 1: Literature review processes

Figure 2: Data analysis process

2.2 Main results

2.2.1 Annual Scientific productions indicators

The literature review assessment covered the period from 2003 to 2023, coinciding with the establishment of the European Food Safety Authority (EFSA) and extending up to February

2023. This timeframe reflects the European Union's transition towards producing safer food products for consumers. The annual scientific publications have been increasing since 2003 and it can be divided into 3 time-frames. From 2003 to 2013 (first time frame), the scientific production was limited and low, resulting on the annual production of 25 papers on average for this period, regarding food fraud. For the second time frame (2013-2018), the scientific production increased significantly, leading to an annual production of 200 articles in 2018, while the average production for this period was quadrupled to 121. Post 2018 (third time frame), the annual scientific production had a straight increase reaching up to 400 articles in 2021 on an annual basis. This gap between the different time frames is raising awareness regarding food fraud issues. Both the EFSA's report on pesticides and the Horsemeat scandal that broke in 2013 indicate that these two incidents were the catalysts for the European strategy to eliminate food fraud (EFSA, 2013; EFSA, 2015). After 2019, the increase can be attributed to the change of the consumer behaviour, alongside the COVID-19 pandemic outbreak, as well the rise of sensitivity towards consumers' preferences for food of higher quality and safety standards (EFSA, 2013; EFSA, 2015).

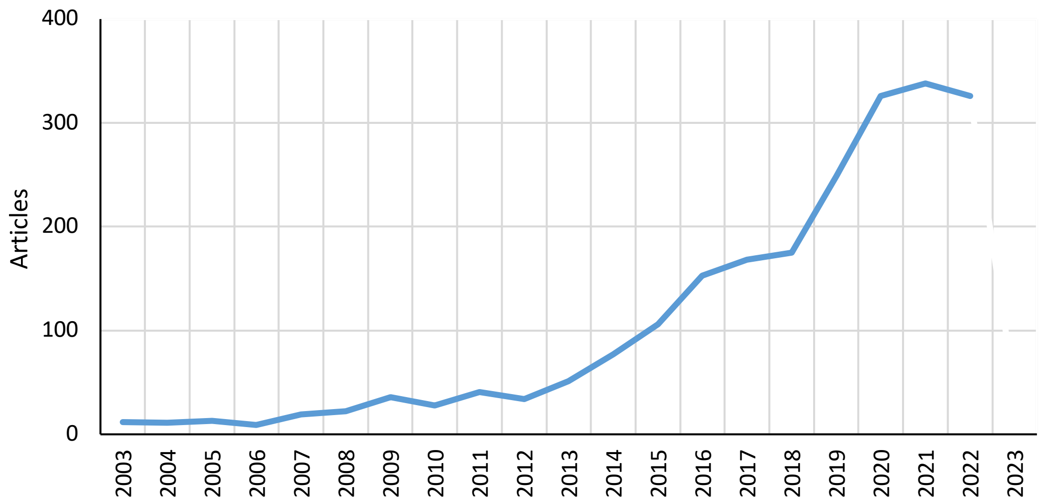

Figure 3: Trend of annual scientific production on food fraud

2.2.2 Most relevant affiliations

Figure 4 presents the top ten paper affiliations to institutions contributing to the academic output related to food fraud assessment. The four most important of them have more than seventy-five articles published about the food safety and authenticity topic. Queen University Belfast appears at the top of this list with 129 articles published, following with 78, 77, and 76 respectively from the University of Barcelona, Michigan State University and Wageningen University.

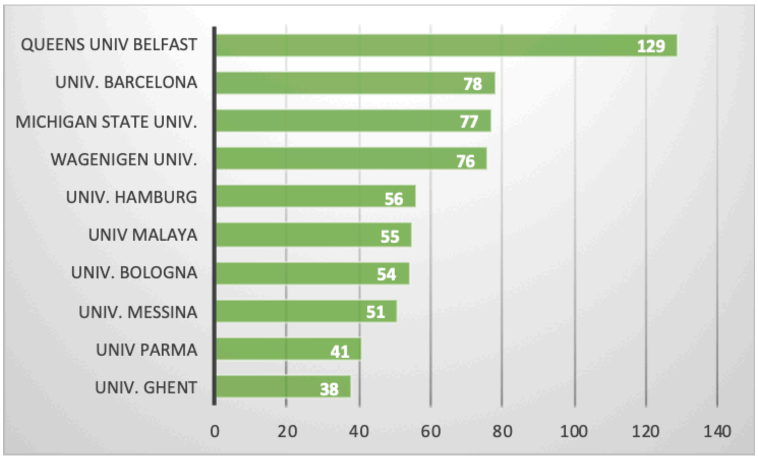

Figure 4: Representation of the most relevant affiliations

Figure 5 presents the authors having the greatest contribution on food fraud. The authors with the highest scientific production have more than twenty papers in the field. It should be stated that the research work about food fraud is mostly limited within the presented group of researchers.

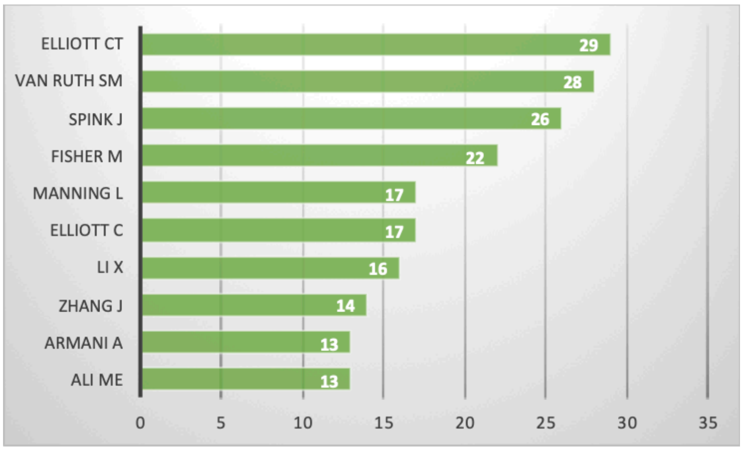

Figure 5: Representation of the most relevant authors in food fraud publications

2.2.3 Most relevant source

Figure 6 presents the top ten journals of this field. Three journals in particular had more than one hundred publications (FOOD CONTROL, FOOD CHEMISTRY, FOODS). The impact factor (IF) of Food Control journal is 5.548 for the academic year 2022-2023 similar to the IF of Foods (5.561), while the IF of Food Chemistry is higher (7.514).

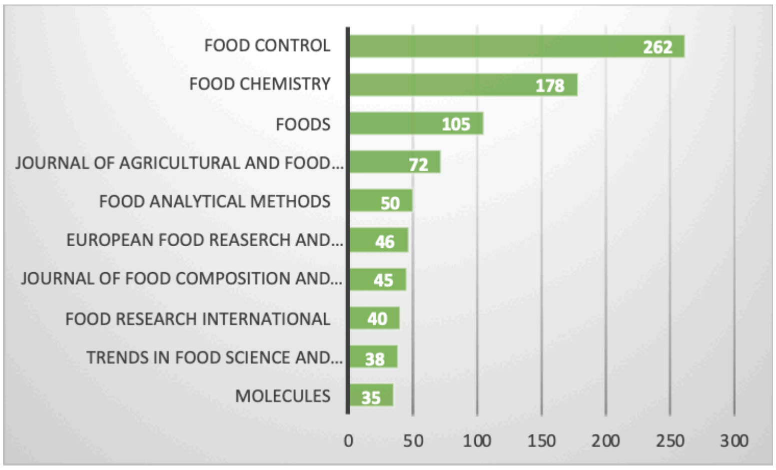

Figure 6: Representation of the most relevant Sources

2.2.4 Production sources over time

As previously mentioned, the scientific production had a radical increase, starting from 2013. Figure 7 presents the publication annual scientific production per journal. As it can be seen, Food Control displays a higher publication rate than Food chemistry. Foods is also present more articles after the year 2019. The year 2018 seems to be crucial, due to the fact that this is a starting point for a significant gap between the increasing rates of the aforementioned journals.

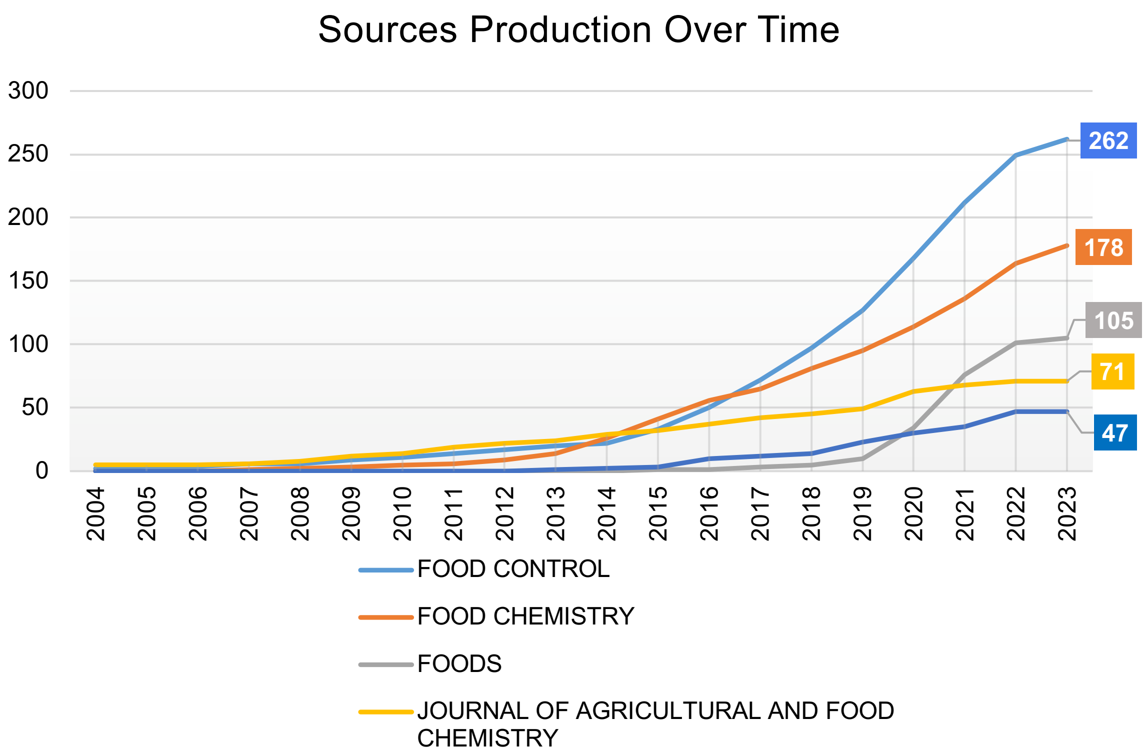

Figure 7 Representation of the most relevant resources compared by the number of documents

Publications originated from several countries around the world, not being restricted to specific regions. China and Italy in particular, have the greatest contribution, regarding published scientific results. The second segment of Figure 8refers to the academic journals supported from the previously mentioned countries. Most of the publications for the top three journals are coming from China. As the analysis shows, eight Keywords were obtained, namely (in a descending order): *food fraud, adulteration, Chemometrics, fraud, authenticity, food safety, traceability* and *food*. Furthermore, results have been acquired by using the above stated keywords which are presented in Chapter 4.

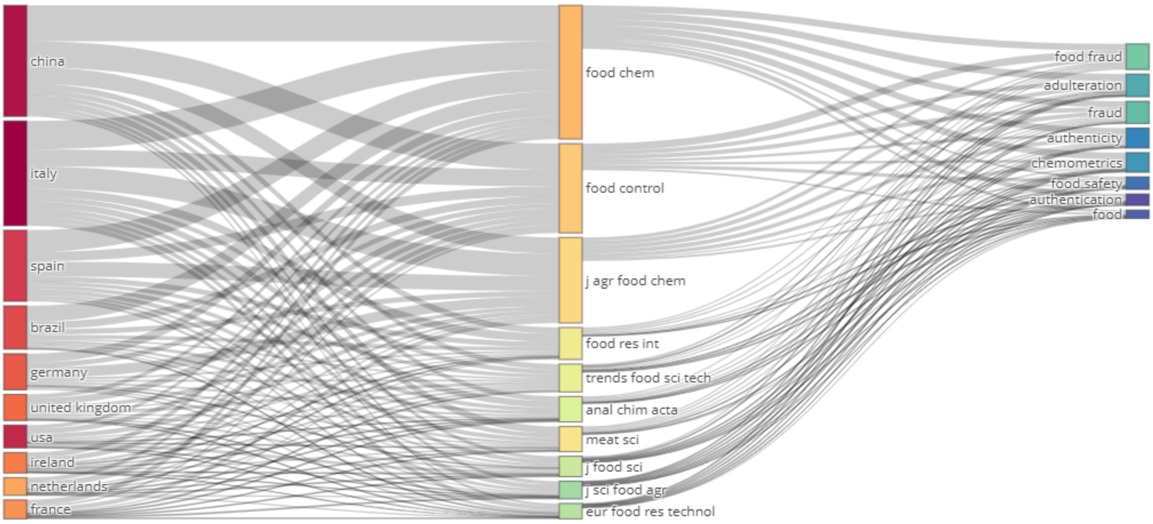

Figure 8: Sankey figure of Origin-Source-Keywords

2.2.5 Co-Citation network

Figure 9highlights the existence of five groups and their relationships as a co-citation network. It can be observed that almost all the publications are cited with a similar frequency, proven by the similar size of the presented dots. Moore et al. (2012) and Spink & Moyer (2011) papers have high impact, relevance and credibility in this network.

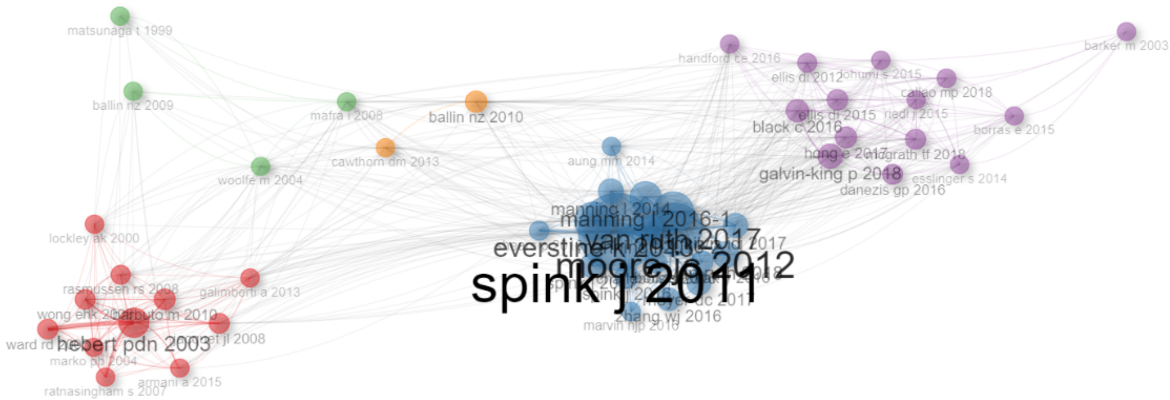

Figure 9: Sankey figure of Origin-Source-Keywords

2.2.6 Historiogram

Providing more information about the chronology of citations, in Figure 10, in the blue group most of the recent publications cited two main publications (as above) in 2011 and 2012, indicating again the importance of these two papers regarding food quality, and safety. A smaller independent group is also identified, without specific orientation. However, its references are being considered outdated since these publications have been made prior to

2010. Nevertheless, there is an ongoing assumption if these papers have set the basis for future publications, as in the beginning of 2010s some important and relevant publications regarding the topic of food quality, fraud and safety have been published.

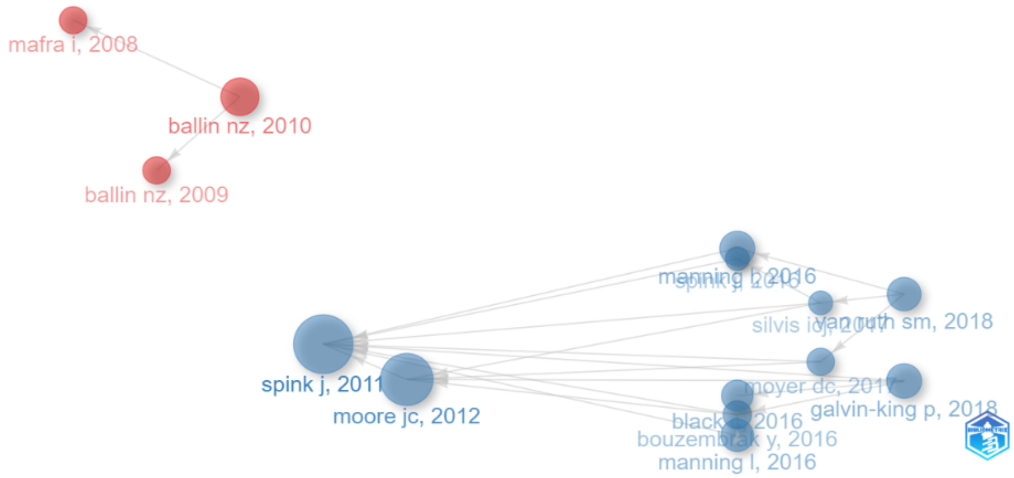

Figure 10: Historiogram of food fraud related publications

2.2.7 Scientific production and collaboration between countries

Scientific findings varied significantly on a national basis. As already stated, China and Italy had the highest scientific outputs on this topic. Brazil, United States, Spain, and Germany, generated fewer publications, but had important impacts on these topics. In the map below (Figure 11), links among different countries that had a minimum of five collaborations related to the food fraud topic are depicted. These connections and collaboration provided strong evidence that food fraud, authenticity and quality are global topic and challenge, not limited to one country. Thus, there is potential for the creation of standardized and/or harmonized quality plans.

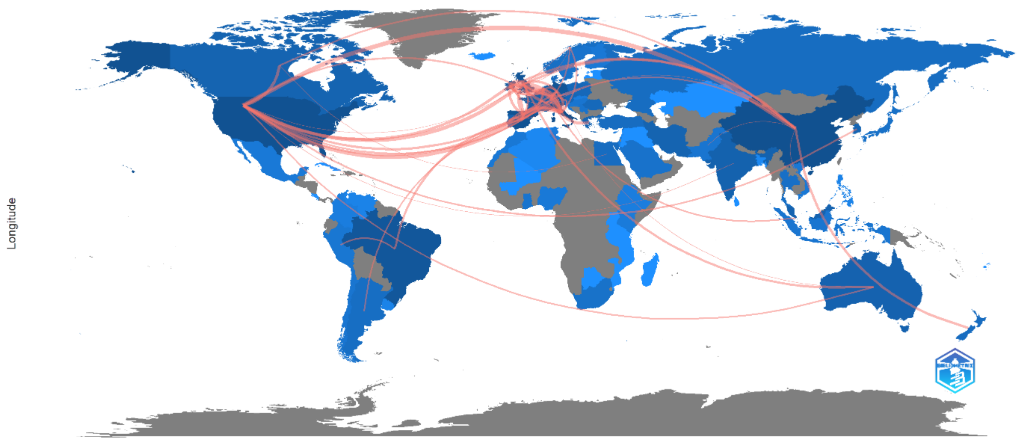

Figure 11: Map of Scientific production and collaboration links among countries assessing food fraud.

2.2.8 Most frequent terms

The most frequently used terms in publications highlighted the significance of several aspects of the food supply chain are presented in the following Figure 12 in order. The terms identification, adulteration, authentication and quality were the most frequently used. Classification, fraud, spectroscopy and products were a the second most important cluster of terms. It should be underlined that the acquired terms provide a general approach on the food fraud issue, and are not representing the materials and methods used in this field. This literature review indicates that more specific keywords should be used to easily distinguish the content of each paper, especially in view of the increase in numbers of publications in this field.

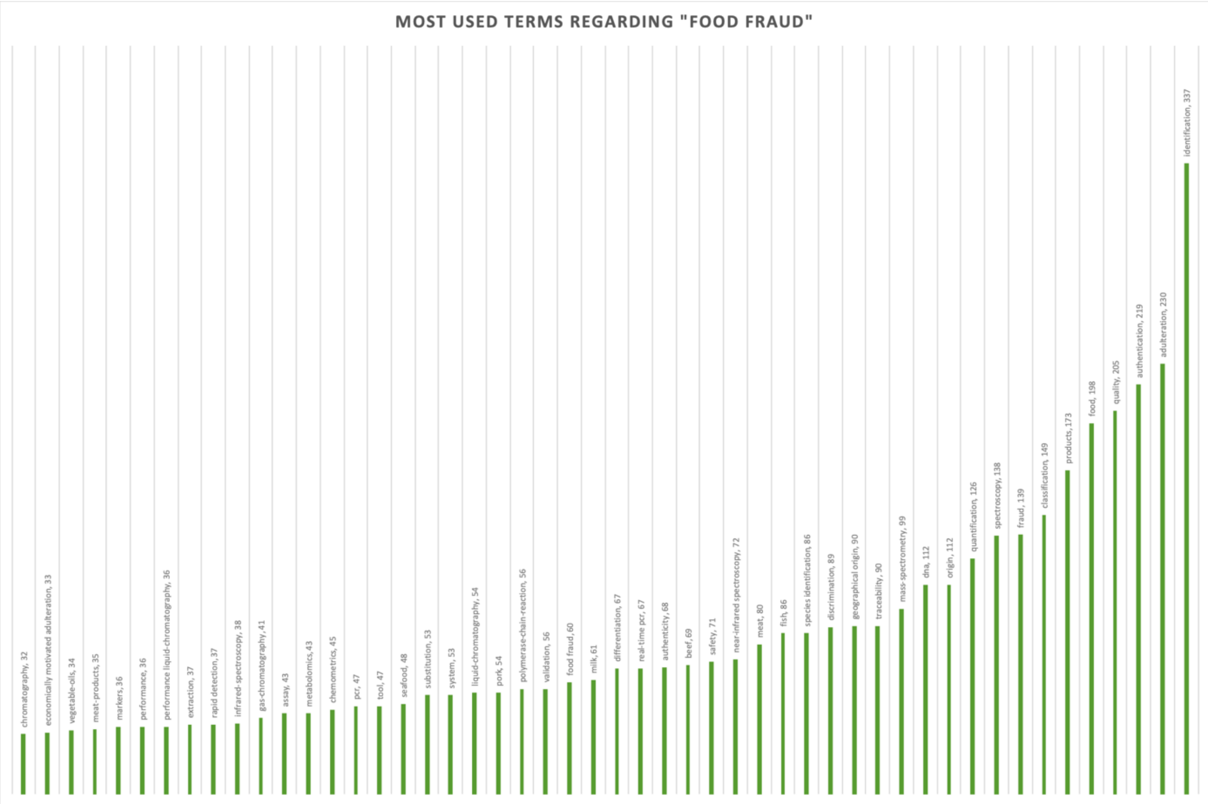

Figure 12: Analysis of food fraud most relevant keywords

2.2.9 Conceptual structure map

For a deeper understanding of the dynamics of the terms used in the scientific production, a conceptual structure map was obtained through the Multiple Corresponding Analysis (MCA) method. Two main groups were recognized as shown in Figure 13. The first group that is highlighted in red, contains the majority of the keywords regarding *food transformation* and *science*, as well as the *safety* and *traceability*. Meanwhile, the second group contains *seafood* and *substitution*. Two sub groups can be identified within the red group. The first one refers to the applied methodologies (e.g., chemometrics, metabolomics and markers) and the second one is referring to the different meat sources (e.g., meat, beef, pork). It is of a paramount importance that fish meat is an independent cluster, meaning that there is a special treatment towards this sensitive product. Overall, the MCA model can explain 69.3% of the involved keywords variability, which is considered as representative for the whole sample of 2,331 papers being incorporated in this literature review.

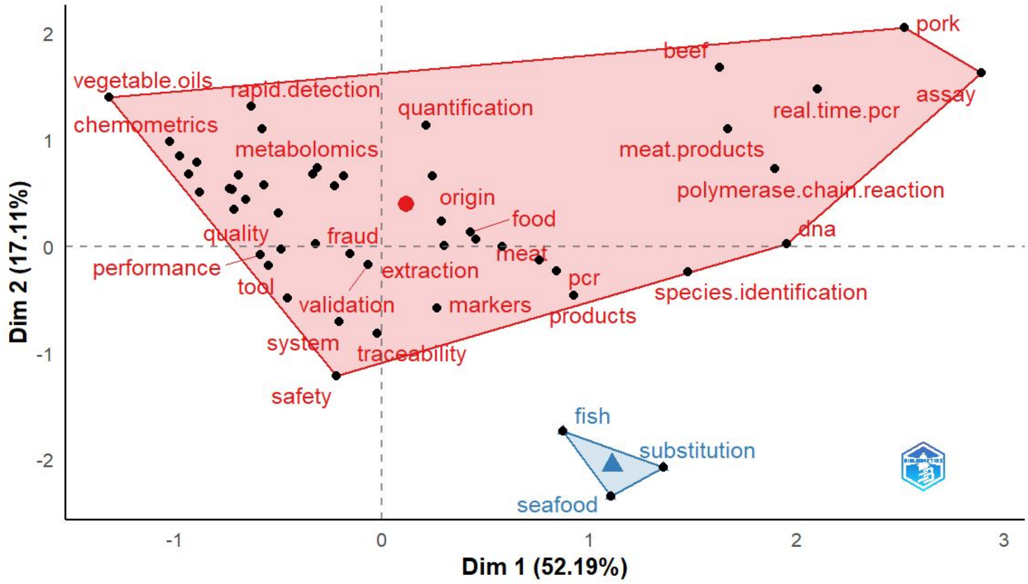

Figure 13: Analysis of food fraud most relevant keywords

2.2.10 Topic dendrogram

Due to the fact that Figure 13 clusters were not clearly explained through the MCA model, Figure 14 provides a deeper classification of the involved keywords. Although two main clusters/groups can be identified identically to the Conceptual structure map, there are three main sub-groups of the previously stated group 1 (Figure 14), that can be observed as following:

- Meat and molecular biology
- Biochemistry of food
- Quality and food safety

Meat and molecular biology are referring more to the early stages of the FSC. Biochemistry of food represents mostly the protocols that are taking place in the processing phase of food products. Quality and food safety are referring to the monitoring the whole FSC. Notably, food fraud issues are present for all the involved actors and stakeholders.

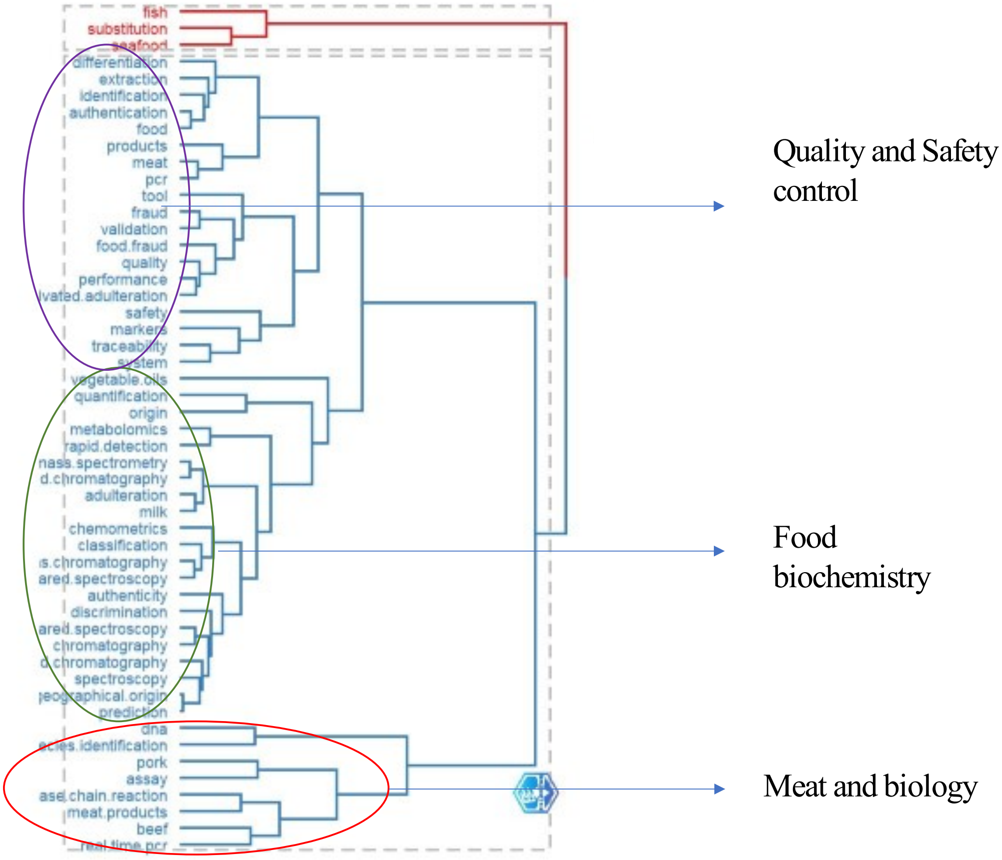

Figure 14: Dendrogram analysis to cluster the food categories based on keywords

2.2.11 Summary

Over the last decade trends in topics have been changing, leading to reorientation of scientific exploration of food fraud and its assessment in FSCs. Up until 2017, the terms quality, authenticity, food safety, and supply chain monitoring were absent. Before 2017, almost all keywords and trend topics were focused on the food science and biochemistry domains, rather than the quality of products and elimination of food fraud in the FSCs. In 2019, there was a shift towards a more holistic approach for increasing food safety standards, and provides more insights into the implementation of new technologies for monitoring.

This literature review has been conducted to assure that ALLIANCE is in accordance with the current status of the academic approaches. In the light of this, the major contribution of this literature review stands on the analysis of terms used to ameliorate the research findings of the ALLIANCE with the existing literature. Connection between different terms researchers and countries have been highlighted leading to a better understanding of the current situation, regarding the need for implementation of Blockchain technology in the Agri-food sector.

2.3 Attributes and classification of technologies on FSCM

In this subsection, the base layer of the development of the technologies prior to their use in agriculture is introduced. The scope of this section is to provide insight into the technologies in general, while their implementation in agriculture is presented in the proceeding sections. In the review conducted, the dominant technology was Blockchain, followed by IoT, Artificial Intelligence, and Big Data. Blockchain and IoT provide reliable traceability systems and offer guarantee of food authenticity and safety. AI on the other hand enhances automation and digitalization, and can provide predictions for food fraud, while Big Data supports the prementioned technologies and improve decision making.

2.3.1 Blockchain

The origin of blockchain technology can be traced back to its initial applications in the financial sector, specifically in the field of digital currency (Bitcoin). The utilization of Blockchain technology has proliferated across diverse domains and transformed multiple commercial applications, owing to its attributes of decentralization, dependability, minimization of transactional charges by removing intermediaries, and data storage security, as technological advancements continue to progress. Blockchain is a decentralized system of record-keeping, wherein various nodes engage in communication with one another during transactions(Akram et al., 2020). Akram et al. (2020) identified decentralization, immutability, and transparency as the key characteristics of Blockchain which are described as follows:

- *Decentralization*: In general, transaction systems process in a centralized manner whereby a central entity facilitates transactions and levies an extra transaction fee to carry out this work. The necessity of a central unit for transaction processing is obviated in the context of Blockchain, given that the algorithms inherent to this technology serve to uphold the integrity of data across the decentralized network (Vora et al., 2018).

- *Immutability*: Pertains to the characteristic that once information has been recorded onto a Blockchain, it remains immutable and cannot be modified or altered. The reason for this lies in encryption of data and interlinking with the preceding block in the chain, making any attempts to modify it practically infeasible without necessitating the modification of all blocks in the chain. Furthermore, the entirety of the data is distributed among numerous computers in a decentralized fashion, thereby rendering any attempts to modify or manipulate it considerably more challenging. The characteristic of immutability makes blockchain a highly suitable platform for ensuring secure transactions and storage of data (Z. Zheng et al., 2017).

- *Transparency*: Transparency, within the context of blockchain technology, pertains to the capacity of any individual to observe and authenticate the information that has been documented on the blockchain. The decentralized and distributed nature of blockchain networks enables the maintenance and validation of data integrity through a network of nodes, comprised of computers. The public ledger on a blockchain records all transactions, thereby rendering them visible to all network participants. Consequently, all individuals involved in the network possess the ability to observe the transactions and data that are being documented in a synchronous manner (Rahman et al., 2021).

To fully leverage the potential of Blockchain technology, it is imperative for businesses to implement a flexible strategy that addresses previously encountered obstacles to development, particularly those of a technical nature (Wang et al., 2019). Furthermore, smart contracts can be incorporated into a Blockchain network. Smart contracts offer numerous benefits, such as enabling the automatic initiation of business processes and mitigating transaction expenses (Akram et al., 2020). Data management systems and applications that utilize Blockchain technology are currently accessible and have the capability to fulfil most needs (Javaid et al., 2021).

The utilization of blockchain technology encompasses a range of disciplines, such as cryptography, mathematics, algorithms, and economic models. Additionally, it involves the integration of peer-to-peer networks and distributed consensus algorithms to address conventional distributed database synchronization issues. The utility of blockchain technology lies in its ability to facilitate digital signatures, and enterprises have come to recognize its potential as a distributed technology for constructing secure transactional blockchains (Akram et al., 2020). According to Akram et al. (2020); Rahman et al. (2021); Wang et al. (2019); Zheng et al. (2018) Blockchain is divided into three categories, public, private and consortium as shown in Table 1:

Table 1: Types of Blockchain

Type	Description
Public	A public blockchain is open to the public and anyone can join without specific permission. All individuals involved in the network possess the ability to peruse in this network. However, not everyone has the right to transact/write which depends on whether the Blockchain is additionally permissionless or not. Public Blockchains are characterized by immutability and decentralization. Once a listing has been validated, it becomes unchangeable, and users can be assured that their transactions remain unaltered and intact.
Private	Access to the private Blockchain is restricted to authorized members, necessitating a formal request for permission from the designated Blockchain administrator. The Blockchain system enables varying degrees of access, which dictate the privileges of users with regards to writing, reading, and controlling the system. In this instance, entities employ distributed ledger technology while refraining from disclosing their information to the public. The security level provided by private Blockchains is inferior to that of public Blockchains, thereby allowing the owner to modify entries.
Consortium	Consortium Blockchain refers to a blockchain-based system that is managed by multiple organizations, as opposed to a single entity. It is not of a public nature, but rather one that is authorized. Furthermore, it has a high resemblance to private blockchains.

2.3.2 Internet of Things (IoT)

The concept of Internet of Things (IoT) pertains to the interconnectedness and communication between the virtual and physical worlds (Gilchrist, 2016). Moreover, it enables enterprises to acquire enhanced comprehension of their operations and resources by means of sensors, software, processors, and cloud-based data storage. As a result, it provides the means to transform business processes using the results derived from the analysis of the resulting data using sophisticated analytical tools as feedback (Gilchrist, 2016).

IoT has the ability to monitor and retrieve data from interconnected devices. Within the framework of Industry 4.0, it is feasible for an enterprise to amass a significantly greater volume of data and subject these to analysis, ultimately culminating in the acquisition of knowledge. Understanding the functioning of processes enables programming of devices to collaborate towards achieving predetermined outcomes with greater efficacy (Manavalan & Jayakrishna, 2019). IoT can be categorized into five components of system architecture, as presented in Table 2.

Table 2: IoT System Architecture components

Category	Description
Sensors	Sensors are a fundamental component of IoT as they facilitate the detection of events or alterations in the surrounding environment by providing pertinent

	information. In recent times, sensors have experienced a significant reduction in both cost and size, rendering them economically and technically viable for ubiquitous deployment within a company. This includes employment in quality control on the production line, as well as monitoring air quality in office spaces.
Communications	The existence of IoT is contingent upon the availability of communication channels among machines, sensors, and other devices. The channels employed in IoT facilitate the transmission of substantial volumes of information among the interconnected components through diverse protocols.
Platforms	IoT platform is a software application that facilitates the monitoring and management of diverse endpoint categories, including device management. The platform generally furnishes infrastructure capabilities that facilitate fundamental and sophisticated procedures and digital commercial activities.
Devices	IoT devices are networked systems that possess the capability to produce and transmit data via a communication channel to a designated platform. These electronic gadgets could potentially incorporate integrated sensors, processors, antennas, and software.
Cloud	A cloud refers to a network infrastructure that facilitates the connectivity and interoperability of various devices and applications. This includes the infrastructure, servers and storage required for real-time processing. A cloud also includes the services and standards necessary to connect, manage, and secure different IT devices and applications.

2.3.3 Big Data

The term "Big Data" refers to datasets that are characterized by their immense volume and complexity, which renders conventional statistical analysis software inadequate for their processing. Big Data analysis is a multifaceted procedure that involves scrutinizing data to reveal valuable insights, including but not limited to concealed patterns, correlations, purchasing patterns, and consumer preferences. The results of this analysis can assist organizations in making well-informed business decisions (Marvin et al., 2017).

According to Khan et al. (2017), acquisition of data in the Supply Chain 4.0 framework is a complex undertaking that involves various technologies, machines, sensors, IoT devices, and communication networks. Acquiring this information, performing preliminary processing, and transmitting it to the automated system requires a comprehensive comprehension of big data technologies. One of the primary objectives of enterprises is to conduct an analysis of large datasets. The analysis of large-scale data in SC has prompted professionals to explore diverse methodologies for prospective strategizing and informed decision-making. Several significant domains pertaining to the analysis of Big Data include fraud detection, recommender systems, industrial error identification, process mining, administration, machine data, transportation, market analysis, production analysis, and recommendations for new products (Khan et al., 2017).

Vopson (2021) reported that in 2018, the global volume of data generated, recorded, replicated, and consumed amounted to 33 zettabytes (ZB). These data experienced a rise to 59 zettabytes in 2020 and is anticipated to attain a value of 175 zettabytes by the year 2025. But where is all this massive amount of data stored? Digital information is commonly stored in three distinct types of locations (Sharma & Pandey, 2020). First is the global collection of so-called endpoints, encompassing IoT gadgets, computers, smartphones, and other storage devices. The secondary storage location comprises various facilities such as cellular transmission towers, institutional data centres, and physical premises such as academic institutions, governmental agencies, financial institutions, and manufacturing plants. Most data are typically stored within data servers and cloud data centres (Khan et al., 2017). Attempting to give an insight into the difficulty of managing, storing and extracting information from these data,

Table 3 quotes the main areas of managing and analysing this data in the context of SC 4.0:

Table 3: Domains of Big Data

Domains	Description
Data Storage	The information is gathered from various sources and consolidated into a single database for convenient retrieval. Various databases are available for storing data, including structured data such as those found in data warehouses, as well as databases that are more suitable for storing unstructured data that can be processed based on specific use cases. (e.g. Data lakes). (Sharma & Pandey, 2020)
Data Processing	Data Processing generally encompasses tasks of cleansing, harmonizing, converting, and consolidating data. To ensure the consistency, uniformity, and conversion of data originating from diverse sources, the data processing procedure necessitates the sequential retrieval of each individual data entry. In cases where the volume of data is limited, the velocity of data processing is typically slower and takes place within the confines of the database where the data is stored. With the growth in data volume, data processing is conducted outside of databases to circumvent the constraints and additional workload imposed by the system. (Khan et al., 2017)
Predictive Analytics	This pertains to the estimation of the likelihood of a future occurrence. Predictive analytics is frequently employed in the Agrofood sector to forecast crop yields. By utilizing various data sets such as weather patterns, soil quality, and historical yield data, farmers can employ machine learning models to forecast crop yield for a specific year. An instance of utilizing machine learning in agriculture could involve the implementation of historical data from the previous five years by a farmer to train a model that can forecast the yield of their forthcoming soybean harvest. The predictive model has the capability to incorporate various factors including precipitation, temperature, and soil moisture content in order to generate its forecast.
Prescriptive Analytics	It is an area of business analysis that aims to find the best course of action for a given solution. Descriptive analytics involves the extraction of comprehensive insights into a given scenario through the analysis of historical data. Also, predictive analytics entails the identification of patterns in past events to forecast future occurrences and determine the likelihood of such events. (Sharma & Pandey, 2020)
Streaming Analytics	It is the analysis of large volumes of data transmitted in real time and resulting in an action or series of actions, such as financial transactions, equipment failure, or another trigger. These triggers indicate changes associated with a system at a point in time such as a click, sensor reading, or some measurable activity. Real-time data management, data cleansing, advanced analytics, and pattern-of-interest detection have the potential to significantly decrease processing time and cost. (Sharma & Pandey, 2020)

2.3.4 Artificial Intelligence

The advent of information and communication technologies (ICT), particularly in conjunction with the Internet of Things, big data, and cyber-physical systems, has enabled the application of requisite flexibility and intelligence to address the exigencies of industry 4.0. Within this context, Artificial Intelligence is regarded as a pivotal technology that can effectively tackle the challenges and transform the manner in which production processes and business models are organized (Peres et al., 2020).

Artificial Intelligence is a sub-field of computer science that is focused on the creation of data-processing systems capable of performing tasks that are typically associated with human intelligence, including but not limited to reasoning, learning, and self-enhancement (ISO/IEC/IEEE 24765, 2017). From the SC standpoint, AI technologies are perceived as aiding systems in their ability to perceive their surroundings, process acquired data, and resolve intricate issues. Additionally, these technologies facilitate learning from experience, thereby enhancing their capacity to address specific tasks (Peres et al., 2020). The anticipations surrounding Artificial Intelligence within supply chains are substantial and subject to frequent modification; meeting these expectations can be challenging due to the need for high-quality data, significant investment in expertise and infrastructure, and the complexity of integrating AI with existing systems and processes. Table 4 outlines the primary domains of AI pertaining to supply chain management.

Table 4: Domains of AI

Domains	Description
Algorithms	Algorithms necessitates the amalgamation of tangible, virtual, and heuristic knowledge. The management, development, and control of the model give rise to a high degree of complexity. Artificial intelligence algorithms, such as classification, regression, and clustering algorithms, are commonly utilized in various applications. For an algorithm to function effectively, it is imperative that it is provided with dependable data (i.e., precise, accurate, and unbiased). The utilization of an algorithm with inadequate or imprecise datasets may lead to outcomes that fall short of anticipated results.
Data	The implementation of AI in Supply Chains necessitates the utilization of data that are distinguished by their high volume and diversity, originating from diverse units, products, and other sources. The success of AI models in supply chains is heavily dependent on the quality of the training data, which must be accurate, clean, and appropriately labelled. Therefore, data quality is a crucial factor in ensuring the usefulness of these solutions. The issue of producing synthetic data that exhibits a strong resemblance to data derived from genuine operational contexts persists, thereby enabling the extension of industrial AI solutions founded upon authentic scenarios.
Decision-making	The level of fault tolerance tends to be minimal, while optimization problems place a significant emphasis on efficiency. Currently, the degree of independence exhibited by applications remains relatively limited, thereby restricting their functionality to highly specific and rigid parameters that offer supervisory decision-making support.
Infrastructures	The hardware and software components are designed with a significant focus on real-time processing capabilities, prioritizing industrial-level reliability while meeting stringent requirements for high security and connectivity. The establishment of appropriate infrastructure is of utmost importance in order to guarantee the requisite standards of quality, security, and dependability that are necessary to enhance the acceptance of AI solutions within the SC sector.

3 SOTA on Food Traceability

3.1 Food Traceability

In the past 20 years, due to numerous incidents in the food industry, food producers and manufactures faced a worldwide growing problem: to deliver consumers safe products. As a result of numerous food scandal outbreaks, consumer worry over the safety of their food increased (Zhang et al., 2020), leading many to increase the amount of money they spend, in exchange for better quality food (Demestichas et al., 2020), with safety guarantees of transparency and integrity (Aung & Chang, 2014a; Myae & Goddard, 2012; Riccioli et al., 2020; Tang et al., 2015).

Governments also put more effort towards the goal of providing safer food for their people by imposing a new set of rules and legislations (Charlebois et al., 2014; van der Meulen, 2015). This was all needed, especially when one takes into consideration the sociological, economical and environmental effect of a poorly performing traceability mechanism for food supply chain. It is estimated that around 2.2 million people die yearly from diarrheal diseases, a large percentage of whom are children (Demestichas et al., 2020). From an economical point of view, illnesses from foodborne diseases impact negatively people performance and health, reducing their economic output and placing pressure on healthcare systems. From an environmental point of view, food transport has reached greater distances than ever before thus requiring more and more resources and energy. Multiple other proofs of food traceability necessity exist. So, what is traceability, its structure, objectives and how can it be used in the food industry?

To start, several definitions exist for traceability. In literature, traceability will be defined as "the ability to access all information relating to that which is under consideration, throughout its entire life cycle, by means of recorded identifications" (Olsen & Borit, 2013). At first, traceability emerged in the industrial engineering world, to safeguard product quality (Wall, 1994). It was used to differentiate between products, for intended reasons (Smyth and philips, 2002). Then, in the 1980s, traceability systems made their entrance in the food sector, this time to guarantee the safety of the products. As stated by the Codex Alimentarius Commission (CAC) in 2003, food safety is the insurance that the food purchased by a consumer should not inflict any damage to the later if the rules of preparation are respected. It started with recoding, using paper or an electronic document, basic product information. In its second stage of development, in the year 2008, IoT integrated with traceability systems and made real-time data sharing across the whole supply chain possible. And now, in its third stage of development, we are able to enhance the traceability system with Artificial Intelligence (J. Qian et al., 2020). Not only did the technology improve, but also rules and regulations shaped this revolution in traceability systems. For example, in the European Union, EC 178/2002 states that food operators must integrate traceability in their production chains (EU, 2002), recording the supplier, and customer addresses and names, amount exchanged, the date of delivery and the product names. This is the principle of the "one-step-back-one-step-forward" approach adopted by the EU (EU, 2002). This is with accordance with the tracking and tracing, retrospective analysis proposed by Schwägele in 2005 (Schwägele, 2005). While tracking enables the verification of the path of a product downstream, tracing gives us the ability to verify its origin in the opposite direction. This is essential to any traceability system, alongside the main core entities (product and activity) and its structure (route and extent). Besides that, traceability systems primarily rely on traceable resource units or TRU, usually grouped into batch, trade or logistic unit and is referred as a "quantity that undergoes the same processes" (Aung & Chang, 2014) with allocated identities assigned by keys or other identifiers, that can be read with RFIDs or barcodes (Ruiz-Garcia et al., 2010). Needless to say, that no batch, logistic unit or trade can have the same identifiers as another one. This is to achieve the following objectives: companies can now increase the quality of their food products to diversity from competitors, elevate the efficiency of their supply chain in terms of management and simplify food safety and quality traceability (Golan et al., 2004). For example a solution was developed to monitor meat, its process and delivery dates during the whole production cycle until it reaches the consumers' table (Mousavi et al., 2002), a tracking and tracing prototype for agriculture batch products was introduced by Ruiz-Garcia et al., 2010 ; so that farmers can decrease their exposure to safety liability risk and increase their production in a cost-effective manner; for example, Personal Digital Assistant or PDA technology allowed cucumber growers to trace in real-time and keep record of their field; and finally, to increase consumers' confidence and trust in the food they consume.

Nevertheless, we are always observing a tendency from consumers to increasingly demand more and more information and data integration in the food management, and processing sector. This trend is paving the way for smarter and more sophisticated traceability systems that can offer a competitive advantage to some food producers who market not only their product, but also the data and information about its processing through its whole value chain as well.

3.2 Resilient Food Supply Chain Systems using Blockchain

The global food supply chain has been challenged in recent years due to various factors, such as climate change, pandemics, and economic crises. While Blockchain technology has shown promise in enhancing the traceability, transparency, and security of the food supply chain, thereby reducing the likelihood of food fraud and ensuring the safety and quality of food products, it becomes essential the FSC have the capabilities to adapt and recover from the potential fraud incidences shocks.

In this State-of-the-Art (SOTA) report, we discuss the application of blockchain technology in building resilient FSC systems with integrated IoT devices, that are monitored and controlled by tools that include all the constraints that can impact the FSC and provide end-to-end visibility (Dasaklis et al., 2022).

3.2.1 SOTA including comparison

Any FSC is vulnerable to disruptions, such as natural disasters, foodborne illnesses, and of course fraud. While there is a growing interest in using blockchain along with IoT (Balamurugan et al., 2022) technologies to create more traceable, transparent and trusted food supply chain systems (Marchese & Tomarchio, 2021), the need for FSCs to increase their resilience in the risk of vulnerabilities and frauds becomes more and more essential. Supply chain resistance is wrongfully linked only with the capability of resisting to the negative effects of a disruption, but it refers also to the ability of the FSCs to maintain its operational efficiency in supporting the value chain (Cin7, 2023). Towards increasing the resilience of the FSC in the risk of food vulnerabilities and fraud incidences, Blockchain technology can be utilized for the quicker identification and removal of the adulterated food products from the production/ distribution/ processing line and make the FSC related information more accessible streamlining the flow of information end-to-end along the path from farm-to-fork. To this end, we chose to compare two popular and widely-used blockchain solutions, namely Hyperledger Fabric and Ethereum that their implementations are used for many blockchain enabled agrifood FSC systems.

Hyperledger Fabric (Gao et al., 2020) is a blockchain platform that has been developed as an open-source solution from the Linux Foundation, with a specific focus on catering to the requirements of enterprise use cases. It provides a modular architecture that allows the customization of the consensus algorithm, membership services, and smart contract execution. Hyperledger Fabric also supports private transactions and permissioned networks, which make it a suitable choice for supply chain applications that require privacy and scalability. By allowing control of the participants membership, Fabric establishes a more secure and resilient network of transactions. Moreover, Hyperledger Fabric's Modular architecture, which allows the creation of different multiple channels that represent smaller groups or subsets of the participants and their corresponding transactions in the FSC, enables the separation of the data and the related operational processes, thus allowing for resiliency in operation management of the FSC when a fraud incidence occurs, and/or is identified and the operational processes and the related products are being segregated.

Ethereum is a Blockchain platform that can also support the execution of smart contracts (Ethereum, 2023; Omar et al., 2022; Salah et al., 2019). It provides Solidity which is a programming language that offers Turing-completeness and enables developers to compose intricate smart contracts capable of automating the implementation of business logic and automate and enforce agreements among different participants. Through smart contracts fraudulent activities can be prevented or minimized, as smart contracts are executed based on predefined rules, thus reducing the risk of human error or intentional manipulation and increasing the operational resiliency of the FSC. In case of a fraud being identified, the smart contract is self-enforced, e.g. can be used to exclude the identified adulterated parts from the FSC line and calls for the mitigation plan to be executed. Moreover, through decentralized Identity management, Ethereum allows for verifiable credentials and allows the participants within the FSC to evaluate the trustworthiness and credibility of other participants/suppliers before executing the business transaction or the smart contract. In case of a low trustworthiness level of a specific supplier, the user can deny the execution of the transaction and reduce the risk of products stemming from low reputation supplier entering the supply chain. Ethereum also supports the development of decentralized applications (DApps) that can interact with the blockchain network.

3.2.2 Innovation through ALLIANCE (Beyond SOTA)

The use of Blockchain technology to enable resilient food supply chain systems poses great potential for innovation and progress beyond the state of the art. It is apparent that the use of blockchain can improve the security and transparency of the FSCs, and enable increased traceability along the supply chain path. However, in order to build resilient food supply chain systems with the use of Blockchain that can maintain their operational efficiency several aspects should be considered. First, real time monitoring (with IoT) and assessment (with AI/ML) of the critical control points in the FSC can be used on one hand to timely detect and prevent fraudulent activities within the FSCs, but also it can be used to minimize associated risks that are linked with supply and demand uncertainties, price fluctuation differences when a particular product has an outlier value in any of its accompanying data before entering the FSC. Despite the fact that Blockchain are tamperproof systems that can ensure data integrity, assurance of the veracity of the quality-label status of the food products is a challenge to overcome as it requires all processes within FSC to be fully automatized and prevent human interventions. In addition, this can allow also the seamless automated execution of the smart contracts minimizing the risk of human intervention improving the capability of the system to faulty or suspicious products. The aforementioned aspects constitute challenges that we aim to explore through ALLIANCE and through continuous research and development to deliver Blockchain enabled solutions that improve the resiliency of FSCs in the case of food fraud incidences.

3.3 Vulnerability Risk Assessment for Critical Control Points Identification in quality-labelled FSCs

Vulnerability risk assessment and critical control point identification are two important aspects of ensuring food safety in the FSC system. Vulnerability risk assessment involves all processes used for identifying potential vulnerabilities within the food supply chain that may compromise the safety and quality of food products. It includes a comprehensive analysis of the entire supply chain, end-to-end from farm to fork, with an aim to identify potential hazards that could arise at each stage of the FSC. This could include biological, chemical, and physical hazards, as well as the potential for intentional adulteration, counterfeiting, or fraud.

Once these vulnerabilities have been identified, it is important to prioritize them based on their potential impact and likelihood of occurrence. This allows food supply chain stakeholders to allocate resources more effectively with an aim to prevent and mitigate these risks.

On the other hand, critical control point identification involves all processes used for identifying the specific pain points within the food supply chain where hazards can be controlled or prevented. These points are known as critical control points (CCPs), and they can include all processes that control raw material/products production and processing to packaging and distribution. By identifying these CCPs, food supply chain stakeholders can implement specific countermeasures to control and monitor the potential hazards at each stage. This may involve implementing food safety protocols, such as good manufacturing practices (GMPs) or Hazard Analysis and Critical Control Points (HACCP) systems.

3.3.1 SOTA including comparison

3.3.1.1 Methodologies

HACCP is a food safety management system that is Internationally recognized and has been adopted as a tool for ensuring safe food products and production by commercial food processors. This management system was originally devised by Pillsbury in the early 1960s to produce safe food for the space industry, upon request by NASA (*SAFE FOOD ALLIANCE*, 2019). With the passage of time, the food industry adopted the system, which was subsequently standardized by the CAC and is currently utilized worldwide. The implementation of regulations in the European Union is carried out through Commission Regulations 852/2004 and 853/2004. Risk management through HACCP has been well-known applied management system for food safety. However, HACCP principles have not been designed to detect or mitigate deliberate attacks on a system or process. Such attacks include deliberate contamination, electronic intrusion, and fraud. The relatively new concepts of TACCP (Threat Assessment and Critical Control Points) and VACCP (Vulnerability Assessment and Critical Control Points) have been introduced to the foreground aiming at tackling and preventing specific potential adulteration opportunities within the SC. The following picture shows the main differences among those systems.

Figure 15: Differences among HACCP, TACCP and VACCP. (Source: https://www.fssc.com/)

Nevertheless, these systems share common steps (from building multi-disciplinary teams, conducting risk assessment, creating plans continuous monitoring and analysis of threats or vulnerabilities and continuously reviewing and revising the plan to accommodate new strategies against risks and stay updated) on diversified methodologies to achieve different objectives (globalfoodsafetyresource, 2023; Saiassurance, 2021). Particularly, the TACCP approach is primarily focused on safeguarding food security and involves a methodical approach to risk management that entails assessing potential threats, identifying vulnerabilities, and implementing appropriate controls across various aspects of the food supply chain. These include materials and products, procurement processes, premises, personnel, distribution networks, and business systems. The TACCP team, which is composed of experienced and reliable professionals with the necessary authority to effect procedural changes, is responsible for executing this approach, while VACCP targets at Food Fraud and involves identifying the points in the food production process where intentional adulteration or contamination could occur, and then implementing controls to reduce the risk of those vulnerabilities being exploited. This includes assessing the risk of intentional contamination by insiders, such as employees or contractors, as well as by outsiders, such as terrorists or competitors. VACCP involves conducting a vulnerability assessment to identify the potential vulnerabilities in the food supply chain, evaluating the risk associated with each vulnerability, and implementing control measures to prevent, detect, and respond to any potential food fraud incidents. The motivation for using Food Defence Management Systems the need for protection against the intent to cause harm to consumers or businesses, whereas the motivation for Food Fraud Management Systems is the need for protection of consumers against unlawfull practices for economic benefit that is linked to food adulteration and fraud. The motivation for Food Defence is the intent to cause harm to consumers or businesses, whereas the motivation for Food Fraud is exclusively for economic benefit.

3.3.1.2 Standards

To strengthen and harmonize food safety standards around the globe, GFSI (which stands for the Global Food Safety Initiative) - a collaborative platform of leading food safety experts, retailers, manufacturers, and other stakeholders - benchmarks various food safety certification programs against its own requirements, helping to ensure that they are consistent, effective, and reliable.

The GFSI Requirements on Food Fraud Include two fraud mitigation steps: 1) Require a company to perform a food fraud vulnerability assessment, to identify potential vulnerability and prioritise food fraud mitigation measures and 2) use a control plan that the company can follow (GFSI Global Food Safety Initiative, 2014). In order to mitigate any potential public health risks that are reliant on the food fraud vulnerabilities.

GFSI adopts VACCP as a key component of its food safety management systems. VACCP is a preventative measure that helps to identify and mitigate the risk of intentional adulteration or food fraud in the FSC. This includes actions such as product substitution, counterfeiting, and intentional contamination. GFSI recognizes the importance of VACCP in ensuring the safety and integrity of the food supply chain and requires that food safety management systems include measures to prevent food fraud. As such, many of the GFSI benchmarked schemes, such as BRCGS (BRCGS, 2023), FSSC 22000 (FSSC, 2023), and SQF(SQFI, 2023), have incorporated VACCP into their food safety management systems.

3.3.2 Innovation through ALLIANCE (Beyond SOTA)

Blockchain and IoT (Internet of Things) technologies have the potential to greatly enhance the effectiveness and efficiency of VACCP systems in the FSCM.

Blockchain technology can record and verify transactions or events in a secure and transparent way. It can be used to create an immutable and transparent record of food products' end-to-end journey from farm to fork, improving traceability, accountability, and transparency in the FSC, making it easier to identify the source of any contamination and take appropriate actions to mitigate the risk. Thus, ensuring that the food is safe and free from contaminants throughout the entire supply chain. Moreover, IoT technology, involves the use of connected devices and sensors that can monitor and track various aspects of the food supply chain, including temperature, humidity, and other environmental conditions.

In ALLIANCE, by combining Blockchain and IoT technologies, we aim to improve the robustness and effectiveness of VACCP systems by enabling sensors and connected devices to gather data on temperature, humidity, and other conditions during transportation and storage, which can then be recorded on a blockchain ledger. By integrating VACCP with Blockchain and IoT, the performance of critical control points can be continuously monitored, enabling real-time validation and verification of results complying. The result of a CCP measurement can be verified by the consensus mechanism of the Blockchain platform. If any issues arise during transportation storage or in any other step of the FSC, the blockchain can provide a transparent and tamper-proof record of history (measurements, time and location), allowing timely actionable decision-making for addressing the issue. Moreover, in the context of ALLIANCE we aim to explore how self-executed smart contracts can be leveraged to automate and streamline compliance procedures, identify food fraud vulnerabilities and inform the responsible actors, reducing the time and cost required for manual inspections and audits. This can improve overall efficiency and productivity, while also enhancing the safety and quality of the food supply chain.

3.4 AI-enabled Early Warning and Decision Support System

3.4.1 SOTA Including comparison

Food fraud poses a significant threat affecting not only the integrity of the food supply chain but the public health as well (Manning, 2016; Spink & Moyer, 2011b). Continuous monitoring and digitalization, e.g., using Blockchain technology, of the food supply chains can provide increased transparency and traceability capturing all complex networking routes. However, additional smart mechanisms are required to measure the operational performance which needs to adhere to increased standards requirements for GI and organic food. These mechanisms can help detect and prevent food fraud incidents in the production lines and supply networks (Aung & Chang, 2014c; Umezuruike, 2003).

An AI-enabled Early Warning and Decision Support System for food fraud prevention can be a powerful tool in mitigating the risk of fraudulent activities in the food supply chain. This system can use predictive analytics, machine learning algorithms, and data from various sources to identify potential areas of vulnerability in the supply chain and alert stakeholders to potential fraud incidents. The system can be designed to monitor a wide range of data, including supplier and vendor information, product quality data, and supply chain transactions. By analysing this data, the system can identify patterns and anomalies that may indicate fraudulent activities, such as the use of unauthorized ingredients or the mislabelling of products.

One of the key benefits of this system is its ability to provide early warning alerts, which can help stakeholders take proactive measures to prevent fraud from occurring. For example, if the system detects a pattern of suspicious activity, it can alert stakeholders to investigate further, take corrective action, and prevent further fraud from occurring. Another potential benefit of an AI-enabled Early Warning and Decision Support System is its ability to provide decision support to stakeholders. By analysing data and providing insights, the system can help stakeholders make informed decisions about risk management, supplier selection, and other critical areas.

Overall, providing the opportunity to make on-time and accurate decisions to combat food fraud, based on insightful information that will be result of automated predictive analytics and thorough AI-based assessment of various factors and parameters (e.g., price fluctuations, food supply chain performance measurements, operational conditions), will allow producers and processor to develop strategic food fraud mitigation plans.

3.4.2 Innovation through ALLIANCE (Beyond SOTA)

An AI-enabled Early Warning and Decision Support System (EWDSS) for food fraud mitigation has a high innovation potential and can go beyond the state-of-the-art in several ways. To this end ALLIANCE will incorporate advanced AI mechanisms and predictive analytics to conduct continuous vulnerability risk assessment for detecting food fraud and blind holes across the food supply chain and leverage prescriptive analytics to propose insightful recommendations to actors for making preventative interventions and plan actionable policies against food fraud. The vulnerability risk assessment will cover several food chains and will be applied on the organized demonstrative Pilot studies.

First, EWDSS can integrate and analyse multiple sources of data, such as supply chain data, market data, and consumer data, to identify potential risks and early warning signals of food fraud. By applying machine learning algorithms and predictive analytics, the system can continuously monitor and analyse data to detect patterns and anomalies that may indicate fraudulent activities. Second, the system shall leverage advanced technologies such as Blockchain, IoT, and Big Data analytics to ensure the traceability and transparency of the entire SC. This can help to identify and isolate the source of any fraudulent activity and prevent further spread of contaminated or fraudulent products. Third, the system can enable decision-makers to make timely and informed decisions based on real-time data and insights. This can help to mitigate the impact of any fraudulent activity and prevent its recurrence in the future.

Overall, ALLIANCE's framework for vulnerability risk assessment will encompass sensing IoT, AI, Big Data Analytics and Machine Learning technologies to complement the Blockchain functionality aiming to monitor food supply chains, collect and analyse historic and real-time data along the FSCs, detect fraud issues that compromise the integrity of food supply chains, thus enhancing producers' ability not only to plan and ensure food quality, but also to protect the identity and ensure authenticity of their food products.

3.5 Interoperability Mechanisms in Complex Food Systems

3.5.1 SOTA including comparison

Interoperability pertains to the capacity of different networks to communicate and exchange information with one another in an effective and seamless way. In other words, interoperability refers to the capacity of disparate systems to effectively collaborate, share information, and facilitate the transfer of value among them. Furthermore, the absence of interoperability between hardware or software platforms in the agricultural sector results in technology users, such as farmers, being constrained to a user-agreement with a particular company (Glaros et al., 2023). This presents a technical obstacle for farmers, resulting in a less efficient and more time-consuming approach to business management. In addition, the findings of a study (Glaros et al., 2023) indicated that medium-scale farmers encountered significant difficulties due to the absence of inter-platform interoperability. Additional time and effort are needed to execute recurring duties, such as inputting identical inventory information on various platforms, which can result in frustration and, in some cases, cessation of platform utilization. In the light of this, the INTER-IoT methodology endeavours to furnish unobstructed interoperability, thereby facilitating vendors and developers to interact and interoperate while preserving their ability to compete by delivering a superior product and experience (Fortino et al., 2018). In addition, it facilitates the design and expeditious market entry of IoT devices, smart objects, and/or services for any enterprise, thereby establishing novel IoT interoperable ecosystems, considering the lack of universal IoT standards. Moreover, in Kayikci et al., (2022), it is stated that the establishment of universal guidelines for the acquisition and dissemination of data enhances the compatibility between stakeholders in the FSC and enhances the precision and availability of data. Nonetheless, accomplishing this objective poses a significant challenge given the intricate global landscape within which the FSC operates.

Another study, the objective of which is to develop a secure resolution for the interoperability of blockchain technology, proposed a methodology that entails the utilization of a relay scheme that is founded on the Trusted Execution Environment (Bellavista et al., 2021). Furthermore, Blockchain can enhance the implementation of interconnected and expandable food traceability systems through the utilization of GS1 standards (GS1, 2023; Keogh et al., 2020). Blockchain is considered as a viable solution that can have a beneficial effect on collaborations and data sharing within the FSC. The utilization of blockchain technology facilitates the establishment of a comprehensive and inclusive framework that fosters an unparalleled degree of transparency and visibility of food products during their exchange among FSC partners. The integration of Blockchain technology with GS1 standards enhances the level of interoperability among exchange parties in global Food Supply Chains (Keogh et al., 2020).This integration also enables a shift from the conventional or linear SCs that operate in silos with restricted data sharing.

3.5.2 Innovation through ALLIANCE (Beyond SOTA)

Enhancing interoperability can be achieved through the utilization of standardized protocols. It is imperative to implement this approach as it guarantees the longevity of networks from their inception. Moreover, it would facilitate the development of a robust ecosystem while circumventing any potential problems related to vendor lock-in (Bhat et al., 2021). This is a matter worth contemplating for companies involved in the installation of blockchain technology. While the majority of platforms operate as isolated systems, it appears that technological advancements are leading towards a paradigm that has the potential to facilitate an interconnected network of networks. Adherence to a standardized set of blockchain implementation protocols is imperative to prevent the solution from lagging behind. The proposed initiative by ALLIANCE aims to establish a Food Supply Chain Interoperability Management Framework that will facilitate the seamless and reliable collaboration and sharing of information of different FSCs. Additionally, it will harness the potential of sensor systems and data analysis tools to enhance the efficiency and security of the FSC. Through ALLIANCE we aim to address the issues of inadequate interoperability and suboptimal performance efficiency in relation to data veracity. To achieve this, the project will establish a service architecture that expands upon the data model of GS1 EPCIS. This architecture will incorporate hardware and software interoperability layers that facilitate the collection and dissemination of data from various sensors. Additionally, a range of specialized analytical techniques will be investigated and used to enable the extraction of insightful information from data, reports or visualisation.

3.6 Technology limitations and gaps for Food Traceability in the literature

Before diving into the technological gaps in current traceability systems, it is necessary to acknowledge the existence of other, non-technological problems that immensely affect operating traceability chains and important economic sectors. Members of the food supply chain currently use two methods to safeguard food safety and quality and boost customers' trust. The first being with regulations and standards to manage the food supply chain. The second one is through a traceability system that keeps track of all logistical operations (track and trace). In the results of our Delphi method, we observed a clear gap in the French regulations that packers capitalized on. Here we are talking about honey packers outside the French territory, mixing different kinds of honey, from different origins, without the need or obligations to specify the percentages of honey mixed. On the other hand, inside the French territory, packers and honey producers (beekeepers) are required to specify the origin of honey, the name, its origin, and in case It Is mixed with other types of honey, the percentages. This situation is creating an unfair competition, driving down the price of honey and putting local beekeeper's livelihood and future at risk, alongside all the pollination services they provide. This situation shows how vital it is to have in place adequate rules and regulations, to ensure the proper functioning of important economic sectors. Moving on to the technological gaps in traceability systems, starting with one of the most modern tools: Artificial Intelligence, or AI for short. It is used in decision support and early warning systems. The challenge here lies with the provision of advanced mechanisms whose goal is measuring the performance of multiple operations requiring them to be conform with the current and everchanging standards for organic food and GI for example (Aung & Chang, 2014c; Umezuruike, 2003). Moving on to Blockchain technology, and because of the vulnerability of food supply chain, they remain very exposed to natural disasters, supply chain fraud, food born illnesses and other disruptions. Consequently, blockchain technology is gaining interest in FSC (Marchese & Tomarchio, 2021). However, this technology requires a lot of resources to build and maintain, has limited scalability, demands abrupt learning necessity and a high energy consumption. Another challenge is the present inconsistency in conventional labelling, the later, with the provided data, does not lead to increased customer's trust in the product. The need is urgent for quality information validation procedure based on modern tracking and tracing methods (Beulens et al., 2005). Meaning that it is time to fulfil this technological gap, by providing stakeholders with product-tracking and tracing tools, to help businesses in the origin identification process in quality control situations (Golan et al., 2004). Another problem facing food traceability is the nature of the chain itself. The most obvious difference between other chains and food chains lies in the fact of the continuous changes from the time raw materials are harvested from farms, until they reach their final destination. To maintain the quality and safety of food as it changes hands, several times, through the whole supply chain is a key task. The cold supply chain is a perfect example, those products are highly perishable and vulnerable to environmental changes such as light, humidity, temperature etc. Thus, they require additional qualitative and logistical tracking opening the way for the need of real-time traceability, which is in itself a technological challenge. In the case of a food outbreak, a traceback investigation, which is a method to identify the origin and distribution line of product responsible of the food born outbreak, can be very time-consuming especially in the case of absence of distribution records and proper labelling (already cited as a technological problem), the operation might become more complex, if not to say Impossible to achieve. These problems originate from the limited use of modern and advanced technological tools and the absence of rules to adopt these technologies as well, that allow stakeholders to conduct traceability operations efficiently and rapidly.

Additional constraint found in literature pertains to the lack of interoperability. In the agricultural sector, interoperability between software or hardware platforms obliges farmers and other technology users to operate with a single enterprise which result in decreased efficiency and additional time to conduct business. This goes without mentioning the supplementary effort and time needed to perform recurring actions, resulting in confusion and termination of platform usage (Glaros et al., 2023). Additionally, the compatibility between various networks is not guaranteed, and there is an absence of universal data standards. Facilitating active collaboration between companies with varying levels of technological maturity in terms of data collection and propagation of relevant information to end-users is likely to pose a significant challenge (Katsikouli et al., 2021). Furthermore, it must be acknowledged that in some regions where the raw materials are gathered, technological expertise may be limited and there may be no dependable internet connectivity. In addition, farmers are required to operate with a collection of ICT tools that frequently produce data that is poorly interoperable (Marvin et al., 2022). This results in a significant challenge in consolidating farm-generated data in a manner that is both usable and trustworthy, as well as transparent, robust, and under control.

4 SOTA on Food Safety and Authenticity

4.1 Food Fraud: Context of Safety and Quality

The terms of quality and safety are often confused and considered as the same. According to (FAO, 2003), food quality consists of the aspects of food from the consumer's point of view, including all types of contamination, spoilage, origin, flavour, and texture. On the contrary, food safety consists of the hazardous aspects of the food that can negatively affect the consumer. As shown from the most cited articles, Spink & Moyer (2011) have also provided definitions of food quality and food safety, underlying that in most cases these events are unintentional as shown below. On the following lines these two definitions are presented.

Food alteration is an unintentional spoilage or deterioration of food that leads to economic loss due to lower quality or soiled product. This can be attributed to the specificity of products, whether it is physical or chemical, that is abiding to industry standards. Meanwhile food fraud can lead to economic losses, as a result of unsuitable product, lower margins, lost tax revenues, or brand equity damage, as a result of occurrences or consumer concerns. Food quality incident, even if unintentional, remain as a food safety incident.

On top of that, from the manufacturer's point of view, quality refers to a combination of characteristics that are essential for the commercial success of a commodity (Singhal et al., 1997).

Food Safety incident: Food Safety incident is an unintentional act of food contamination, by known ingredients, organisms, mishandling, or processing. On the contrary, food fraud is an intentional act with the aim of economic gain. Unconventional adulterants remain unknown until handled in food fraud cases, which is not the case in food safety cases. Food fraud and food safety both lead to public health risk (Spink & Moyer, 2011a).

Both definitions are providing a multidisciplinary approach (economic, environmental and social aspect), as it has been introduced through the Sustainable Development Goals (United Nations, 2023). Economic losses and increased medical expenses can be considered as direct negative externalities, if food fraud is not addressed in a timely manner. Food spoilage is another effect of low food safety and quality standards, leading to negative environmental effects, by increasing deficiency and carbon footprint (Aung & Chang, 2014d). Regarding the social aspect of the above-mentioned terms, public health is directly affected by unsafe food. Many outbreaks have been witnessed, such as the 2013 horsemeat incident in processed beef, and the 1981 toxic Spanish olive oil. These incidents highlight the importance of Food safety and its maintenance across the FSC.

As mentioned above, food fraud has no universally accepted definition. It is often identified as the intentional substitution, tampering, or misrepresentation of a product to the consumer. Nevertheless, food fraud is one of the major concerns and challenges that threaten the safety, quality and authenticity of FSC. Different classification and categorization of food fraud have been covered in several publications. In general, two main categories can be recognised 1) packaging and appearance of the product, 2) product composition and state. Moreover, according to (Brooks et al., 2021) seven primordial categories can be identified:

Table 5: Primordial Food fraud categories (Brooks et al., 2021)

Food Fraud type	Definition
Substitution	Replacement of an ingredient with another of lower value
Dilution	Incorporation of a cheap ingredient in a higher value product without declaration

Counterfeiting	Illegal imitation of a legal product and package
Mislabelling	Wrong or missing information on the label or product document
Concealment	Hiding damage or spoilage of a product or one of its ingredients
Gray Market	Trading product outside of a legal market
Unapproved Enhancements	Use of undeclared procedure and undeclared substance to improve food quality

Additionally, the results of the study of Visciano & Schirone (2021) are confirming that food fraud cases were mainly concerning unapproved enhancement, substitution, mislabelling, and inappropriate documentation, for the time period 2015-2019.

Quality and safety management is critical to control all the FSC phases, and to prevent food fraud. Many food management systems provide a guidance to manufacturers to ensure, and implement quality and safety standards in the FSC. These are divided into three main preventions subtitles: food safety is the science targeting the limits for unintentional adulteration (e.g., HACCP), food defence focuses on intentional adulteration and is more behavioural oriented (e.g., TACCP), and food fraud tackles the intentional adulteration as well, but in an economical context (e.g. VACCP)(Pustjens et al., 2016).

4.2 Next Generation portable DNA Sequencing for Food Analysis

4.2.1 SOTA including comparison

Food safety and authenticity are major concerns throughout the entire food production and distribution process. There are several methods currently used for identifying food adulteration, including spectroscopic, chromatographic and protein approaches. Even though spectroscopic methods serve as powerful analytical tools, there is still the limitation of expensive ultra-sensitive instrumentation requirements. Moreover, the contemporary analytical instruments, which enable the retrieval of vast chemical information, have emerged as a consequence of the interdisciplinary connections among various research domains, including food, computer, engineering, and analytical sciences and fetch information from many samples quickly and in some cases with less personnel effort. However, the commonly employed traditional methods despite their ability to detect adulteration based on marker compounds, come with critical caveats of diverse nature and impact Table 6

Table 6: Comparison of different discrimination methods available for detection and quantification of adulterated extra virgin olive oil

Discrimination Methods	Advantages	Disadvantages
GC	Stable and traditional methods for discrimination of adulteration of EVOO	Time consuming sample extraction
	Exhibit higher sensitivity and efficiency	Higher temperature oven may degrade test sample
	Accurate and precise	Well-trained personnel
	Rapid separation and analysis	
	Less sample required	
IR	Minimum sample preparation	Time consuming data analysis
	Non-destructive and rapid determination	Calibration curve construction
	High reproducibility	Well-trained personnel
Raman	Non-destructive	Fluorescence of adulterant can interfere with spectra

	No sample preparation	High intensity laser can cause sample degradation
	Less sample required	Well-trained personnel
	Rapid method	
HPLC	Easy to use	Expensive
	Highly precise	Time consuming sample extraction
	Fast/high resolution	Laborious to develop new methods
		Cumbersome to troubleshoot
NMR	Short analysis time	Expensive
	Moderate sample preparation	Low sensitivity requiring a large amount of sample
	Non-destructive	Well-trained personnel
DSC	Easy to use	Solely quantitative
	High speed analysis	Time consuming sample extraction
	Less adverse impact environment	Impossible to detect adulterants of high oleic vegetable oils by deconvolution analysis

Moreover, using proteomic approaches might meet the needs of a food authenticity process, though it can be labour-intensive and expensive to prepare reagents. Depending on the type of adulteration, DNA-based methods may offer a more accurate and effective method for food authentication. In most cases, DNA-based methods exploit the sequencing of specific DNA sequences to extract information about the components of a tested product. Although these molecular methods are widely used, they do have some limitations, the most significant of which is their lack of high-throughput impact. Next Generation Sequencing is emerging as an increasingly important tool in this regard, as it enables simultaneous screening of multiple genomic regions, thereby enabling the identification of all components in food samples (Haynes et al., 2019; Hong et al., 2017). Next Generation Sequencing is already used in many areas within food analysis serving as a promising tool for authentication purposes, however its cost and specialized expertise requirements are limitations yet to be addressed.

4.2.2 Innovation through ALLIANCE (Beyond SOTA)

The FSC encompasses multiple stages, from food production to the end consumer. However, food fraud and adulteration can occur at any point in the SC, leading to mistrust and loss of confidence among consumers. As these problems continue to grow, there is a pressing need for new technologies that can provide stakeholders with accurate and efficient testing capabilities to monitor the situation. To overcome these drawbacks, it becomes imperative to invest on innovative methods and instrumentation with the aim to develop rapid, accurate and environmental-friendly techniques for the detection and quantification of Extra Virgin Olive Oil (EVOO) adulteration. The implementation of high-throughput sequencing methods has transformed DNA into an accessible source of information, and bioinformatics into a science capable to translate DNA data into meaningful biological knowledge. This includes the identification of novel genetic markers, reflecting the genetics differences amongst species and/or within the same species. As a result, such capacity of distinguishability clearly represents a pivot in the DNA-based food authenticity, with its major advantage being the accuracy and consistency of results. By leveraging advanced DNA-based approaches, including a portable device Figure 16 capable of conducting on-site DNA-authentication tests for food authenticity purposes, while the DNA-data are then fed to a ML/AI pipeline that will classify them according to their varietal composition, will enable all food industry actors to monitor each stage of the supply chain with greater transparency and accuracy. Lastly, the utilization of a blockchain system that will host the DNA-results is an innovative step that will strengthen the trust-bonds of all the stakeholders among the value chain. This will provide increased validity to food products and enhance the confidence and trust of the consumers.

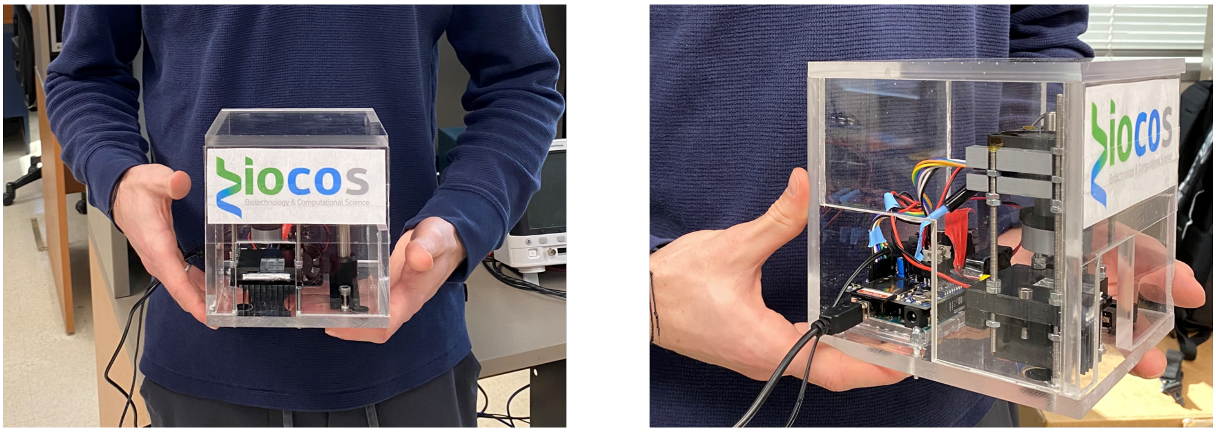

Figure 16: Prototype of portable device for DNA-based authentication

4.3 Food fraud detection with Advanced Spectroscopy

4.3.1 SOTA including comparison

(Near Infrared Spectroscopy (NIR) and hyperspectral imaging have demonstrated promising results over beans, with both desktop and portable devices. For example, Plans et al. (2013) proposed dispersive NIR, FT-NIR (Fourier Transform Near Infrared Spectroscopy technology) and MIR (mid-infrared spectroscopy) using laboratory benchtop and portable instruments for the determination of the main components in ground endosperm of common beans (protein, starch, and amylose). The study employed Partial Least Squares Regression (PLSR) to establish a correlation between the spectra matrix and the reference value. The regression model was subsequently validated through full-cross-validation. The portable systems for near-infrared (NIR) and mid-infrared (MIR) spectroscopy exhibited favourable predictability. In another article, Hermida et al. (2006) determined moisture, starch, protein, and fat in common beans (Phaseolus vulgaris L.) by NIR spectroscopy. A modified PLS was used to get predictions models. Square correlation coefficients of calibration above 0.9 were obtained for training, and above 0.88 for test data. Fat prediction models got worse results. Sensory properties prediction using NIR was also evaluated (Plans et al., 2014). The feasibility of using NIR to determine aroma, flavour, mealiness, seed-coat perception, seed-coat brightness, and seed-coat roughness in common beans was evaluated (eleven trained panellists). Spectra of raw, undried cooked and dried cooked beans common were used. Good results were achieved for flavour and mealiness. Finally, there are not so many scientific works using hyperspectral imaging. An example is Mendoza et al. (2018) that used this technology to predict dry bean cooking time. PLS models were developed from hyperspectral images to forecast the absorption of water and duration of cooking for both soaked and unsoaked beans.

Only two articles have been found using NIR and Hyperspectral technology to discriminate varieties of beans. Sun et al. (2016) explored the efficacy of visible and near infrared hyperspectral imaging technique, operating within the wavelength range of 390–1050 nm, for the purpose of discriminating between different varieties of black beans (Anhui, Liaoning, Jilin varieties). In this study, 3 classification techniques, based on spectral feature, image feature, and the combination of spectral and image features, were used. The findings indicate that the optimal rate of correct discrimination, which was 98.33%, was attained through the utilization of a fusion of spectral and image features. The second article by Qian et al. (2022), demonstrates the use of FT-NIR to establish origin (4 origins) and variety (5 varieties) of Baha Siber mung bean in order to protect a geographically Baha Siber mung bean. The best model for origin prediction has a coefficient of determination of R2=0.9802, and for variety prediction has a coefficient of determination of R2=0.9683. This method provides a new brand protection way for geographical indication products of mung bean.

NIR is usually used in discrimination of origin and varieties of different kind of grains. In Kabir et al. (2021), authors claim that visible and Near-Infrared Spectroscopy (Vis-NIR) combined with machine learning techniques can be an essential tool for tracing the origin of millet, contributing to a safe authentication method in a quick, relatively cheap, and non-destructive way. This methodology was employed to differentiate among 16 distinct varieties of millet that have their origins in diverse regions of China. Five machine learning techniques were used to train the model for classification purposes. These techniques provide F-score (harmonic mean of the precision and recall) values between 0.988 and 0.995. Marquetti et al. (2016) used partial least squares discriminant analysis (PLS-DA) and near infrared spectroscopy to analyse different coffee genotypes that were cultivated in Brazil. 94.4 % of correct classification of validation samples was achieved using the best model. NIR was utilized by Ziegler et al. (2016) to distinguish between flours and kernels of high-value ancient species and less expensive bread wheat. They claimed that NIR is a rapid and powerful method for product authentication. They used flour and kernels of wheat (homogeneous and heterogeneous, respectively) and PLS-DA model to get accuracy values of 80–100%. Besides, the detection of adulterations of spelt flours with bread wheat flours was also feasible. A good example of tracing the geographical origin of lentils using NIR is described in Innamorato et al. (2019). This work discriminates lentils from two origins, Italy and Canada. FT-NIR and FT-MIR spectroscopy was used. FT-NIR provided a prediction ability from 91 to 100% for cross- and external validation. Also, hyperspectral image was used to discriminate varieties. For example, Zhang et al. (2012) used hyperspectral image to discriminate among six varieties of commodity maize seeds. Visible-NIR (380–1.030 nm) hyperspectral images of 330 samples were used to train machine learning methods and get 98.89% accuracy. Texture analysis was included in the work pipeline. A typical application to differentiate between two species is Arabica/Robusta coffee classification (Calvini et al., 2015). The present study employed near infrared hyperspectral imaging to analyse green coffee samples. The mean spectra obtained from each hyperspectral image were utilized to construct both the training and test sets. Sparse method and classical methods were applied and similar results were achieved. Results achieved 100% accuracy in grain classification and 90.6 % in pixel classification. A good example of hyperspectral imaging application to geographical Origin Discrimination is the work (rice application) of (Changyeun et al., 2017). The objective of this research was to put forth a technique utilizing visible/near-infrared (VNIR, 400-1000 nm) hyperspectral imaging to rapidly differentiate between domestic and imported rice based on their geographical origin. The models for discriminating geographical origin demonstrated a discrimination accuracy exceeding 99.99%.

In conclusion, it can be said that both NIR and hyperspectral imaging have their own challenges and opportunities in the field of discrimination of origins and varieties. Reviewing available literature on this topic, a major challenge has been identified for heterogeneous samples and their implications. Heterogeneous samples have differences in their spatial distribution and NIR technology performs just point measurements. When measurements are made on grain samples, a high number of repetitions over different parts of the sample should be performed, or a rotatory plate should be used to present sample to NIR probe. Another issue is the presentation form of the sample. Usually, flour of grains is used to take spectra, instead of whole grain. This is due to heterogeneity of grains and milling the grain facilitates access to the interior of the grain. Usually, the inner part of the grain is more related to physical-chemical properties of grains than skin. On the contrary, it is easier to take spectra from skin (direct) than flour (some preparation). So, it is important to explore different alternatives and compare them.

Hyperspectral imaging has no spatial measurements problems, quite the opposite to NIR. Hyperspectral technology can scan all samples. Samples are presented in a moving tray, or a conveyor belt and a hyperspectral image of the sample is taken (in-line). This is its major advantage compared with NIR. Still, technology has its own challenges. Presentation form of samples is a challenge like in NIR. Is it necessary to measure the inner of the grain? Or skin measures are enough? There is another major disadvantage, hyperspectral imaging is more difficult to handle than NIR. Disposition of the required elements (geometries), parameters of measurement (speed of tray, integration time, frame rate of lines acquisition, etc) and other multiple parameters are elements to consider. The above constitute challenges that have an impact on accuracy and on the reliability of the results. Moreover, developing a measurement protocol for people without a strong technical background is also a challenge. This protocol must be clear, concise and the operator can execute it in an agile way, being able to diligently solve the problems that arise.

4.3.2 Innovation through ALLIANCE (Beyond SOTA)

Through ALLIANCE, we aim to develop solutions based on advanced spectroscopy to effectively tackle the above challenges. The lack of efficient, widely accepted, and reasonable methods focusing on EVOO authenticity and traceability create opportunity to fraudsters to exploit its valuation, deceive consumers, undermine food safety/security and of as a result conduct unfair and illicit commercial practices. In ALLIANCE, we aim to leverage the capabilities of DNA sequencing method, by using on-site a portable DNA authentication and traceability system for the EVOO inspection and validation. Collecting DNA profiles at the olive orchards (by conducting a Geo-Genetic mapping) as well as, at every stage of the supply chain (milling, storage, bottling, retail), will be achieved through a portable DNA-based device that performs High Melting Curve analysis. The resulting DNA profiles, will be analysed with an AI/ML postprocessing pipeline with an aim to classify the variety of each lot of a label, creating a “digital DNA fingerprint". The aim is to safeguard this DNA fingerprint information using tamper-proof Blockchain enabled FSCs to improve the traceability and create trustworthy and transparent auditable FSC operational processes.

4.4 Digital Knowledge Base for Food Fraud

4.4.1 SOTA including comparison

While incidences of food adulteration and fraud has been increasing, due to the globalisation of supply chains and the complexity of transportation networks and logistics systems, the need to adopt methods and systems that can provide knowledge with an aim to improve the understanding of food fraud practices and operations and focus on safeguarding the authenticity and integrity of food, becomes more and more demanding. Apart from the aforementioned innovative technologies that aim to directly safeguard and improve the performance of FSCs against Food Fraud and the great attention and awareness that prevention and fight against food fraud is receiving from academia, industry, governments, environmental, food and health safety organizations and individuals, there is a need for a knowledge repository that provide and share reliable information for detecting and mitigating food fraud. Currently, a universal, community-accepted database that collects, processes and analyses everything related to the possibility of detecting food fraud is missing. Instead, there is a large number of very diverse databases and datasets, not all maintained or open access, representing a serious loss of knowledge (Sorokina & Steinbeck, 2020). Moreover, in this regard, a unified and universal repository is necessary to prevent the duplication of online resources and to streamline research on food fraud. Currently, most of the food fraud databases are commercial paid services that do not provide consultation or Information free-of-charge and cannot be accessed without payment or subscription fees. However, there are several European Initiatives and networks established for the fight against Food Fraud and provide tools and services for sharing knowledge and information regarding detection of food fraud incidences (Hong et al., 2017). Among the most well-known are those that arise as Knowledge Bases from EU-funded research projects as well as the Rapid Alert System for Food and Feed (iRASFF, 2023) and the EU Food Fraud Network (European Commission, 2023) that fosters collaboration and exchange of knowledge between the European Commission, member states, Europol (European Union Agency for Law Enforcement Cooperation) and Eurojust (European Union Judicial Cooperation Unit).

4.4.2 Innovation through ALLIANCE (Beyond SOTA)

Within ALLIANCE, the formation of a unique database (digital knowledge base) for preventing food fraud in quality-labelled food products will be created. The aim is to create a web-based portal (knowledge management repository), that can provide and share scientific knowledge on issues pertaining to food fraud. The main purpose of this portal is to provide a pool of knowledge, supporting increased searchability means, where all related articles, publications, and documents relevant to Food Safety, Food Authenticity, and Food Traceability will be hosted in a structured way and can be easily accessed. Moreover, ALLIANCE Knowledge Base will facilitate the interested readers acquire a comprehensive knowledge about historic data, incidences current practices, the challenges and the technologies that are related with the need to safeguard food-quality and prevent and mitigate unlawful practices and of course allow them to make informed decision choices. The database will be initially established using the results obtained throughout the implementation of the activities related to Arilje raspberries pilot study. Further on, the database will be updated with the data related to other products that are the subject of ALLIANCE.

4.5 Prevent Food Fraud with Predictive Analytics

4.5.1 SOTA Including comparison

The issue of food fraud is increasingly prevalent within the food industry, with projections indicating that it incurs significant financial losses for the global food sector annually. Food fraud pertains to the purposeful and calculated practice of misleading consumers or clients with the aim of obtaining financial benefit. With the increasing complexity of global food supply chains, it has become more difficult to detect and prevent food fraud.

Machine Learning (ML) techniques have shown great promise in detecting and preventing food fraud. One of the main advantages of ML is its ability to process large volumes of data from multiple sources, including sensory data, transactional data, and environmental data, to identify patterns and anomalies that may indicate food fraud. ML algorithms can be trained on large datasets of authentic and fraudulent food products to identify patterns in the data that are indicative of fraud. These patterns may include changes in product composition, abnormal levels of contaminants or adulterants, and unusual storage or transportation conditions. In addition to detection, ML can also be used for prediction, enabling food companies to anticipate potential risks and take proactive measures to prevent fraud before it occurs. For example, ML algorithms can be used to analyse data on suppliers, distributors, and other key players in the supply chain, to identify potential areas of risk and take preventative measures.

Predictive analytics can also be used to identify potential food fraud risks by analysing data from various sources, such as historical data on food fraud incidents, supplier information, market trends, and social media. By analysing this data, predictive analytics can identify potential fraud hotspots and provide early warning signals that can help prevent future incidents. The combination of ML and predictive analytics offers a powerful approach for food fraud prevention, enabling food companies to detect and prevent fraudulent activities before they occur.

However, there are also some challenges associated with the use of ML in food fraud prevention. One major challenge is the need for high-quality data, which is often difficult to obtain in the food industry due to the large number of variables involved. In addition, ML algorithms can be complex and require significant computational resources, which may not be available to all food companies.

4.5.2 Innovation through ALLIANCE (Beyond SOTA)

Food fraud prevention with ML and predictive analytics has great potential for innovation and progress beyond the state of the art. Here follow some potential areas for advancement:

1. **Integration with blockchain technology**: The use of blockchain can enhance the security and transparency of the FSC, which is a crucial aspect of food fraud prevention. The integration of blockchain with ML and predictive analytics can enable real-time monitoring of food products throughout the supply chain, reducing the likelihood of fraudulent activities.

2. **Multi-model approach**: The use of multiple models for food fraud detection can significantly enhance the accuracy and reliability of predictive analytics. Combining different algorithms and techniques, such as deep learning, anomaly detection, and network analysis, can help detect fraudulent activities that may go undetected with a single model.

3. **Real-time monitoring**: ML and predictive analytics can be used to monitor the food supply chain in real-time, enabling timely detection and response to fraudulent activities. This can help prevent fraudulent products from entering the market, reducing the risk to public health and safety.

4. **Integration with IoT**: The integration of IoT devices can provide real-time data on various parameters, such as temperature, humidity, and location, which can be used for food fraud prevention. ML and predictive analytics can be used to analyse this data and identify any deviations from the expected parameters, which may indicate fraudulent activities.

Overall, the potential for innovation and progress beyond the state of the art for food fraud prevention with ML and predictive analytics is significant, and ALLIANCE through continued research and development can contribute significantly on the food industry and public health.

4.6 Consumer Demand Assessment and Strengthening

4.6.1 SOTA Including comparison

Consumer behaviour towards an agri-food product is also connected to the exchange of information between consumers and producers (Polenzani et al., 2020). In this perspective, the implementation of product traceability has the potential to play an essential role in enabling consumers to gain a more comprehensive understanding of the product, and by extension, the entire production process. This, in turn, can foster a heightened level of trust regarding the product (Marozzo et al., 2022).

The use of Blockchain technology has caused significant changes in supply chain management, particularly in the agricultural industry where BC-based traceability is now considered a critical tool for ensuring the safety and quality of farm products (Y. Zheng et al., 2023). The employment of blockchain technologies has the potential to optimize supply chain procedures, enhance the transparency of production and business practices, and transfer these advantages to a final consumer who is progressively mindful of sustainability concerns (Adamashvili et al., 2021). Regarding food traceability, consumers' attitudes towards blockchain technology and its potential to improve food safety and traceability, subjective norms, and perceived behavioural control may impact their intention to use or request products traced using blockchain technology (Y. Zheng et al., 2023). Despite this, the adoption of blockchain technology for agricultural traceability is not yet widespread. Insufficient research has been conducted on the investigation of consumers' procurement inclinations towards commodities founded on blockchain traceability mechanisms, the determinants that impact such inclinations, and their relative comparison with extant traceability alternatives.

The theory of planned behaviour (TPB) and the health belief model (HBM) are theoretical constructs, suitable to assess consumer demand for blockchain traceability, which refers to the use of blockchain technology to trace and verify the origin and authenticity of food products (Y. Zheng et al., 2023).

In a study (Hoppe et al., 2013), TPB and the HBM were utilised as they are among the most used and tested models for predicting behaviours and intentions. In this perspective, the TPB suggests that consumers' intentions to buy or consume food products are influenced by their attitudes towards the safety and authenticity of the food product, subjective norms, and perceived behavioural control, such as the perceived ease or difficulty in identifying and avoiding food fraud (Ajzen, 1991). The TPB has demonstrated efficacy across diverse settings within the realm of consumer choice research (Lin, 2007), including food choice, where it has been used to determine why one product is chosen over another (Nardi et al., 2019), and to forecast the behaviour and preferences of consumers in relevance with organic products (Armitage & Conner, 2001).

In a study, the traceability of the factors influencing the purchase intentions of coffee consumers via blockchain using the TPB are explored (Dionysis et al., 2022). The study provides insights into factors influencing consumers' purchase intentions, finding that blockchain-traceable coffee attitude, subjective norm, and perceived behavioural control were positively associated with purchase intent.

Another study using the TPB also investigated the factors influencing the intentions of the food traceability blockchain to assist Chinese consumers in ensuring the safety and quality of organic food products (Lin, 2007). The aforementioned research has revealed that the qualities of attitude and perceived behavioural control exert a significant and positive impact on the intention to use blockchain technology, whereas subjective norms exhibit a positive but insignificant correlation with use intent.

The work done by Menozzi et al. (2015) undertakes an analysis of consumer attitude and behaviour towards traceable food, with the objective of elucidating the underlying intention to purchase such food products through the application of the TPB. Conversely, the HBM was founded upon four constructs, namely perceived susceptibility, perceived severity, perceived benefits, and perceived barriers (Rosenstock, 1974). The aforementioned concepts have been posited as a theoretical framework to account for individuals' propensity to engage in action. The more recent iterations of the model incorporated the notion of modelling and cues for action. The underlying premise was that these cues would trigger a state of preparedness and instigate observable conduct (Davinson & Sillence, 2014).

The HBM focuses on consumers' perceptions of the health risks related to the consumption of fraudulent food products (Harrison & Ho, 2012; Prochaska & Velicer, 1997; Rosenstock, 1974). The HBM suggests also that a consumer's decision to consume a food product is influenced by their perception of the health risks correlated with the consumption of fraudulent foods (Dionysis et al., 2022).

4.6.1.1 Consumers Perception

Consumers are the last point of the FSC and are the ones receiving the final products or goods; therefore, consumer knowledge and perception of food safety, quality, and fraud is primordial. Consumers' behaviour towards the commodities and the fraudulent cases serves as a reflection tool for the improvement of food quality and safety and reduction of food fraud. Moreover, it will pave the way for food fraud prevention.

Consumer perceptions of food safety and fraud are not isolated or independent issues. Instead, they are connected to a consumer's socioeconomic and demographic data status, culture, tastes, and previous experiences. Nevertheless, changes in attitude do not always result in behaviours that improve the safety of the food consumed. It is possible to draw the conclusion that consumers require professional support with food safety issues. That is the reason why awareness is a key element towards higher food safety and quality standards in the FSC (Wilcock et al., 2004).

In a focus group study conducted in China on consumer attitudes towards food fraud in some commodities originating from Europe, food safety related to fraudulent risks was the main concern. From their perspective, two main categories of food fraud were mentioned: Mis-description, emphasising their fear of unlisted ingredients and Adulteration, highlighted by the excessive use of pesticides and hormones. It should be noted that respondents were not able to distinguish between food safety and food fraud as a concept (Kendall et al., 2019), which shows the importance of raising awareness and education about the definition of food fraud, food safety and food quality.

4.6.2 Innovation through ALLIANCE (Beyond SOTA)

Although this task cannot be called a technology offer, it will provide important results to better understand how consumers react, behave, accept or reject technologies and innovations that can be used to ensure the quality of quality labelled food and prevent fraud and adulteration. This can result in protecting consumers from becoming victims of illegal practises related to the food they consume. Notwithstanding the common need to combat food fraud and to adopt technological and methodological countermeasures to protect the health of citizens and consumers, people have different beliefs depending on their technological background, level of education, place/countries of origin, habits, etc. For this reason, in ALLIANCE we intend to conduct a consumer demand assessment in all FSCs, including consumer segmentation and spatial analysis. This will lead to a better understanding of consumers' willingness to accept innovative technologies (used to combat food fraud) and quantify the elasticity of demand (for food sourced from protected FSCs).

4.7 Technology limitations and gaps for Food Safety & Authenticity in the literature

4.7.1 Identified gaps

The reliability of data stored on a blockchain database surpasses that of a centralized database due to its inherent immutability, which prevents any form of tampering or alteration of the data once it has been entered into the system. Notwithstanding its potential benefits, blockchain technology is incapable of safeguarding against fraudulent activities that were instigated prior to the inclusion of data in the system. The lack of alignment between the digital and physical components of the product represents a significant vulnerability within the system. Therefore, one of the most formidable challenges pertains to the fact that the quality of data stored in a database is contingent upon the quality of the input, commonly referred to as the Garbage In - Garbage Out issue. Blockchain is tamper proof and the information can be verified, however the data insert to the system cannot be verified.

Through the analysis of data, predictive analytics has the capability to detect potential areas of fraudulent activity and offer timely warning indicators that can aid in the prevention of future occurrences. A significant obstacle in the food industry pertains to the requirement for data of superior quality, which is frequently arduous to acquire owing to the vast array of variables implicated. Furthermore, machine learning algorithms can exhibit intricacy and necessitate considerable computational capabilities, which may not be universally accessible to all food enterprises.

A matter of importance to consider in relation to determining what information ought to be documented on a blockchain is harmonization. The process of determining the appropriate subset of quality management data that should be accessible and disseminated among supply chain stakeholders, as well as across supply chains, is a complex undertaking (Patro et al., 2022). The primary objective is to discern pertinent and significant data that can uphold a just, enduring, and reliable market, while safeguarding the confidential business information that pertains to competitiveness. Since data inputs will be coming from a variety of sources / pilots - we will be facing the arduous tasks of harmonizing them into a common data model before placing it in a shared storage. At the same time, each country has its own regulations that must be taken into account, when creating an interoperable system. The blockchain technology is incapable of addressing the obstacles arising from the coexistence of varied regulations and standards governing products within a single supply chain.

Finally, another of the technological challenges is to design an access control mechanism that caters to the requirements of all stakeholders, providing granular control over the accessibility of specific components of the system to different entities. The efficacy of utilizing blockchains for on-chain storage of extensive data is limited, thus the management of off-chain storage is an issue. The quandary of whether to store information on in a collaborative cloud platform or a decentralized one presents various technical, legal, and trust-related implications that necessitate extensive research.

4.7.2 Potential Solutions based on the literature

Some potential solutions can be implemented to enhance the system's resistance to fraudulent attempts that might have been initiated prior to the input of data into the system:

- The digital ledger can be enriched with cryptographically signed certificates that are issued by independent third parties to verify compliance with various standards such as organic farming, fair trade, or IFS (Katsikouli et al., 2021).

- Analytical methods can be utilized to determine the chemical, physical, and biological properties of food products that are an essential component of quality management systems. Some of these methods can also serve to authenticate organic production, establish the geographical origin of a product, or detect the presence of alteration (Camin et al., 2017; Hakme et al., 2020). The assessment and verification of distinctive spectral characteristics of the product at various points along SC can serve as a means of ensuring quality control, as any deviations resulting from factors such as dilution or substitution of the primary material would become apparent. This information can then become an input into a Blockchain system.

- The integration of data produced by IoT devices into quality management procedures could be propagated through a digital ledger. An instance can be found in the utilization of spectroscopic sensors in conjunction with multivariate data analyses for Herbs and spices adulteration detection (Black et al., 2016; Sørensen et al., 2016).

Regarding lack of interoperability between each party's system can be addressed by utilizing interoperable software that integrates services provided by diverse vendors utilizing varying technologies. For instance, a farmer uses different software than the processor and these systems are not interoperable with each other. An interoperable software, such as Blockchain-based SCM system, can be used to integrate the services provided by both the farmer and the food processor's systems. This can enable seamless and secure exchange of data related to the raw material, such as its origin, quality, and certification information, between the two parties. More specifically, the farmer's crop data can be recorded on a Blockchain platform, and the food processor can access this data using their own software system via a secure application programming interface (API).

In addition, to fully leverage the potential of the technology, it is imperative that all stakeholders within a supply chain exhibit a willingness to share pertinent data on a common digital ledger.

The task of managing diverse standards necessitates comprehensive documentation certificates, with the aim of facilitating a clear comprehension of the quality benchmarks that a product adheres to.

Contemporary supply chains have expanded to encompass various countries with varying regulations and extensively implemented methodologies. The feasibility of developing a universal system that caters to all conceivable use cases appears doubtful. In the process of designing such systems, it is essential to consider compatibility and scalability as crucial factors in making decisions.

To ensure the authenticity of food, we must adopt a systematic but pragmatic strategy. Stakeholders throughout the supply chain will likely have to implement additional steps to verify authenticity to ensure the provenance and production process, which add value to the product. However, it is unfeasible to undertake comprehensive food testing at every stage of the supply chain. A successful strategy for assuring food authenticity will concentrate on the ingredients and processes that are most at risk, employ a variety of risk control, and make sure that analytical testing resources are used as efficiently as possible. It is unlikely that any system design accommodates all conceivable use cases. Nonetheless, compatibility and scalability of such systems must be taken into consideration while creating them.

5 User Needs and Requirements

This Section presents the methodology towards gathering the "user need and requirements" per envisioned FSC/Pilot Use Case demonstrator. Through the ALLIANCE project the following case studies are being investigated, namely: *(1) PDO/PGI Extra Virgin Olive Oil (IT), (2) PDO Feta Cheese (GR), (3) Organic Honey (FR), (4) PGI Austrian Fava beans (ES), (5) PGI Lika potatoes (HR), (6) Organic pasta (IT), and (7) PDO Arilje raspberries (SR).*

ALLIANCE provides innovative solutions that act as authenticity enablers for the fight against food fraud, safeguarding the FSC's Integrity and transparency and ensuring trustworthy data sharing and veracity of information relating to food products. However, the offered technology solutions must/should correspond to the user needs and requirements of each stakeholder meeting particular conditions and prioritization criteria. Therefore, It Is essential for serving the scope of the project apart from presenting and offering these solutions to the stakeholders, to identify also their special needs and requirements (in terms of operational, technical, business, structural prerequisites) following a strategic elicitation process that is based on the Delphi technique (to be outlined imminently in section 5.1). This elicitation process will facilitate the development of the technological solutions and assuring that the developed solutions meet the stated needs of the originating stakeholders in each FSC.

5.1 Collecting User Needs & Requirements

Collecting user needs and requirements is the process of defining user expectations for a new product or service being designed and implemented. Moreover, it includes all those tasks that are used to identify the involved stakeholders and actors of a procedure, product or service as well as to determine their needs and the conditions to be met. An abstract definition of a need or requirement Is the prerequisite capability that is essential to be used by a user or stakeholder to solve a particular problem or execute a specific task meeting specific condition.

The methodology that we followed in ALLIANCE to collect the user needs and requirements, relies on the Delphi Technique. Our aim to use this iterative approach was to establish a consensus opinion about the problems and the weaknesses that the different FSC (examined in ALLIANCE) face and to identify the most appropriate solutions to be applied considering the technology offerings of the ALLIANCE consortium.

In general, according to Hugé et al., 2010, the Delphi method is a technique of structuring an assembly communication procedure to effectively allow this cluster of individuals to resolve a complex problem. In this procedure, experts are organized in a structured group. It offers a systematic method involving professionals in problem discussion and analysis on complex issues, to transform through a response iterative process, various opinions and views into a shared idea (Benitez-Capistros et al., 2014).

Generally, Delphi technique starts with a draft survey directed to a cluster of participants or expert, leading to a succession of rounds of debate amongst the group participants, all that while a facilitator is controlling the feedback process. Each participant is assigned a position within the panel by the facilitator (described below). Now, participants can complete their respective role in the survey again and adjust their answers. After each round, members are asked to rethink the elements and opinions that were presented by the cluster in the previous round. This procedure can be repeated multiple times before a consensus is reached. Usually, a consensus is reached after two to four rounds. Often, if multiple rounds are needed, we observe a decline in the number of participants (Allen et al., 2019) . Detailed examples of Delphi surveys can be found in the following research (Hasson et al., 2000; Landeta, 2006; Wentholt et al., 2009a).

The Delphi technique is extensively used in social sciences and engineering, in an extensive range of research fields, from public health to medicine (Boulkedid et al., 2011), food security (Wolfe & Frongillo, 2001) and food safety and policy (Wentholt et al., 2009b).

Our methodology started with the identification of the involved actors and stakeholders per FSC, which includes the potential users of the product or service. Each PUC owner has acted as a facilitator and identified in the respective PUC's Food Supply Chain the involved stakeholders (e.g. farmers/producers, cooperatives, processors, retailers, consumers, etc.). Then, each PUC owner sent to the identified stakeholders a questionnaire (see ANNEX-1 QUESTIONAIRE) with instructions to comment and to provide their knowledge based on their personal opinion, experience, or previous research. The Delphi were elaborated in three rounds:

a. Delphi round 1:

At the beginning of this round, CIHEAM team explained the Delphi technique to all participants, to get more familiar with the procedure. Then, CIHEAM team selected the experts they were going to investigate. The objective of this round is to complete the first part of a questionnaire provided by ALLIANCE project team, named “User need and requirements”, with the help of field experts. In sequence, each PUC owner compiled and grouped the answers/comments from the returned questionnaires and asked comments and revisions on the provided answers for more clarifications. The next step was to gather data on the users' needs, expectations, and preferences. The meetings took place as follow and lasted for 1 and a half hour for each Pilot:

Demonstrator 1: PDO/PGI Olive Oil and Extra Virgin Olive Oil On 21/02 from 11:00-12:30

Demonstrator 2: Dairy Production of PDO Feta Cheese On 22/02 from 11:00-12:30

Demonstrator 3: Organic Honey On 20/02 from 9:00-10:30

Demonstrator 4: PGI Faba Beans On 20/02 from 15:30-17:00

Demonstrator 5: PCI Lika Potatoes On 21/02 from 9:00-10:30

Demonstrator 6: Organic Pasta On 20/02 from 10:30-13:00

Demonstrator 7: PDO Arilje Raspberries On 20/02 from 10:30-13:00

We analysed the collected data to identify common patterns, problems or procedures and we identified specific user categories (e.g. farmers/producers, cooperatives, processors, retailers, consumers, etc.) that represent the different types of users and their needs. These user categories serve as a guide throughout the design process, helping to ensure that the technology offerings of the ALLIANCE platform are tailored to meet the needs of the users per PUCs.

b. Delphi round 2:

The next step is to translate the user needs into specific requirements that the product or service must meet. Common classification of requirements involves creating a list of functional and non-functional requirements. Functional requirements are used to describe the fundamental properties of the system components, describing processes, actions, and technical properties. Non-functional requirements capture properties that the system’s functions must have such as usability, reliability, security, GDPR compliance, and performance. The meetings of the second round took place as follow:

Demonstrator 1: PDO/PGI Olive Oil and Extra Virgin Olive Oil On 21/03 from 14:00-16:00

Demonstrator 2: Dairy Production of PDO Feta Cheese On 23/03 from 14:00-16:00

Demonstrator 3: Organic Honey On 20/03 from 9:00-10:30

Demonstrator 4: PGI Faba Beans On 20/03 from 14:00-16:00

Demonstrator 5: PCI Lika Potatoes On 21/03 from 11:00-13:00

Demonstrator 6: Organic Pasta On 22/03 from 14:00-16:00

Demonstrator 7: PDO Arilje Raspberries On 23/03 from 9:00-11:00

c. Delphi round 3: Matrix elaboration

Finally, we prioritized the collected requirements based on their importance to the users and the feasibility of implementing them, following the MoSCoW prioritisation technique which (stands for must have, should have, could have and will not have) and created a requirements matrix per technology offering for each PUC. This will help to ensure that the product or service meets the most critical needs of the users and is delivered within the constraints of time, budget, and other resources. This third round took place from 25th of March 2023 to 24th of April 2023.

5.2 ALLIANCE Technology Offerings

Each technology offering of the ALLIANCE platform has been described and communicated by the PUC owners to each FSC's stakeholders. Based on those descriptions, the elicitation of user needs, and requirements process revealed the specific requirements of the stakeholders for the following technology solutions they have been offered. Furthermore, the requirements of the users are harmonized in order to facilitate the proceeding steps. To clarify, the feedback provided by the stakeholders was consolidated into a shared terminology. Below, we give the brief descriptions of the technological solutions that the ALLIANCE brings.

Table 7: Tech. Offering 1 - Blockchain Platform

Tech. Offering 1	Blockchain Platform
Description	The ALLIANCE Blockchain platform provides immutability of the transactions and records stored in multiple participating sites, and minimizes the risk of fraud and enhances transparency and fairness through smart contracts. Trust management platforms based on blockchain networks (public permission-less and private permissioned) are utilized for food provenance monitoring and automated auditing of the key supply chain processes. ALLIANCE Blockchain platform can be used to track and granularly monitor each stage of the FSC, for every raw or processed food product where harvest, storage conditions, transportation, logistics monitoring details can be collected (with increased automation using IoT) and processed throughout supply chains.

Table 8: Tech. Offering 2 - Vulnerability Risk Assessment for Critical Control Points Identification in quality-labelled FSCs

Tech. Offering 2	Vulnerability Risk Assessment for Critical Control Points Identification in quality-labelled FSCs
Description	ALLIANCE's vulnerability risk assessment system identifies important factors and evaluates them in terms of importance. Different vulnerabilities and risks per chain are assessed, involving food fraud drivers and enablers and investigating food chain stakeholders' attitudes towards fraud. Leveraging robust, fair, explainable AI techniques, the Risk Assessment mechanism provides insightful findings that contribute to the detection, prediction and prevention of fraudulent practices in national and EU level. ALLIANCE's vulnerability risk assessment encompasses sensing IoT, AI, Big Data Analytics and Machine Learning technologies to complement the Blockchain functionality aiming to monitor food supply chains, collect and analyse historic and real-time data along the FSCs and detect fraud issues.

Table 9: Tech. Offering 3 - AI-enabled Early Warning and Decision Support System

Tech. Offering 3	AI-enabled Early Warning and Decision Support System
Description	The AI EWDSS acts as the main driver of the ALLIANCE ecosystem, employing the other technological components of the project, including the fraud detection, the interoperability, the traceability and tracing and the smart packaging/labelling solutions. The AI EWDSS relies on AI and provides timely alerts for food security threats by taking into account and evaluating all the phases of food production, processing and transportation and incorporating rapid-testing and sample food analysis results. Moreover, with AI analytics informed decision support is offered to food actors, to take countermeasures and proactively prevent food fraud incidences and ensure health and public safety.

Table 10: Tech. Offering 4 - Interoperability Mechanism in Complex Food Systems

Tech. Offering 4	Interoperability Mechanism in Complex Food Systems
Description	ALLIANCE interoperability mechanism allows different platforms owned by stakeholders within the food chain to communicate efficiently and allow products, resources and data to be managed in a coherent way. The mechanism relies on Blockchain technology and follows the GS1 EPCIS standard for cross-chain and interoperability protocols to enable distinct blockchain networks (different FSCs) to interact and integrate, communicating seamlessly. The ALLIANCE Interoperability mechanism allows for the sharing of data between chains to consolidate data sources related to food authenticity and traceability, including a) IoT infrastructures and b) provision of data (by the processor through forms or semi-automatic measurements). It will allow interoperation agreements between different and fragmented FSCs to enable continuity of data flows and traceability on the logistic services by including a common coding for definition of the food products, locations and routing used in the logistics execution to ensure that different stakeholders (from different FSCs) have the same and unambiguous understanding of this basic supply chain information.

Table 11: Tech. Offering 5 - Next Generation portable DNA Sequencing for Food Analysis

Tech. Offering 5	Next Generation portable DNA Sequencing for Food Analysis
Description	DNA fingerprinting will be used for the on-site DNA authentication and traceability of the Extra Virgin Olive Oil. By collecting the DNA profiles at the olive orchards (Geo-Genetic mapping), ALLIANCE solution for DNA fingerprinting can perform at every stage of the supply chain (milling, storage, bottling, retail), using a portable DNA-based device conducting High Melting Curve analysis. The DNA profiles are processed using an AI/ML postprocessing pipeline for the accurate and automated varietal classification of each lot of a label, thus creating a “digital DNA fingerprint"

Table 12: Tech. Offering 6 - Advanced Spectroscopy NIR and HSI

Tech. Offering 6	Advanced Spectroscopy NIR and HSI
Description	ALLIANCE offers a fast, non-destructive, easy to use and low-cost analytical method to detect and quantify adulterations. Using NIR and HSI integrated with chemometrics for the modelling of acquired data and the extraction of the chemical fingerprint of the analysed compound, a hand-held portable NIR device captures the spectra of the sample and through AI analysis detects fraud in the samples.

Table 13:Tech. Offering 7 - Digital Knowledge Base for Food Fraud

Tech. Offering 7	Digital Knowledge Base for Food Fraud
Description	ALLIANCE provides a digital knowledge base which aim is to accelerate (among the various food stakeholders) the exchange of knowledge, information, data, best practices, lessons learnt, well-established processes in the food chains of quality-labelled food products, along with policy documentation and regulations for policies for data sharing in food systems in EU. It will offer the means for a deeper understanding of the operational challenges that each food chain (examined in the projects) faces in the context of data availability and transparency, and an analysis of socioeconomic drivers of the food fraud as well as the behavioural analysis of the food criminals.

Table 14: Tech. Offering 8 - Prevent Food Fraud with Predictive Analytics

Tech. Offering 8	Prevent Food Fraud with Predictive Analytics
Description	ALLIANCE provides a mechanism that will help authorization bodies and authorities prevent food fraud. This mechanism will be based on predictive analytics and will provide forecasts on potential food fraud incidents in national and EU level along with insights on the evolution of such phenomena. Moreover, this mechanism will rely on the Vulnerability Risk Assessment and include information in the proposed Early Warning System. and Decision Support System.

5.3 Demonstrator 1 - PDO/PGI Extra Virgin Olive Oil

5.3.1 Introduction

Olive oil is being considered as the most high-priced source of fat for covering nutritional needs for humans. The high olive oil nutritional value and price, alongside low consumer purchasing power, make olive oil more prone to fraudulent acts. This is directly related to the higher value and quality of extra virgin olive oil in different countries (Yan et al., 2020). On a global scale, olive oil complies to different standards and norms, depending on the corresponding affiliation, such as the International Olive Oil Council, Codex Alimentarius, and other EU regulations. These norms aim to facilitate the international trade market, and harmonise the global olive oil quality, in order to reduce olive oil fraud (Conte et al., 2020). According to food fraud reports, released by the Joint Research Centre of the European commission, olive oil is one the most mentioned commodities that has higher risk of fraud. It should be stated that each report includes several types of fraud, such as mislabelling or adulteration of the same product (Casadei et al., 2021). Olive oil fraudulent acts are of wide range, according to the results of anti-fraud inspection in Spain, where olive oil was produced from a non-Protected designation of origin area (PDO), but labelled and marketed as so (Rébufa et al., 2021). Another issue is that other oils are being sold as virgin olive oil, with dye and seed oils or other additives being intentionally mixed (Casadei et al., 2021). Other fraud case examples have been identified, like mixing extra virgin olive oil with vegetable oil, causing the occurrence of stigmastadiene (Conte et al., 2020). There are several methods for olive oil quality and purity evaluation, and each serve a different purpose. Quality assessment focuses on the quality of the fruit, oxidation status, and quality of olive oil (virgin or lower quality). Meanwhile, the purity assessment focuses on the findings or absence of extraneous oils, refined oils, esterified oils, and pomace oil within the olive oil commodity (Conte et al., 2020). These quality measures are essential alongside the global norms, to ensure the reduction of olive oil fraud cases, especially with the emerging global trade market.

5.3.2 Organizations/stakeholders involved

The potential stakeholders are actually everyone involved in the supply chain. However, the key stakeholders that are keener on the adoption of an authentication and traceability system are:

- the producers
- the importers/exporters (e.g. regulatory/authority bodies of foreign countries)
- wholesalers and Olive Oil companies producing private labels from olive oil they purchase.
- the consumers

The stakeholders involved in the value chain of Masoutis retailer are listed as follows:

- Producer: Production of the raw materials.
- Manufacturer: Supply and storage of raw materials, supply and storage of packaging material, manufacturing process, storage of the end product.
- Manufacturer / Distributor: Dispatch of the product to Masoutis' Logistics Center premises under appropriate conditions.
- Masoutis: Product quality inspection, Storage in facilities, compartmentalized in both dry and cold storage.
- Masoutis/ Distributor: Distribution under appropriate conditions to Masoutis stores

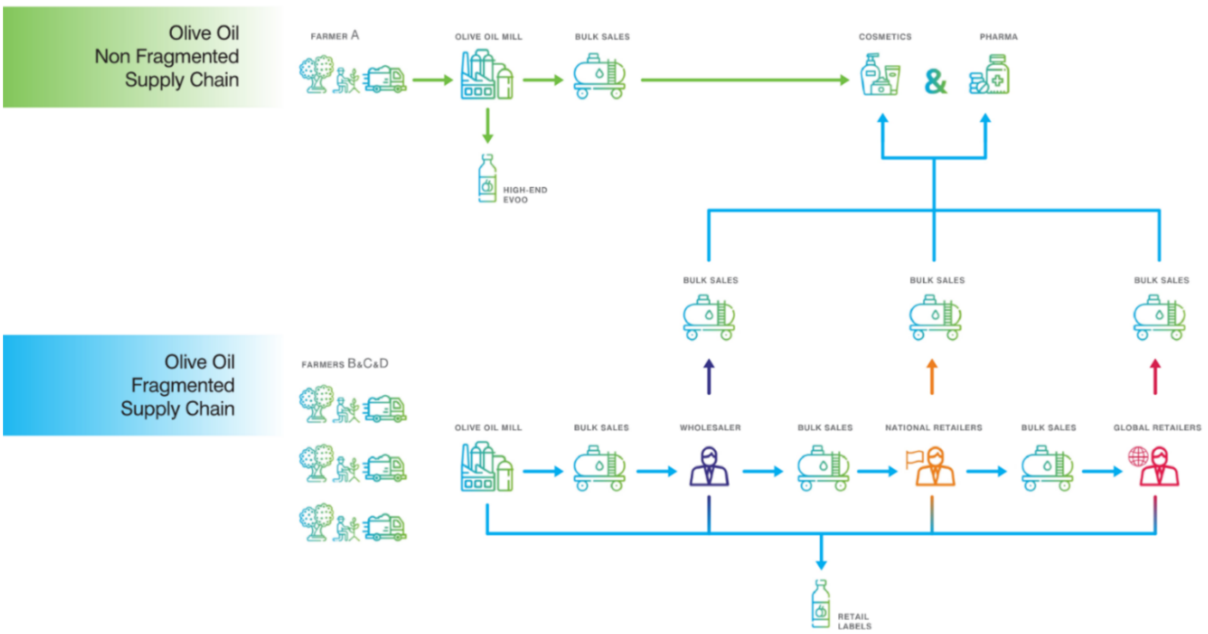

Figure 17: EVOO Supply Chains Fragmented and non-Fragmented

5.3.3 Existing Infrastructure & Operations

5.3.3.1 FSC Production part - EVOO

A typical example of a producer having a linear supply chain that wants to apply BioCoS's authentication and traceability system will follow the path below:

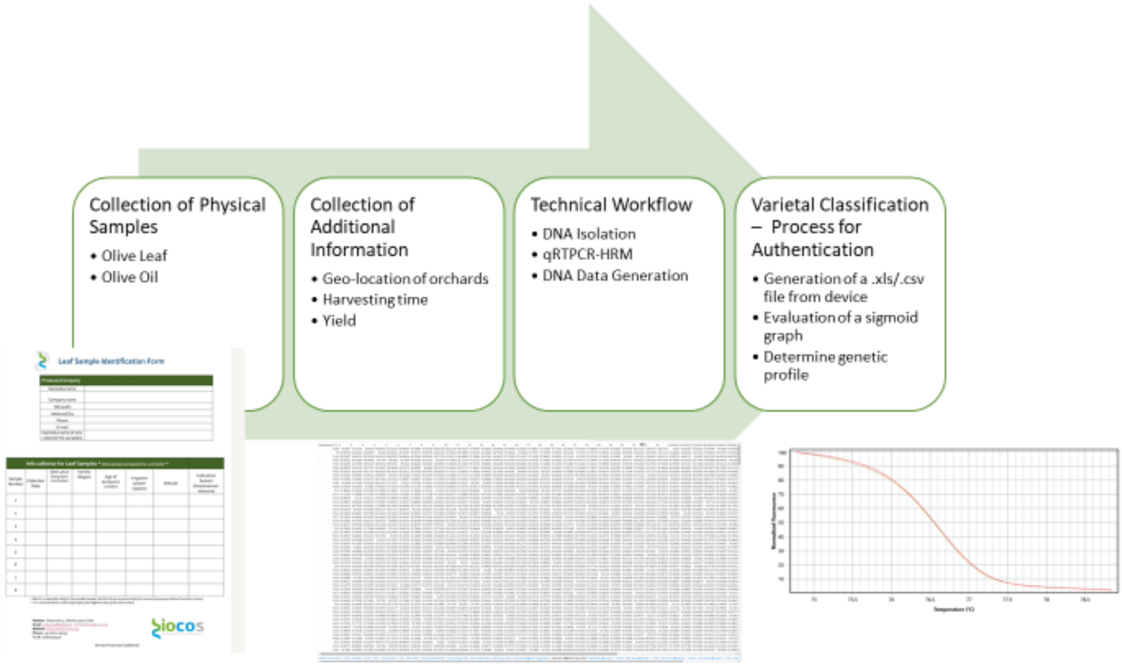

Figure 18: PDI/PGO EVOO Authenticity and Classification Analysis

First, physical samples of leaf from the orchard are collected, and the second physical sample collection will be carried out once the olive oil from the correspondent orchard is produced. The flow for both sample types are the same, and is depicted on the flow of action below. In order to ensure traceability, since the scheme below addresses directly the authentication (genetic profiling) of the samples, we carry out the olive oil analysis in the key points of the supply chain that are more vulnerable to fraudsters. In this case, specifically, additional analysis of the olive oil will take place once the olive oil is stored and ready to be bottled, and then a random analysis on a bottled final product will be performed. The expected result should always correspond to the initial genetic profile of the orchard and its extracted olive oil.

For each producer, it is mandatory to fill in a form with additional information regarding their orchards, as depicted in the figure above. The process downstream - after the delivery of the samples - is mainly technical and includes DNA isolation, quantification and quality assessment of the extracted DNA and then finally qPCR-HRM analysis. The latter generates what from now on will be referred as "DNA Data". The form of the raw data is depicted in the figure above. Lastly, in order to assess the varietal classification of the sample, the data are automatically plotted, and they create a sigmoid curve that allow us to determine the genetic profile of the sample.

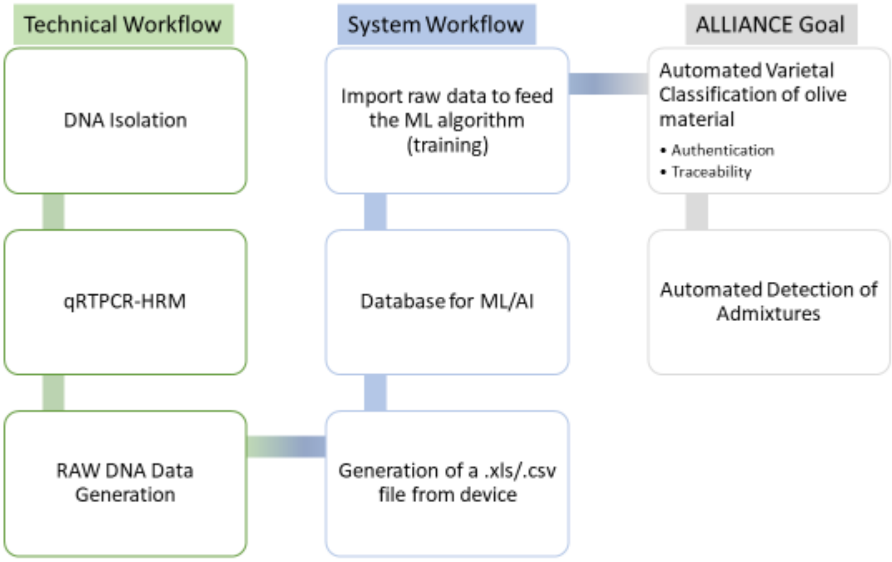

Figure 19: PDI/PGO EVOO Workflow

5.3.3.2 FSC Retailing part - Masoutis

The current infrastructure of Masoutis retailer consists of logistics, IoT sensors, ICT systems, and facilities. Specifically:

- There is a WMS system for the logistics centre that communicates with different databases where information related to the product is stored (quantity, expiration date, date of receiving, location where it is stored in the warehouse, date of delivery to each store). Data are imported into the system either by using a computer through automated processes or interfaces or by using scanners wirelessly.
- Sensors for 24-hour temperature monitoring in all compartments of the logistics centre. A BMS (Building Management System) is utilised, and the database used for this process doesn't communicate with the ones mentioned above for the WMS system.
- Sensors for 24-hour temperature monitoring on tracks equipped with a refrigeration system.
- Sensors for 24-hour temperature monitoring on freezers and refrigerators in most of Masoutis' stores

An ERP-like system is applied to the stores, but it is not as accurate and detailed as that implemented in the warehouse.

Table 15: PDO/PGI Extra Virgin Olive Oil processes

Farmer/Producer/Wholesalers/Importers/Exporters	Technical Workflow
Process 1	DNA isolation
Process 2	qRTPCR-HRM
Process 3	RAW DNA Data Generation
Farmer/Producer/Wholesalers/Importers/Exporters	**System Workflow**
Process 4	Output Result from the device (csv/xls format)
Process 5	AI/ML Database
Process 6	Import Data for ML/AI Training

Process 7	Automated Variatel Classification of Olive material
Process 8	Automated Detection of Admixtures
Masoutis - Retailer	**Data collection system: internal traceability records**
Process 9	-Register of product receipt: product description, quantity, expiration date, temperature measurements.
Process 10	-Storage register: temperature measurements, product id, product quantity, storage id, product sampling number, sampling parameter results
Process 11	-Deliveries register: temperature measurements, GPS measurements, product id, product quantity
Process 12	-Register of product receipt on the stores: product description, quantity, expiration date, temperature measurements, inspection data on the quality of the product

5.3.4 Weaknesses and Problems Identification

We have classified the pain-points/gaps of authentication and traceability of the product (the olive oil) based on i) the supply chain needs, and ii) the stakeholders' need.

In respect to the supply chain pain-points, their complexity and fragmentation represent probably the driving factor of reduced visibility and transparency between the different stakeholders. In turn, this gives space and facilitates unfair competition, as well as adulteration actions for illegitimate profit. Moreover, due to its physicochemical nature (liquid), the olive oil represents an excellent target for fraudsters. Indeed, all the above intensify the need for transparency through authentication and traceability in an immutable way.

From the stakeholders' point of view, other gaps that are interconnected and/or indirectly linked to the supply chain pain-points have been identified. For the producers, a crucial aspect is the lack of product differentiation actions coupled with low valorisation of their produce. On the other hand, olive oil companies must find smart solutions to gain higher profit by increasing their sales, be a step ahead of their competitors and raise brand awareness. Wholesalers frequently find it difficult to export olive oil – especially in non-producing countries – due to regulatory barriers or even slow-paced inspections. As a matter of fact, the average number of days required for an inspection to take place (from sample to result) is 41 and 75 days for producing and non-producing countries, respectively. Lastly, in this equation, another pivotal role is played by the modern consumer that demands true label transparency (especially in the non-producing countries), which is often translated in mistrusting the brand's provided information.

Table 16: Identified Problems and Weaknesses of the FSC per stakeholder

Supply Chain		
Prob. No.	**Structural Problems**	**Weaknesses**
Problem 1	Complexity	Unfair Competition
Problem 2	Fragmentation	Opportunities for olive oil adulteration
Stakeholder: Producers		
Problem 3	Lack of Product Differentiation	Low Valorisation of the Olive Oil produce
Stakeholder: Olive Oil Companies		
Problem 4	Cannot increase their brand awareness	Cannot efficiently increase their sales and their reputation among consumers
Stakeholder: Wholesalers		
Problem 5	Regulatory Barriers on Import/Export	Delays in inspection process to complete
Problem 6	Slow Paced Inspections	Delays in inspection process to complete
Masoutis: Retailer		

Problem 7	Scattered data and information that generated through products distribution	Interoperability-compatibility: The data are not compatible and not easily accessible.
Problem 8	Lack of digitalised critical information in stores such as lot number and expiration date, and quality after receiving the products and arranging them in appropriate conditions.	Traceability: Data collection and recording are made manually. So, human errors are quite frequent.
Problem 9	Lack of Digital Temperature monitoring all along products transportation in associate's trucks	Data Reliability: No control over the reliability of the data input to the system. For example, in case of inappropriate storage temperature, the product delivery must not be received.
Stakeholder: Consumer		
Problem 10	True label transparency cannot be guaranteed	Mistrusted information concerning the brand and the product.

5.3.5 User Needs & Requirements Identification

In this subsection, we present the user needs and requirements for the EVOO FSC. Firstly, we present the mapping of the identified problems with the corresponding ALLIANCE technology solutions. In the following Table, we associate the problem with the offered solutions, and we link to the respective stakeholder and the emerging need.

Table 17: User needs and requirements for the EVOO FSC

Stakeholder	Identified Need	Problem to Tackle	ALLIANCE Technology Offering
Producers/Olive Oil Companies/ Wholesalers	Test the authenticity of PDI/PGO EVOO for adulteration and admixtures	Problem 3, 4, 5, 6	**Technology Offering 5: Next Generation portable DNA Sequencing for Food Analysis** i) varietal analysis of PDO/PGI EVOO. ii) detect adulteration and admixtures **How**: Use of Portable next generation DNA Sequencing devices
Supply Chain	Complexity and Fragmentation of the Supply Chain	Problem 1, 2	**Technology Offering 1: Blockchain Platform: Enable Traceability in fragmented Supply Chains. How:** Use of Blockchain to digitalize the FSC and enable traceability **Technology Offering 4: Interoperable FSCs**: **How**: Connect and make fragmented FSC interoperable with Blockchain.
Producers/Olive Oil Companies/	Increase brand awareness and raise trust on the label	Problem 4	**Technology Offering 1: Blockchain Platform** Enable traceability using Blockchain **How**: Blockhain will enable traceability in the FSC of EVOO. The results taken from testing samples along with the FSC with the aid of Portable next generation DNA Sequencing devices, will be injected into the Blokchain.

Wholesalers/ Inspective Authorities	Efficient solutions for import/export inspections	Problem 5, 6	**Technology Offering 5: Next Generation portable DNA Sequencing for Food Analysis** I) varietal analysis of PDO/PGI EVOO. ii) detect adulteration and admixtures **How**: an automated and portable molecular device able to identify the varietal composition of the produced olive oils on-site.
Supply Chain	Need for a knowledge base to record incidents and practices for fraud in complex and fragmented food systems	Problem 1,2	**Technology Offering 7: Digital Knowledge Base for Food Fraud:** **How:** A digital knowledge management system that will act as a repository of information dealing with issues related to PGI/PDO EVOO fraud.
Supply Chain	Continuous monitoring and assessment of the performance of the FSC.	Problem 1,2	**Technology Offering 2: Vulnerability Risk Assessment for Critical Control Points Identification: How:** AI-based food fraud vulnerability assessment to identify and assess potential vulnerabilities and risks, determine pain-points In the FSC of the PDO/PGI EVOO **Technology Offering 3: AI-Early Warning and Decision Support System: How:** Allow users make informed decision making by providing them with recommendations that will analyse FSC performance data to forecast possibility of fraud. **Technology Offering 8: Prevent Food Fraud with Predictive Analytics: How:** User will be able to forecast risks. Even those with low probability but with high impact, will be assessed and relative risk mitigation and prevention plans will be recommended.
Consumers	Increased Level of Trust for a product	Problem 10	**Technology Offering 1: Blockchain Platform: How:** Allow consumers access trustworthy information and the history considering the food product they wish to buy
Masoutis	Digitalization of critical information in stores such as lot number and expiration date, quality (which are not properly registered on arrival)	Problem 7,8,9	**Technology Offering 1: Blockchain Platform:** Digitalize the documents and the operational processes. **How:** Along with Blockchain enable use of digital devices to automize the data collection processes and the data analysis in critical control points.
Masoutis	Need for compatible data and operations	Problem 7	**Tech. Offering 4: Interoperability Mechanism in Complex Food Systems:** An interoperability mechanism based on Blockchain will allow different platforms owned by stakeholders within the food chain to communicate and exchange data efficiently, thus allowing products, resources and data to be managed in a coherent way.

			How: Using a unified data model to harmonize collected information and use of Blockchain-enabled interoperability protocols.

After having identified an initial mapping of the current problems with the offered solutions, we proceed with the elicitation of specific requirements based on a user needs assessment, we come up with a Requirements Matrix per Technology offering. Each technology offering aims to tackle specific problems and eliminate weaknesses. However, in order to be applicable, each technology offering has been associated with specific requirements (Req. No, Requirements Description). Those requirements have been posed by the stakeholders. Each requirement is described whether it belongs to a functional or non-functional type and it is prioritized using the MoSCoW technique with four different classification priorities (must-have, should-have, could-have, and won't-have).

Table 18: Requirements Matrix -Technology Offering 1 - BC Platform

Technology Offering 1			Blockchain Platform					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1,2,7,8,9,10	Maximizing accessibility of product information to all stakeholders involved in the olive oil value chain and create a stronger trust bond between them. Prevent tampering with the data.	Currently, the FSC of the EVOO is characterized by high level of fragmentation. There is a lack of tamper-proof traceability systetm to ensure transparency and traceability	1	Ensure Security and Privacy of the data	Non-Functional	MUST HAVE	All Stakeholders participating in the EVOO Supply chain (Producers, farmers, Olive Oil Companies, Wholesalers, Importers/Exporters)	PUC 1: 10 olive oil growers from the CIA association of Perugia (IT), that they produce monovarietal PDO olive oil. They wish to increase the valorization of their product. They expect that a DNA-based authentication will safeguard their produce. Using a traceability solution will allow them to filter out the paths and intermediaries that exploit their valorised product to admix it with low quality vegetable oil. Wholesalers, retailers, importers and exporters increase their confidence for their supplies because they can access trustworthy and untampered information considering their supplies.
			2	Allow users to search for products by scanning a tag (QR code) by their portable device, view the history timeline	Functional	MUST HAVE		
			3	Allow FSC participants (except consumers) to record the event (time, location, lot number, production, variety, weight) that they have received a product	Functional	MUST HAVE		
			4	Allow DNA-analyst record on blockchain a certificate that the olive oil is EVOO via a GUI	Functional	MUST HAVE		
			5	Reliable, Trustworthy Digital Solutions responding to queries	Non-Functional	MUST HAVE		
			6	Interoperability with IoT protocols to send/receive Information	Functional	MUST HAVE		
Comments								
N/A								

Table 19: Requirements Matrix -Technology Offering 2 - Vulnerability Risk Assessment for Critical Control Points Identification in quality-labelled FSCs

Technology Offering 2			Vulnerability Risk Assessment for Critical Control Points Identification in quality-labelled FSCs					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1, 2	Vulnerability assessment to identify and assess potential vulnerabilities and risks, determine pain-points In the FSC of the PDO/PGI EVOO	No such a system exists	7	Usable by all stakeholders in a multi-tenant environment	Functional	MUST HAVE	All Stakeholders participating in the EVOO Supply chain (Producers, farmers, Olive Oil Companies, Wholesalers, Importers/Exporters)	PUC-1: All stakeholders can be informed with the corrective action to be taken when monitoring indicates that a particular CCP is not under control.
			8	Reliable: Provide trustworthy unbiased and explainable reports	Non-Functional	MUST HAVE		
			9	Assess the entire FSC: Provide a holistic assessment of the FSC and not target myopically on well-known pain points	Non-Functional	MUST HAVE		
			10	Allow producers, wholesalers, Importers to request a Vulnerability Risk Analysis to assess the CCP risk	Functional	MUST HAVE		
Comments								
N/A								

Table 20: Requirements Matrix -Technology Offering 3 - AI-enabled Early Warning and Decision Support System

Technology Offering 3			AI-enabled Early Warning and Decision Support System					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1, 2	Support Stakeholders to make Informative decisions.	No such a system exists	11	Reporting and Recommending: Create alerts when a risk has a high probability to occur, evaluate historical data and sensor measurements, allow stakeholders for informed decision making and recommend mitigation strategies to prevent risk from happening.	Functional	MUST HAVE	All Stakeholders participating in the EVOO Supply chain (Producers, farmers, Olive Oil Companies, Wholesalers, Importers/Exporters)	PUC-1: Identified stakeholders are provided with timely information to make adjustments and ensure control of the process to prevent violating the critical limits. AI analysis on the monitoring data can indicate proactively whether a deviation might. EVOO FSC participants can benefit with proactive warnings that allow them to respond in time/
			12	Reliable: Provide quantify risk levels and explain how the outcome has been reached	Non-Functional	MUST HAVE		
			13	Easy to use: All participants of the FSC should be able to use this service without any special training.	Non-Functional	MUST HAVE		
Comments								
N/A								

Table 21: Requirements Matrix -Technology Offering 4 - Interoperability Mechanism in Complex Food Systems

Technology Offering 4			Interoperability Mechanism in Complex Food Systems					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1, 2,7,8,9	Enable interoperability in fragmented FSCs	No such a system exists	14	Allow interoperability with other FSCs and harmonize data so that different FSC can interoperate and exchange data information	Functional	MUST HAVE	All Stakeholders participating in the EVOO Supply chain (Producers, farmers, Olive Oil Companies, Wholesalers, Importers/Exporters)	PUC-1: Users of fragmented FSCs of the EVOO can experience improved and trusted product-information exchange and can correlate fraud incidences back in time with information of previous stages in the FSC and hence identify the source of the fraud and its related fraudsters.
			15	Seamless and Transparent Data Sharing	Non-Functional	MUST HAVE		
Comments								
N/A								

Table 22: Requirements Matrix -Technology Offering 5 Next Generation portable DNA Sequencing for Food Analysis

Technology Offering 5			Next Generation portable DNA Sequencing for Food Analysis					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 3, 4, 5, 6	Authentication of PDO olive oil from specific varieties as reported In the GA from Perugia (IT) area, using a portable device	The device is currently into a prototype level, but it is able to carry out DNA-authentication for five Greek olive varieties	16	Portable. Allow for on-site inspection and sample validation. Users have the capability to carry a lightweight portable device to perform DNA sequencing analysis for fraud detection.	Functional	MUST HAVE	All Stakeholders participating in the EVOO Supply chain (Producers, farmers, Olive Oil Companies, Wholesalers, Importers/Exporters)	PUC-1: Utilizing a portable DNA sequencing device for on-site authentication of EVOO, provides a powerful inspection tool to every participant user in the FSC. Intermediaries are able to detect near real-time before they accept the delivery whether the product that they have been supplied is an authentic one and not an admixture.
			17	Reliable: Allow users have access on consistent data results when they use the device.	Non-Functional	MUST HAVE		
			18	Accurate: Allow users within FSC to know the level of uncertainty per conducted test.	Non-Functional	MUST HAVE		
Comments								
collection of samples of olive leaf and olive oil to develop a custom-based authentication solution								

Table 23: Requirements Matrix -Technology Offering 7 - Digital Knowledge Base for Food Fraud

Technology Offering 7			Digital Knowledge Base for Food Fraud					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1,2	Need to create Knowledge Database where all stakeholders can access and query searchable data and information about Food Fraud incidences.	No such a system exists	19	Allow users to search for food fraud issue by keyword and filter the results based on different attributes	Functional	MUST HAVE	All Stakeholders participating in the EVOO Supply chain (Producers, farmers, Olive Oil Companies, Wholesalers, Importers/Exporters)	PUC-1: Users participating in the FSC can access updated and well-structured scientific information, that is related to fraud in quality-labelled food products and get informed. By leveraging ALLIANCE Knowledge Base, users in the EVOO FSC are expected to optimize their procedures by updating and applying adjustments in the FSC operation according to the latest fraud prevention strategies, systems or protocols.
			20	Easy to use: All participants of the FSC should be able to use this service without any special training.	Non-Functional	MUST HAVE		
			17	Availability of the Knowledge Base: Support parallel queries	Functional	SHOULD HAVE		
Comments								
N/A								

Table 24: Requirements Matrix -Technology Offering 8 - Prevent Food Fraud with Predictive Analytics

Technology Offering 8			Prevent Food Fraud with Predictive Analytics					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1,2	An automated varietal classification of the EVOO samples.	The ML/AI pipeline has been tested to DNA-data of two Greek olive varieties, to allow for an automated varietal classification, a ML/AI. Now it will be adopted to the PDO Italian olives and olive oils.	1	Reporting and recommendation: Use of a visual dashboard to present alerts and notify users regarding possibility of risk and recommend mitigation actions.	Functional	MUST HAVE	All Stakeholders participating in the EVOO Supply chain (Producers, farmers, Olive Oil Companies, Wholesalers, Importers/Exporters)	PUC-1: Users expect to use a dashboard that can have the information of varietal classification presented along with the probability and the uncertainty in prediction.
			2	Authentication of users and samples: Ensure users and data samples are the legitimate ones.	Functional	MUST HAVE		
			3	Explainability of results: Allow for data-driven and algorithm-driven explainability to reduce uncertainty, prevent confusion and increase trustworthiness of AI/ML predictive analytics.	Non-Functional	MUST HAVE		
Comments								
Minimizing the human intervention, the DNA-data will be classified seamlessly via ML/AI algorithms								

5.4 Demonstrator 2 - PDO Feta Cheese

5.4.1 Introduction

Feta Cheese is a soft white cheese ripened in brine and was adopted as PDO in 2002. For the cheese to bear the name Feta, it has to be produced in continental Greece and on the island of Lesbos, and essentially made by either 100% sheep milk or a mixture of sheep and goat up to a 70-30 ratio. Fraud control measures are taken to prevent the commercialization of white cheese with different ratios than the aforementioned ones, as Feta cheese. Most of the Feta cheese fraud cases are mainly alteration of sheep and goat milk with cow milk, or ratios alteration of sheep and goat milk. Several techniques are used to identify the authenticity of the Feta cheese, such as Matrix-assisted Laser Desorption/Ionization -Time-Of-Flight Mass Spectrometry (Ganopoulos et al., 2013; Kritikou et al., 2022).

5.4.2 Organizations/stakeholders involved

Stakeholders involved in the chain, apart from the Feta production plant, are:

- the milk producers,
- the milk transport company and
- all the certification carriers that have the jurisdiction to check the milk producers and the transports.

The stakeholders involved in the value chain of Masoutis retailer are listed as follows:

- Producer: Production of the raw materials.
- Manufacturer: Supply and storage of raw materials, supply and storage of packaging material, manufacturing process, storage of the end product.
- Manufacturer / Distributor: Dispatch of the product to Masoutis' Logistics Center premises under appropriate conditions.
- Masoutis: Product quality inspection, Storage in facilities, compartmentalized in both dry and cold storage.
- Masoutis/ Distributor: Distribution under appropriate conditions to Masoutis stores

5.4.3 Existing Infrastructure & Operations

5.4.3.1 FSC Production part - Olympos

Olympos' milk transporters receive the milk by recording the data with a PDA. These PDAs have a preinstall software that can be used offline even in areas without Internet access. In addition, they have 4G access in order to send the data to their ERP system. Furthermore, the milk is transferred with trucks which have temperature and location control. Each truck has GPS that transmits its location data to the cloud. These data are captured and represented in a map.

Using this tool, they can check whether the route of the truck is within the correct bounds. The milk is stored in iceboxes and each icebox displays the temperature.

In Olympos facilities, there are machines that measure the quality and possible adulteration of milk. Namely, Milkoscan, Combifoss, and Foodscan are used for the chemical composition (Fossanalytics, 2023). Batcoscan and MOCON are used for possible growth of pathogenic microorganisms, while Cryoscope is used to identify possible water adulteration. Each device utilises its own database and is able to export the results in pdf file. They also have interface software to facilitate the import of the data to their main ERP system. The Figure below (Figure 20) visualise the data flow of the aforementioned devices, while Figure 21quotes an output example of a track's route.

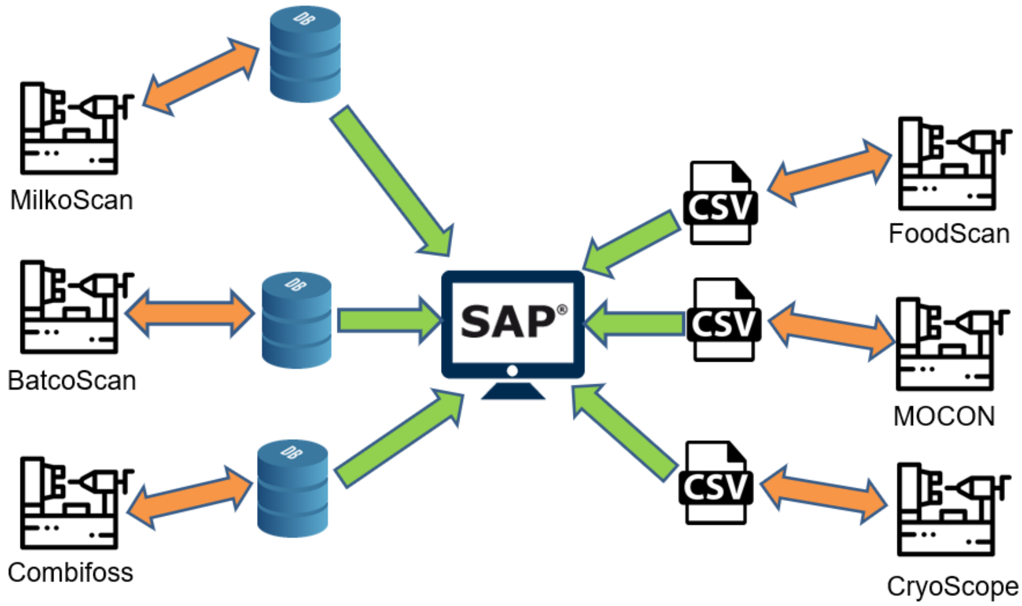

Figure 20: Data Flow of the devices used for quality control

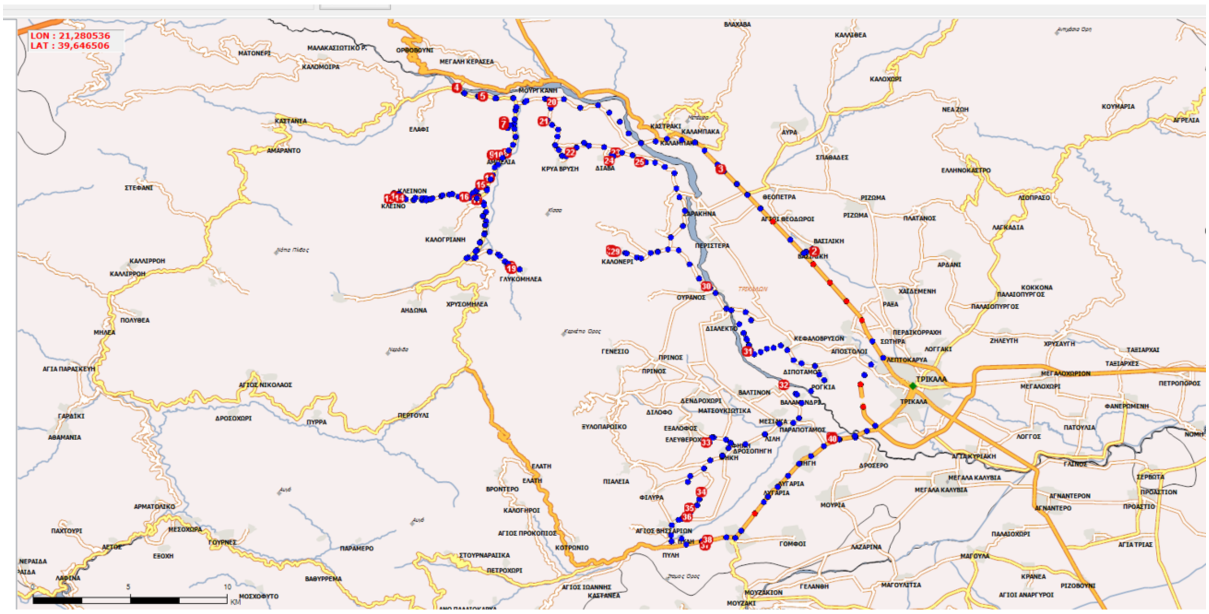

Figure 21: Output of a track's route

5.4.3.2 FSC Retailing part - Masoutis

The current infrastructure of Masoutis retailer consists of logistics, IoT sensors, ICT systems, and facilities. The infrastructure details have already been described in the EVOO use case (Section 5.3).

Table 25: PDO Feta processes

Farmer/Producer	**Data collection system: internal traceability records.**
Process 1	- Milk producer register: milk quantity, date and time, production area, milk variety
Transporter	**Data collection system: internal traceability records.**
Process 2	- Milk transportation register: milk quantity, milk sample id, date and time, farmer information, location, temperature of the icebox, physical condition, pH of the milk, icebox code number, barcode of the sample
Olympos - Processor	**Data collection system: internal traceability records.**
Process 3	- Register on milk receiving process: quantity, time and date, temperature information, physical condition, transportation information
Process 4	- Quality register: temperature, pH, composition (water, cow's milk, % goat milk)
Process 5	- Register of raw material storage: quantity, temperature, storage id, material id
Process 5	- Manufacturing and packaging register: input quantity, output quantity, time and date, product id
Distributor	**Data collection system: internal traceability records.**
Process 6	- Transport Register: product's quantity, date and time, manufacturer's information, location, temperature of the storage, physical condition.
Masoutis - Retailer	**Data collection system: internal traceability records.**
Process 7	- Register of product receipt: product description, quantity, expiration date, temperature measurements, physicochemical measurements on the quality of the product
Process 8	- Storage register: temperature measurements, product id, product quantity, storage id, product sampling number, sampling parameter results
Process 9	- Deliveries register: temperature measurements, GPS measurements, product id, product quantity
Process 10	- Register of product receipt on the stores: product description, quantity, expiration date, temperature measurements, inspection data on the quality of the product

These processes are visualised in the following diagram:

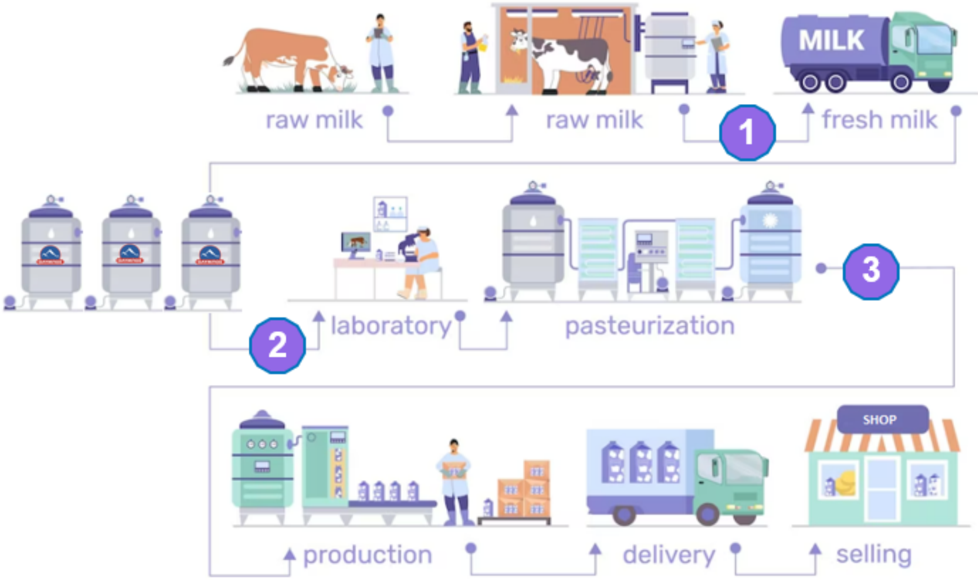

Figure 22: Diagram of the Feta Cheese Supply Chain (original icon source: freepik.com)

5.4.4 Weaknesses and Problems Identification

In this section, the stakeholders' feedback Is presented. More specifically, they identified the weaknesses that stemmed from problems occurring in the FSC of Feta cheese. For each stakeholder, we report those problems and weaknesses.

Table 26: Identified Problems and Weaknesses of the FSC per stakeholder

Milk Producer		
Prob. No.	**Structural Problems**	**Weaknesses**
Problem 1	Low educational level - lack of digitalization literacy	Inertia in digital transformation of the FSC: Most of Olympos' associate Milk producers are not familiar with the utilization of digital technologies
Olympos' associate Transporter		
Problem 2	Low level of automation processes (manual data entries)	Data Reliability: No control over the reliability of the data entries to the system. For example, in case of inappropriate storage temperature, the milk should not be received.
Problem 3	Authenticity control based on sampling	Authenticity: No control over the reliability of the samples received. Samples are taken both from the cooling tanks and from the truck's compartment but the information given by the driver and producers (external partners) cannot be ensured to be reliable.
Problem 4	Low level of connectivity between the PDA software and GPS telematics	Interoperability: Olympos utilise telematics to monitor trucks routing. However, the process of receiving the milk and the GPS system is not interconnected. The goal is to connect the process of receiving the milk from the driver in real time.
Masoutis-Retailer		
Prob. No.	**Structural Problems**	**Weaknesses**
Problem 5	Scattered data and information that generated through products distribution	Interoperability-compatibility: The data are not compatible and not easily accessible.
Problem 6	Lack of digitalised critical information in stores such as lot number and expiration date, and quality after	Traceability: Data collection and recording are made manually. So, human errors are quite frequent.

	receiving the products and arranging them in appropriate conditions.	
Problem 7	Lack of Digital Temperature monitoring all along products transportation in associate's trucks	Data Reliability: No control over the reliability of the data input to the system. For example, in case of inappropriate storage temperature, the milk should not be received.

5.4.5 User Needs & Requirements Identification

In this subsection, the user needs and requirements for the Feta cheese FSC are presented. Firstly, we present the mapping of the identified problems with the corresponding ALLIANCE technology solutions. In the following table (Table 27), we associate the problems, with the respective stakeholder and with the identified need.

Table 27: User needs and requirements for the Feta cheese FSC

Stakeholder	Identified Need	Problem to Tackle	ALLIANCE Technology Offering
Olympos' associate Transporter	Need to monitor the temperature of the cooling tanks in real time.	Problem 2	**Technology Offering 1: Blockchain Platform:** Register all the data related to the product's quality on the ledger. **Technology Offering 2: Vulnerability Risk Assessment for Critical Control Points Identification in quality-labelled FSCs:** AI-based food fraud vulnerability assessment to identify and assess potential vulnerabilities and risks, determine pain-points.
Olympos' associate Transporter	Detection of possible adulteration on receiving process (cow milk, more than 30% goat milk and water)	Problem 3	**Tech. Offering 3: AI-enabled Early Warning and Decision Support System:** employs the other technological components of the project, including the fraud detection, the interoperability, the traceability and tracing **Tech. Offering 8: Prevent Food Fraud with Predictive Analytics**: provides a mechanism that will help authorization bodies and authorities prevent food fraud. **How:** this mechanism will rely on the Vulnerability Risk Assessment and include information in the proposed Early Warning System and Decision Support System.
Olympos' associate Transporter	Need to enable Interconnection with different tracking systems to allow end-to-end monitoring of the route of the truck and record the position from which the milk is received.	Problem 4,5	**Tech. Offering 4: Interoperability Mechanism in Complex Food Systems**: interoperability mechanism allows different platforms owned by stakeholders within the food chain to communicate efficiently and allow products, resources and data to be managed in a coherent way. **How**: Create an interoperable software to exchange and compare data between the two systems that Olympos possess (the PDA and the localization).

Stakeholder	Identified Need	Problem to Tackle	ALLIANCE Technology Offering
Masoutis	Digitalization of critical information in stores such as lot number and expiration date, quality (which are not properly registered on arrival)	Problem 5,6,7	**Technology Offering 1: Blockchain Platform:** Digitalize the documents and the operational processes. **How:** Along with Blockchain enable use of digital devices to automize the data collection processes and the data analysis in critical control points.
sMasoutis	Need for compatible data and operations	Problem 5	**Tech. Offering 4: Interoperability Mechanism in Complex Food Systems:** interoperability mechanism allows different platforms owned by stakeholders within the food chain to communicate efficiently and allow products, resources and data to be managed in a coherent way. **How**: Using a unified data model to harmonize collected information and use of Blockchain interoperability protocols.

After having identified an initial mapping of the current problems with the offered solutions, we proceed with the elicitation of specific requirements based on a user needs assessment, we came up with a Requirements Matrix per Technology offering. Each technology offering aims to tackle specific problems and eliminate weaknesses. However, in order to be applicable, each technology offering has been associated with specific requirements (Req. No, Requirements Description). Those requirements have been posed by the stakeholders. Each requirement Is described whether it belongs to a functional or non-functional type and It is prioritized using the MoSCoW technique with four different classification priorities (must-have, should-have, could-have, and won't-have).

Table 28: Requirements Matrix -Technology Offering 1 - Blockchain Platform

Technology Offering 1			Blockchain Platform					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 2,5,6,7	Automate processes to minimize fraud vulnerabilities in the critical control points, better management and fraud risk counter measuring.	Temperature recording only as an indication on the physical storage facilities and not as data storage. Samples are taken both from the icebox and from the truck's compartment. All this data is stored in Olympos' systems and there is a need to be ensured that the information given by the driver and producers (external partners) is truthful.	1	Allow the stakeholders to know the temperature	Functional	MUST HAVE	All identified Stakeholders of Olympos, Masoutis	PUC 2: The actors expect to digitalise the Feta cheese FSC with BC and IoT and increase transparency along the FSC with better traceability and food fraud identification mechanisms
			2	Allow stakeholders to know the location of the samples taken	Functional	MUST HAVE		
			3	Allow transporter to record data when Internet is inaccessible and update the Blockchain once online again.	Functional	MUST HAVE		
			4	Ensure Security and Privacy of the data	Non-Functional	MUST HAVE		
			5	Reliable, Trustworthy Digital Solutions	Non-Functional	MUST HAVE		
			6	Interoperability with the different software, PDA, ERP, and localization	Functional	MUST HAVE		
			7	Easy to use and low training needed	Non-Functional	SHOULD HAVE		
Comments								
The data is registered on the driver's PDA, the barcode of the icebox, the barcodes of the samples, the number of the compartment of the tank in which the milk is placed, the temperature, the Ph and the quantity can be considered to be entered to the Blockchain								

Table 29: Requirements Matrix -Technology Offering 2 - Vulnerability Risk Assessment for Critical Control Points Identification in quality-labelled FSCs:

Technology Offering 2			Vulnerability Risk Assessment for Critical Control Points Identification in quality-labelled FSC					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 2	Vulnerability assessment to identify and assess potential vulnerabilities and risks, determine pain-points In the Feta and Milk FSC.	No such a system exists	8	Allow users to open a GUI, run a test and receive a report on vulnerabilities.	Functional	MUST HAVE	All identified Stakeholders of Olympos, Masoutis	PUC 2: The actors expect to digitise the Feta cheese FSC with BC and IoT. Furthermore, they wish to assess the performance of the FSC and determine the CCPs by collecting data and analytics from the FSC.
			9	Usable by all stakeholders	Non-Functional	MUST HAVE		
			10	Reliable, Trustworthy Digital Solutions	Non-Functional	MUST HAVE		
Comments								
The data is registered on the driver's PDA, the barcode of the icebox, the barcodes of the samples, the number of the compartment of the tank in which the milk is placed, the temperature, the Ph and the quantity can be entered to the Blockchain								

Table 30: Requirements Matrix -Technology Offering 3 AI-enabled Early Warning and Decision Support System

Technology Offering 3			AI-enabled Early Warning and Decision Support System					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 3	Detection of possible adulteration on receiving process (cow milk, more than 30% goat milk and water)	No such a system exists	11	Allow stakeholders to access reports and recommendations based on the collected data	Functional	MUST HAVE	Olympos' stakeholders and associate transporter	PUC-2: Stakeholders expect to receive information and early warning about detecting admixtures, adulteration and fraud attempts.
			12	Reliable data must be generated in order to detect possible alteration	Non-Functional	MUST HAVE		
			13	User friendly visualization of the results	Non-Functional	MUST HAVE		
Comments								
N/A								

Table 31: Requirements Matrix -Technology Offering 4 Interoperability Mechanism in Complex Food Systems

Technology Offering 4			Interoperability Mechanism in Complex Food Systems					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 4,5	Connect the systems that cannot intercommunicate	Use of telematics and monitoring of trucks routing. There are Scattered data and information that generated through products distribution	14	Connect the process of receiving the milk from the driver in real time.	Functional	SHOULD HAVE	ALL identified stakeholders of Olympos, Masoutis	PUC 2: The expected outcome is to Interconnect the two FSC, Olympos, Masoutis and their systems
			15	Interoperability with Olympos and Masoutis systems	Functional	MUST HAVE		
			16	Standardize data in order to be compatible	Functional	MUST HAVE		
Comments								
Exchange data between the PDA, ERP and Telematics software.								

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Table 32: Requirements Matrix -Technology Offering 8 - Prevent Food Fraud with Predictive Analytics

Technology Offering 8			Prevent Food Fraud with Predictive Analytics					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 3	Detection of possible adulteration on receiving process (cow milk, more than 30% goat milk and water)	No such a system exists	17	Allow stakeholders to access reports and recommendations based on the collected data	Functional	MUST HAVE	All Stakeholders participating in the Feta Supply chain (Producers, farmers, Wholesalers, Importers/Exporters)	PUC-2: The stakeholders expect that they can improve proactive fraud mitigation planning by relying on forecast data produced by the ML/AI analysis on the collected data.
			18	Authentication of users and samples	Functional	MUST HAVE		
			19	Reliability of the results, reports and recommendations of the system	Non-Functional	MUST HAVE		
Comments								
N/A								

5.5 Demonstrator 3 - Organic Honey

5.5.1 Introduction

Honey is one of the most highly appreciated commodities for its nutritional properties and its high quality. Despite being of high value, honey is one of the top products at risk of fraudulent activities in Europe. A Codex Alimentarius was published to maintain the quality and standards of this valuable commodity against risks of frauds (Arroyo-Manzanares et al., 2019; Lastra-Mejías et al., 2020). The economic importance of honey has made it susceptible to several fraudulent activities, such as mislabelling, adulteration, and substitution. One of the major fraud cases is adulteration using cheap quality syrups (e.g., rice syrup, corn syrup, maple, agave, palm syrup...). It is important to mention that honey adulteration is a serious global issue, and is more complex than it seems, due to the presence of different international standards, as well as the fact that there are not enough studies related to unifloral honey, to reduce adulteration risks. Regardless of the continuous effort to reduce these fraud cases, no real solution has been found yet. Furthermore, another major honey fraud issue is mislabelling. Honey depends on its floral and geographical origin; many fraud cases include mislabelling and misleading information regarding the origin and the floral composition of the commodity. Brar et al., (2023) have noticed a confusion amongst stakeholders regarding the establishment of a methodology for honey authenticity and adulteration, as well as a heterogeneity of worldwide standards that induce a consumer confusion in regards of honey quality.

5.5.2 Organizations/stakeholders involved

The two main stakeholders in the Occitanie region were identified and selected:

- ADA Occitanie (Développement de l'Apiculture en Occitanie) is the main organization providing extension services in the regional beekeepers (https://www.adaoccitanie.org/)
- ITSAP – Institut de l'abeille Is the main research and development Institution in the French apiculture sector (https://itsap.asso.fr/)

The users that are related to those actors, form the personas that are being involved in the ADA and ITSAP and undertake a particular work/responsibility to accomplish.

5.5.3 Existing Infrastructure & Operations

There is no official traceability and authenticity protocol for the local beekeepers. Recent years a "honey book" has been installed in the region aiming to convince farmers to provide some important information. This "honey book" has been developed by ITSAP and aims to help beekeepers to track the different operations during the honey production and declare the basis characteristics of their product (e.g. pollen origin, placement of hives, date of production, place of production etc.; see process 1)

Table 33: Beekeeper's Process

Beekeeper/Producer	Data collection system: internal traceability records.

Process 1	All these data are provided physically by every Individual beekeeper. There Is no web-based or automated process. • Apiary address • Harvest date • Type of honey • Extraction date • Total extracted quantity • Type of packaging (pots, buckets, drums, and batch numbers) and quantity • Details of the sale (market, packager) (invoice numbers, delivery note)

5.5.4 Weaknesses and Problems Identification

Here, we present the stakeholders feedback, where they identified their weaknesses that stemmed from problems occurring in the examined value chain.

Table 34: Identified Problems and Weaknesses of the FSC

Beekeeper - Producer		
Prob. No.	**Structural Problems**	**Weaknesses**
Problem 1	Zero to low monitoring of the geographical placement of hives within the region	No traceability system
Problem 2	Zero to low Pollen analyses to determine and control the botanical and geographical origin of honeys	No traceability system

5.5.5 User Needs & Requirements Identification

In this subsection, we present the user needs and requirements for the organic honey value chain. Firstly, we present the mapping of the identified problems with the corresponding ALLIANCE technology solutions. In the following Table, we associate the problem with the offered solutions and we link as well as with the respective stakeholder and the emerging need.

Table 35: User needs and requirements for the organic honey value chain

Stakeholder	Identified Need	Problem to Tackle	ALLIANCE Technology Offering
Beekeepers	Establishment of a traceability and authenticity system	Problem 1, Problem 2,	**Technology Offering 1 & 5: Blockchain Platform & Next Generation portable DNA Sequencing for Food Analysis:** Digitalize the "honey book" documents and provide vital information on the consumers. **How:** Implementing the "The World Bee Project" traceability system by installing GPS sensors to beehives in order to detect the geographical location of the produced honey. Moreover, systematic pollen analyses will be elaborated in order to validate the declaration of the beekeepers and minimize honey adulteration.

After having identified an initial mapping of the current problems with the offered solutions, we proceed with the elicitation of specific requirements based on a user needs assessment, we come up with a Requirements Matrix per Technology offering.

Table 36: Requirements Matrix -Technology Offering 1 - Blockchain platform

Technology Offering 1			Blockchain platform					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1,2	Establish of a traceability and authenticity system	The current monitoring and pollen analyses rely on the declaration of beekeepers in the "honey book"	1	Ensure Security and Privacy of the data	Non-Functional	MUST HAVE	Beekeepers (Member of ADA Occitanie)	PUC-3 - The expectation of the stakeholders Is to digitalize the existing physical "honey book" and registered It In a platform order to provide information to the consumers regarding the botanical and geographical origin of honeys via a barcode
			2	Reliable, Trustworthy Digital Solutions	Non-Functional	MUST HAVE		
			3	Easy to use and low training needed	Non-Functional	MUST HAVE		
			4	Allow the stakeholders to easy register in a platform all the necessary information regarding pollen origin and geographical location	Functional	MUST HAVE		
			5	Allow the consumers to scan a barcode and have all the necessary information about the production of the organic honey in the region	Functional	MUST HAVE		
Comments								
Increase the efficiency of the current manual data collection (and decrease the human errors and false declarations)								

Table 37: Requirements Matrix -Technology Offering 5 - Next Generation portable DNA Sequencing for Food Analysis

Technology Offering 5			Next Generation portable DNA Sequencing for Food Analysis					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1,2	Establish of a traceability and authenticity system	The current monitoring and pollen analyses rely on the declaration of beekeepers in the "honey book"	6	Portable: Allow for on-site inspection and sample validation. Beekeepers have the capability to carry a lightweight portable device to perform DNA sequencing analysis for their product.	Functional	MUST HAVE	Beekeepers (Member of ADA Occitanie)	PUC 2 – Provide an easy and fast procedure for the local beekeepers to evaluate the quality of their products and registered the "honey book" without increasing their significant production costs.
			7	Reliable: Allow beekeepers have access on consistent data results when they use the device.	Non-Functional	MUST HAVE		
			8	Low Cost: Allow all beekeepers to have access to this device without increasing their production costs	Non-Functional	MUST HAVE		
Comments								
Be able to Identify the geographical origin of the produced honey								

5.6 Demonstrator 4 - PGI Asturian Faba beans

5.6.1 Introduction

Beans are being part of the second major agricultural family, “Legumes”. They are of great economic impact in the food market. Grain legumes, such as fava beans are known to be an important source of protein, and are dominant in the human diet as well as in animal feed. Therefore, beans authenticity is essential, as a key element for quality insurance when placed on the market. Various species of beans exist and can be classified on several value levels, based on their origin. This diversity induces mislabelling and the concealment of species, increasing the risk of food fraud in a period where authentication methods are in the need of an improvement to prevent fraudulent acts (Madesis et al., 2012).

5.6.2 Organizations/stakeholders involved

Four relevant actors in the PGI Asturian Faba Bean value chain have been identified and they are listed below. Namely:

- ASINCAR[1], as PGI and PDO management expert
- IGPFA[2], as control body
- Main farmers in IGPFA
- Main packers in IGPFA

The users that are related to those actors, are being involved in the FSC and undertake a particular work/responsibility to accomplish.

5.6.3 Existing Infrastructure & Operations

Current control of authenticity is based on the implementation of **a traceability system** by the different agents involved in each of the stages for obtaining, elaboration, certification and commercialization of the PGI Faba beans. This allows the monitoring and control of the PGI through the compilation and analysis of the data along the chain, which interconnected provide verified information between the agents involved throughout the entire chain. Following, are described the **different processes used by the different agents to fulfil the control and certification processes established by the PGI Control Body**.

Table 38: PGI Asturian Faba beans processes

ASINCAR	**Data collection system: internal traceability records.**
Process 1	- PGI PDO management expert: consulting and technology solution provider to farmers/producers, packers and Control Body.
Farmer/Producer	**Data collection system: internal traceability records.**
Process 2	- Crop register (per plot): cropping date, cropped area, seed variety, kg of seed used, cultivation system, assignment of batch
Process 3	- Harvest register (per plot): harvest date, batch, kg obtained by commercial type (extra category, first, second, others).

[1] https://www.asincar.com/
[2] https://faba-asturiana.org/

Process 4	- Register of packaging, certification and commercialization with own brand (if also packer and/or seller): lot, packaged kilograms, packaging format, commercial category, group and back label numbering, destination (direct sale
Process 5	Register of commercialization with third parties (packers): check book number (with 3 copies, on for farmer, one for the packer and one for the PGI control body), batch, commercial category, kilograms, and destination (packer)
Packers	**Data collection system: internal traceability records.**
Process 6	- Entry register for protected faba bean: check book number, primary producer identification, kilograms purchased, entry lot, commercial category
Process 7	- Register of packaging: lot, category, kilograms packed, units by format, group and back label numbering, destination.
Process 8	- Exit register: batch, commercial category, kilograms, group and back label numbers, destination.
Process 9	- Register of stocks: producer identification, lot, category, stored kilograms
Process 10	- Product movement record
PGI Control Body	**Operator Registration**
Process 9	-Producers: physical/legal person data, farm location, plots
Process 10	-Packers: physical/legal person data, location of facilities (warehouses)
	Control records requested from agents involved
Process 11	-Cropping declaration: provided by the farmers
Process 12	-Harvest declaration: provided by the farmers
Process 13	-Product movement register: provided by packers
Process 14	-Declaration of entries and exits for protected product: provided by the packers periodically
Process 15	-Register of request and delivery of back labels (to packers and producers with their own brand).
	Carrying out on-site verifications:
Process 15	-Review of declared parcels and producer facilities
Process 16	-Visit to packaging facilities
Process 17	-Stock control
Process 18	-Traceability backwards - internally - forwards
Process 19	-Mass balance
Process 20	-Back labelling control
Process 21	-Control over certified product (sampling)

All these processes and controls are reflected in the diagram depicted in Requirements Matrix -Technology Offering 5 Next Generation portable DNA Sequencing for Food Analysis:

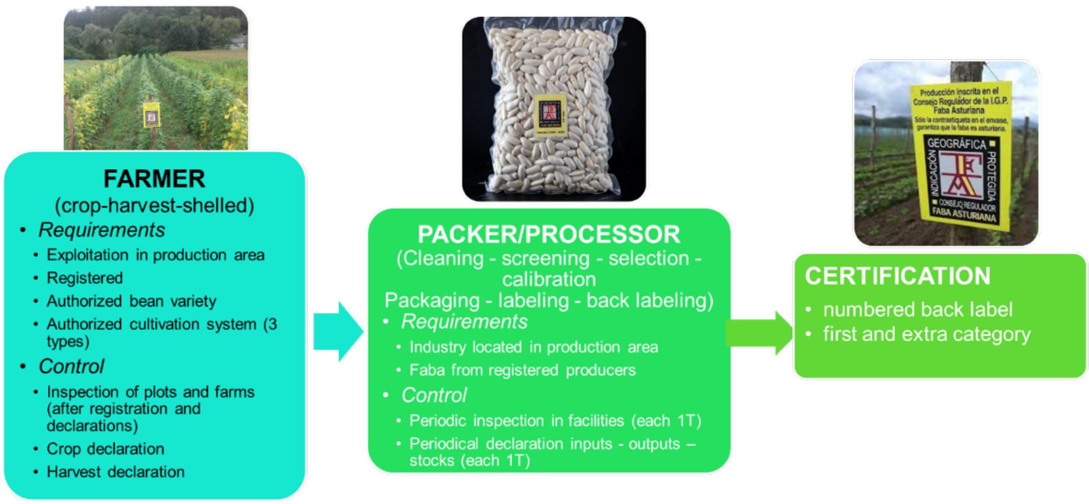

Figure 23: Flow Diagram (Farmer to Certification Body)

5.6.4 Weaknesses and Problems Identification

Here, we present the users feedback, where they identified their weaknesses that stemmed from problems occurring in the Faba Beans FSC. For each stakeholder, we report those problems and weaknesses.

Table 39: Identified Problems and Weaknesses of the FSC per stakeholder

Farmer - Producer		
Prob. No.	**Structural Problems**	**Weaknesses**
Problem 1	Low educational level - lack of digitalization literacy	Inertia in digital transformation of the FSC: Farmers/Producers are not familiar with the digital technologies. Lack of digital literacy prevents them from adopting innovative solutions and they are reluctant to apply changes to improve processes.
Problem 2	Low level of digitalization processes (manual records)	Traceability: No control over the faba classifiers, that are a key step of the value chain. So, there could be a "door" for fraudsters to exploit.
Packers		
Problem 3	Scarce digitization / manual records	Trustworthiness: Data collection and recording are made manually. So, human errors are quite frequent. Dependence on erroneous manual processes.
	Operational Problems	**Weaknesses**
Problem 4	Lack of trustworthy and tamperproof traceability system. Currently, traceability depends on the manual records of producers	Traceability: Readjustments in harvest yields due to differences between the initial tentative harvest declaration made by the farmer and the final official numbers.
Problem 5	Fraud (sale cheaper similar product)	Authenticity: Lack of an authenticity tool that allows identification the main fraudulent practices of the PGI (fake PGI beans and mix several PGI plots).
PGI CONTROL BODY		
Problem 6	Little Digitalization	Inertia in digital transformation of the FSC.
Problem 7	Low level of digitalization processes (manual records)	Reliability: Data collection of the PGI control body is made manually and then key Information is inserted in an Access database. So, human errors are quite frequent.
	Operational Problems	**Weaknesses**
Problem 8	Absence of a reliable and tamperproof to monitor the re-collection process	Traceability: Non re-collection of numbered back labels that have not being used by the PGI body: for example, a producer requests back labels for 1.000 kg and finally just certify 500 Kg. There is no traceability about the recollection of the labels that have not being used.

Problem 9	Absence of electronic and digital devices that facilitate control	Authenticity: Authenticity: No control over the faba classifiers, that is a key step of the value chain. So, there could be a "door" for fraud. Lack of an authenticity tool that allows to identify the main fraudulent practices of the PGI (fake PGI beans and mix several PGI plots).

5.6.5 User Needs & Requirements Identification

In this subsection, we present the user needs and requirements for the Faba FSC. Firstly, we present the mapping of the identified problems with the corresponding ALLIANCE technology solutions. In the following Table, we associate the problem with the offered solutions and we link it to the respective stakeholder and the emerging need.

Table 40: User needs and requirements for the Faba FSC

Stakeholder	Identified Need	Problem to Tackle	ALLIANCE Technology Offering
PGI Control Body	Test the authenticity of the PGI faba against main frauds	Problem 8 and Problem 9	**Technology Offering 6: NIR and HSI Based Solutions:** I) detect mixture of PGI and non-PGI beans; (Ii) mix beans from different plots, that Is forbidden by IGPFA **How:** Use of Portable digital devices based on NIR and HSI to authenticate the PGI Faba beans
Farmers/Packers/ PGI Control Body	Increase the monitoring efficiency of the operations in the FSC	Problem 2, Problem 3, Problem 4, Problem 5, Problem 7	**Technology Offering 1: Blockchain Platform:** Digitalize the documents, operational processes of IGPFA. Exchange information with increased trust and automize the data collection with IoT. We need also to assure the confidentiality and privacy of the shared data, that will be just use with project related purposes. **How:** Along with Blockchain enable use of IoT to digitalize the data collection processes and automatize the data analysis in critical control points.

After having identified an initial mapping of the current problems with the offered solutions, we proceed with the elicitation of specific requirements based on a user needs assessment, we come up with a Requirements Matrix per Technology offering. Each technology offering aims to tackle specific problems and eliminate weaknesses. However, in order to be applicable, each technology offering has been associated with specific requirements (Req. No, Requirements Description). Those requirements have been posed by the stakeholders. Each requirement is described whether it belongs to a functional or non-functional type and it is prioritized using the MoSCoW technique with four different classification priorities (must-have, should-have, could-have, and won't-have).

Table 41: Requirements Matrix - Technology Offering 6 - NIR and HSI Spectroscopy

Technology Offering 6			NIR and HSI Spectroscopy					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1, 5, 8, 9	Authenticate Asturian PGI faba bean and combat main frauds	A similar tool is not existing now. Authentication is based on the PGI traceability system	1	Allow auditors to search for process results, filter them by attribute and sort them by keyword			PGI operators for on-field inspections	PUC-4: PGI operators expect to have a low cost, reliable, portable device that can be used for authenticity evaluation with NIR and HSI sensing.
			2	Portable	Non-Functional	MUST HAVE		
			3	Reliable and Accurate	Non-Functional	MUST HAVE		
			4	Low Cost	Non-Functional	MUST HAVE		
			5	Enough fast (less than a minute to get result)	Non-Functional	MUST HAVE		
			6	Easy to use and low training needed	Non-Functional	SHOULD HAVE		
			7	Results should be transferable to other applications and allow for example differentiation between "Extra" and "Primary" categories	Functional	SHOULD HAVE		
			8	Support multicomponent analysis, provide also the protein content	Functional	SHOULD HAVE		
Comments								
Being able to identify: (i) Mixtures of PGI faba bean with cheaper one (ii) Mixtures of PGI faba beans from different plots								

Table 42: Requirements Matrix - Technology Offering 1 - Blockchain Platform

Technology Offering 1			Blockchain Platform					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 2, ,3 ,4, 6, 7	Automatize data collection and digitalize the FSC with a trustworthy and tamperproof mechanism	Manual data collection and recording. Post-transfer of data to an Access database. Lack of a trusted traceability system	9	Allow users to trace products by scanning a tag (QR code) by their portable device, view the history timeline	Functional	MUST HAVE	PGI Control Body, Farmers, Producers	PUC-Demonstrator 4: Participants in the FSC expect to access reliable data with increased trustworthiness. They wish to have increased monitoring and traceability capabilities within their FSC and experience a fully automatized digital record keeping that will be hosted by a tamper-proof trustworthy mechanism.
			10	Allow FSC participants (except consumers) to record the event (time, location, lot number, production, variety, weight) that they have received a product	Functional	MUST HAVE		
			11	Ensure Security and Privacy of the data	Non-Functional	MUST HAVE		
			12	Reliable, Trustworthy Digital Solutions	Non-Functional	MUST HAVE		
			13	Interoperability with other common IT tools	Functional	SHOULD HAVE		
			14	Easy to use and low training needed	Non-Functional	SHOULD HAVE		
Comments								
Increase the efficiency of the current manual data collection (and decrease the human errors)								

Table 43: Requirements Matrix - Technology Offering 7 - Digital Knowledge Base for Food Fraud

Technology Offering 7			Digital Knowledge Base for Food Fraud					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 2.6	Need to improve the understanding of the food fraud landscape. Need to link identified and reported food hazards in the PGI Faba FSC with the appropriate means and tools to mitigate such incidences.	No such a system exists	15	Allow users to search for food fraud issues by keyword and filter the results based on different attributes and link identified issues with countermeasures	Functional	MUST HAVE	AI PGI Control Body, Farmers, Producers	PUC-4: Users participating in the FSC can access updated and well-structured scientific information, that is related to fraud in quality-labelled food products and get informed. By leveraging ALLIANCE Knowledge Base, users in the PGI Faba FSC are expected to optimize their procedures by updating and applying adjustments in the FSC operation according to the latest fraud prevention strategies, systems 18or protocols.
			20	Easy to use: All participants of the FSC should be able to use this service without any special training.	Non-Functional	MUST HAVE		
			17	Availability of the Knowledge Base: Support parallel queries	Functional	SHOULD HAVE		
Comments								
N/A								

5.7 Demonstrator 5 - PGI Lika Potatoes

5.7.1 Introduction

Potatoes are in the top 10 most important crops globally, being an essential part of many diets around the world. Under EU regulation, potatoes are required to be labelled by their varietal name, as a consumer protection and quality control measure. In a study focusing on the Spanish market, mislabelling fraud cases were detected, but with a percentage gap between cases that are reported as suspicious fraud acts and cases proven as fraud acts. This difference is mostly due to the supposition of different origin samples, knowing that the sample's collection was done randomly and whiched some cases of foreign countries origins. In addition, the mislabelling fraud case appears to be a recurrent problem and not a punctual issue (Lopez-Vizcón & Ortega, 2012).

5.7.2 Organizations/stakeholders involved

The relevant actors in the PGI Lika Potatoes value chain and Migros retailer FSC have been identified and are listed below. These two FSCs, ALLP and Migros will be linked to each other in a later stage of ALLIANCE.

- The Association of Lika Potato Producers (ALPP) at the moment has 7 members, and only one of them is in the system of PGI certification system. Also, there are two producers who are not member of ALPP but they produce and sell potatoes under PGI label.
- Smaller producers are producing and selling directly their potatoes at the doorstep or at local market.
- Verification of PDO/PGI compliance in Croatia is carried out by private certification bodies registered with the Ministry of Agriculture. Biotechnicon Ltd. is the certification body responsible for the process of PGI Lika potatoes certification for both interviewed producers.
- Validity control is also carried out by the Inspecwhich, which operates within the State Inspectorate.
- Two biggest producers have its own seeds, but they also buy smaller quantities from seed suppliers. Packaging (potato bags and boxes) is purchased partly from domestic suppliers and partly from importers. The main distribution channels are supermarkets (LIDL, INTERSPAR), specialized stores, restaurants and online sales.
- The delivery of potatoes to the distribution centres of retail chains goes from the producer through the distributor or through the transport company.
- Online sales work through online platforms and also through parcel delivery companies that deliver directly to the consumer.

In addition, on the retailer side, Migros is comprised of 2987 stores as of the report date operating in all cities of Turkey. Migros owns, 9 distribution centres, 6 fruits and vegetables production facilities, and 11 wholesale warehouses were independently and externally audited for compliance with IFS Product Safety standards. Migros works with 2,942 active suppliers and 20,000 farmers.

5.7.3 Existing Infrastructure & Operations

Infrastructure such as IoT sensors, wireless communication infrastructures or sensing and monitoring technologies are not used in the system of certification, supervision and control of implementation of the specification for PGI Lika Potatoes. No special software is used for control or monitoring either. Only the largest producer has equipment that enables online connection in the warehouse.

The warehouse used is of public type, i.e. it can provide the storage space for other (smaller) producers - the members of the association. The system has cooling regimes that are adjusted automatically in the very new cold storage, and semi-automatically or manually in the older part of the storage where the potatoes are also kept. There is aeration and ventilation equipment installed.

Table 44: PGI Lika Potatoes processes per stakeholder

Farmer/Producer of ALPP	Data collection system: internal traceability records.
Process 1	Production Register: unique producer's number in the association of producers, production plot number, name of production plot, cadastre municipality, cadastral number of the plot, plot area in m2, plant name, planted variety, planted area in m2, Traceability number
Process 2	Storage register: temperature measurements, product id, product quantity
Process 3	Packaging register: product description, quantity, expiration date, QR code, date and time, origin DC
Transporter	**Data collection system: internal traceability records.**
Process 4	- Transportation register: product quantity, date and time, farmer information, location, temperature of the transport, physical condition
Migros	**Data collection system: internal traceability records.**
Process 5	- Register of product receipt: product description, transporter information, quantity, expiration date, temperature measurements, time and date
Process 5	- Register for repackaging: product description, quantity, expiration date, QR code, time, origin DC
Process 7	- Deliveries register: temperature measurements, GPS measurements, product id, product quantity, time and date, origin DC
Process 8	- Storage register: temperature measurements, product id, product quantity, storage id, origin DC
Process 9	- Register of product receipt on the stores: product description, quantity, expiration date, temperature measurements, inspection data on the quality of the product, origin DC

These processes are visualised in a diagram in Figure 24.

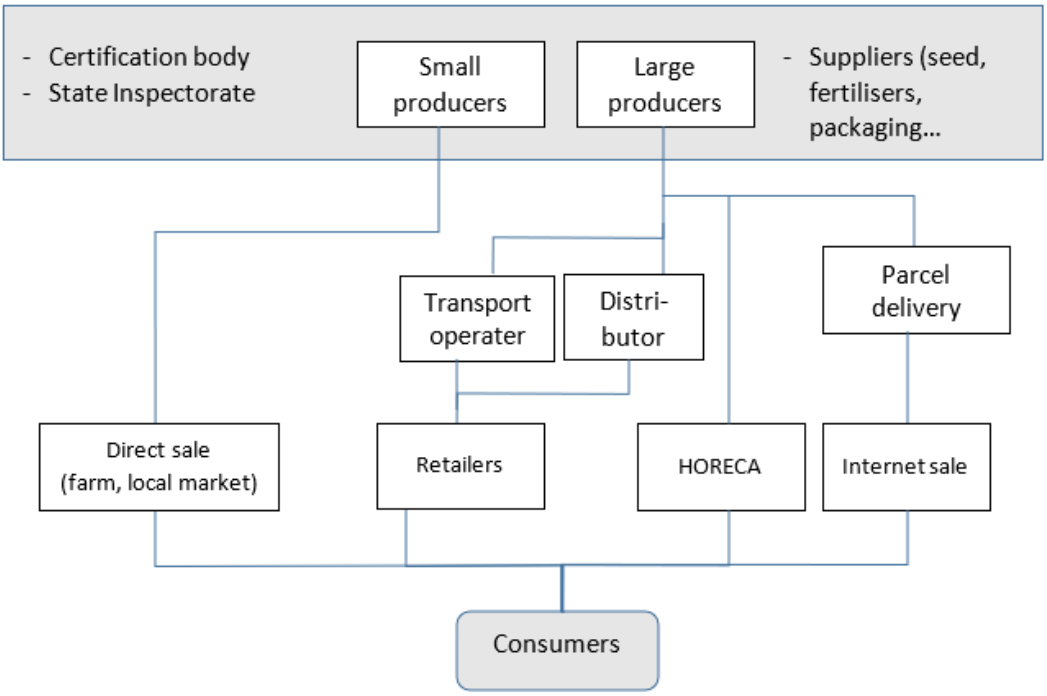

Figure 24: PGI Lika Potatoes SC

5.7.4 Weaknesses and Problems Identification

The table below lists stakeholder feedback identifying weaknesses arising from issues encountered in the Lika Potatoes FSC. For each stakeholder, we report on these issues and weaknesses.

Table 45: Identified Problems and Weaknesses of the FSC per stakeholder

Farmer/Producer of ALPP		
Prob. No.	**Structural Problems**	**Weaknesses**
Problem 1	Low educational level - lack of digitalization literacy	Inertia in the digital transformation of the FSC: Farmers have little knowledge over digitalization technologies
Problem 2	Low level of digitalization processes (manual records)	Lack of Traceability: The main data collected are written down on paper forms and in Excel. Thus, traceability becomes almost impossible and the PGI cannot be guaranteed.
Problem 3	High possibility of fraud attempts - potatoes are not verified	incompleteness of information: There is a lack of verification of imported potatoes and other potatoes outside the PGI certification system is missing.
Problem 4	Lack of know-how in the field of application	Knowledge: Lack of knowledge about technologies that facilitate processes and prevent food fraud.
Migros		
Prob. No.	**Structural Problems**	**Weaknesses**
Problem 5	Data associated to fresh products are restricted	Inadequate transparency: Missing data can result in fault traceability.
Problem 6	Customer awareness	Disinformation regarding the product leading to confidence loss on the company brand.

5.7.5 User Needs & Requirements Identification

In this subsection, we present the user needs and requirements for the Lika Potatoes FSC. Firstly, we present the mapping of the identified problems with the corresponding ALLIANCE technology solutions. In the following Table, we associate the problem with the offered solutions and we link to the respective stakeholder and the emerging need.

Table 46: User needs and requirements for the Lika Potatoes FSC

Stakeholder	Identified Need	Problem to Tackle	ALLIANCE Technology Offering
ALPP	Increasing process effectiveness through digitalization of the operations. Increasing transparency and build trust among the stakeholders	Problem 2,3,5,6	**Technology Offering 1: Blockchain Platform:** Digitalize the documents and operational processes in a way that transparency and immutability of the data is increased. **How**: Along with Blockchain enable the use of IoT to digitalize the data collection processes and automate data analysis in critical control points. Also, end-consumers can benefit from an authenticated product, access the trustworthy related Information, and increase their loyalty to the brand.
ALPP	Food fraud prevention	Problem 3	**Technology Offering 3: AI-enabled Early Warning and Decision Support System:** This system enables the food fraud detection, the traceability **How**: with AI analytics informed decision support is offered to food actors, to take countermeasures and proactively prevent food fraud incidences and ensure health and public safety.
ALPP	Gain know-how about the technologies that can be used for operations	Problem 4	**Technology Offering 7: Digital Knowledge Base for Food Fraud:** this technology enables the exchange of knowledge, information, data, best practices, lessons learnt, well-established processes in the food chains of quality-labelled food products. **How**: A knowledge management system (KMS) will be provided
Migros	Digitalise the operation processes using QR codes	Problem 2	**Technology Offering 1: Blockchain Platform**: Record of every process in the FSC to an immutable platform. **How**: Digitalised processes are recorded and can be easily provided to consumers as a proof of Authenticity.
Migros, ALLP	Interconnect the two FSCs, ALLP and Migros	Problem 5	**Tech. Offering 4: Interoperability Mechanism in Complex Food Systems:** interoperability mechanism allows different platforms to communicate efficiently and allow products, resources and data to be managed in a coherent way. **How**: Use of Blockchain Technology to enable interoperability between two FSCs

Having made an initial mapping of current problems and the solutions offered, we proceed to elicit specific requirements based on an assessment of user needs and create a requirements matrix per technology offering. Each technology offering aims to tackle specific problems and address weaknesses. However, in order to be applicable, each technology offering has been associated with specific requirements (Req. No, Requirements Description). Those requirements have been posed by the stakeholders. Each requirement Is described whether it belongs to a functional or non-functional type and It is prioritized using the MoSCoW technique with four different classification priorities (must-have, should-have, could-have, and won't-have)

Table 47: Requirements Matrix - Technology Offering 1 - Blockchain Platform

Technology Offering 1			Blockchain Platform					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 2,3,5,6	Digitalise and increase in process effectiveness, throughput and credibility	Main data collected are written down on paper forms and Excel. There is a lack of verification of imported potatoes and other potatoes outside the PGI certification system.	1	Digitalise all documents and introduce the digital traceability system	Functional	MUST HAVE	All participating stakeholders of ALPP, Migros	PUC-Demonstrator 5: The actors expect to digitalise the Lika Potatoes FSC with BC and IoT increasing effectiveness and transparency
			2	Record of every process in the FSC to an immutable platform	Functional	MUST HAVE		
			3	Receive product records by inquiring the QR label	Functional	MUST HAVE		
			4	Uptime/Availability 24/7	Non-Functional	MUST HAVE		
			5	Access management related to each partner	Non-Functional	MUST HAVE		
			6	Send product records when Inquired by the QR code	Functional	COULD HAVE		
			7	The records shall be compatible with EPCIS GS1 standards	Functional	COULD HAVE		
Comments								
N/A								

Table 48: Requirements Matrix - Technology Offering 3 - AI-enabled Early Warning and Decision Support System

Technology Offering 3			AI-enabled Early Warning and Decision Support System					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 3	Food fraud prevention	There is no such system	8	Allow stakeholders to access Reports and recommendations based on the collected data	Functional	MUST HAVE	All participating stakeholders of ALPP, Migros	PUC-Demonstrator 5: The actors expect to prevent food fraud of other non-certified potatoes
			9	Reliability of the output results of the system	Non-Functional	MUST HAVE		
			10	Easy to use	Functional	MUST HAVE		
Comments								
N/A								

Table 49: Requirements Matrix - Technology Offering 4 Interoperability Mechanism in Complex Food Systems

Technology Offering 4			Interoperability Mechanism in Complex Food Systems					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 5	Interconnect the two FSCs, ALLP and Migros	The two organization have never cooperated before	11	Interoperability with existing digital IT tools	Functional	MUST HAVE	All participating stakeholders of ALPP, Migros	PUC-Demonstrator 5: It is expected for the two FSCs to be interoperable
			12	Standardize data in order to be compatible following a common data format	Functional	MUST HAVE		
			13	Reliability and security over the data exchanged between the 2 SC	Non-Functional	MUST HAVE		
Comments								

Table 50: Requirements Matrix - Technology Offering 7 - Digital Knowledge Base for Food Fraud

Technology Offering 7			Digital Knowledge Base for Food Fraud					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 4	Gain know-how about the technologies that can be used for operations regarding Food fraud	Verification of imported potatoes and other potatoes outside the PGI certification system is missing	14	Allow users to perform advanced search in the database	Functional	MUST HAVE	All participating stakeholders of ALPP, Migros	PUC-Demonstrator 5: It is expected fot the actors to utilize the Digital Knowledge Base for Food Fraud
			15	User-friendly environment that will facilitate the exchange of knowledge	Non-Functional	MUST HAVE		
			16	Cloud based solution that will facilitate access.	Functional	SHOULD HAVE		
Comments								

5.8 Demonstrator 6 - Organic Pasta

5.8.1 Introduction

Pasta represents the national Italian dish, identity, and is an important component on the Mediterranean table. Italy is the largest Pasta producer around the world, taking over more than 25% of the international market. Durum wheat semolina is the main ingredient used for pasta production, and is considered as a product of a superior quality. A maximum of 3% of soft wheat can be used in the production of dry pasta, in accordance with the Italian law. Products that are intended to be exported, can exceed the restricted amount if labelled accordingly. However, this 3% causes a quality control issue for manufacturers, requesting at the same time a need for more reliable methods to identify durum wheat from non-durum wheat. Moreover, the low prices of common wheat, in comparison to durum wheat, leads to increased amount of soft wheat by the retailers without declaring it, highlighting that wheat flour adulteration lower the quality of the pasta (Casazza et al., 2012; De Girolamo et al., 2020).

5.8.2 Organizations/stakeholders involved

Several actors in the Organic Pasta value chain have been identified and they are listed below. Namely:

- CCPB is the control body that certifies the organic nature of Alce Nero products. It is also the institution certifying our pasta producer.
- Pastificio Felicetti is the partner that produces the pasta. We are interested in involving the quality manager, the plant manager and the pasta maker.
- Molino De Vita is the partner that grinds durum wheat. His involvement is interesting as he is the one who first receives the grain and therefore defines its acceptance.
- Mediterre.bio is made up of individual farmers and cooperatives from Puglia, Basilicata, Calabria and Emilia, producing mostly organic durum and soft wheat, as well as organic extra virgin olive oil. This cooperative cultivates the wheat for our supply chain.
- Coop. Daunia: Cooperative in the province of Foggia (members of Mediterre.bio), deals only with organic agriculture and mainly durum wheat. They are one of our durum wheat suppliers.
- Coop Terra Maiorum: Cooperative in the province of Bari (also members of Mediterre.bio), deals only with organic agriculture and mainly durum wheat production. They are one of our durum wheat suppliers.
- Independent farmers: farmers who give Alce Nero durum wheat but are not part of any cooperative. It is possible that the number of subjects involved will be reduced.

The stakeholders involved in the value chain of Masoutis retailer are listed as follows:

- Producer: Production of the raw materials.
- Manufacturer: Supply and storage of raw materials, supply and storage of packaging material, manufacturing process, storage of the end product.
- Manufacturer / Distributor: Dispatch of the product to Masoutis' Logistics Center premises under appropriate conditions.

- Masoutis: Product quality inspection, Storage in facilities, compartmentalized in both dry and cold storage.

Masoutis/ Distributor: Distribution under appropriate conditions to Masoutis stores

5.8.3 Existing Infrastructure & Operations

5.8.3.1 FSC Production part

The following existing infrastructures and operations exist in the system. Firstly, the system collects data directly from the field In order to monitor the Cappelli durum wheat variety and control the compliance with the organic production principals. Then, the laboratory examines the presence/absence of residues in each pasta samples aiming to validate the organic system compliance. Lastly, the collected data and the analyses are used to set up an organic Cappelli durum wheat pasta fingerprint, to be used as a predictive model.

The original data are collected from residues analysis, hence these consist of chemical data and the quantification of each compound found in the samples. In detail, samples of soil and pasta are going to be selected, collected and identified by means of Alphanumeric codes, then they are sent to accredited laboratory for multiresidue analysis, performed using Quick Easy Cheap Effective Rugged Safe (QuEChERS) approach. All the data is going to be collected as Certificate of Analysis (CoA) and stored on proper Google Drive storage of Alce Nero and Federbio. All the data collected are then used to create a predictive model based on a fingerprint approach: the frequency of absence/presence of a certain residue would be relevant for the definition of the model. Thus, chemical data will be converted into numerical coefficients based on their quantification and frequency.

Additionally, data coming from the selected IoT sensor/AI system will be collected in order to investigate the authenticity of raw material, thus the real selection of “Senatore Cappelli” variety of organic wheat.

All samples are analysed by means of multi-residual analysis. In detail, analysis is carried out using the QuEChERS (quick, easy, cheap, effective, rugged, and safe) pre-treatment technique, which is a trustworthy and accurate method for the extraction of a large number of compounds usually searched in food matrices. Subsequently, a purification of the extracted matrix is performed on each sample in order to make the multiresidual check more accurate. After this purification, pasta samples will be analysed by means of Gas Chromatography (GC) or Liquid Chromatography (LC) paired to mass spectrometry (MS) methods. Each sample spectrum will be compared to many reference standards (one for each potential residue) but also to the one considered as a control sample, free from residues.

5.8.3.2 FSC Retailing part - Masoutis

The current infrastructure of Masoutis retailer consists of logistics, IoT sensors, ICT systems, and facilities. The infrastructure details have already been described in the EVOO use case (Section 5.3).

5.8.4 Weaknesses and Problems Identification

Here, we present the stakeholders' feedback, where they identified their weaknesses that stemmed from problems occurring in the Alce Nero ecosystem. For each stakeholder, we report those problems and weaknesses.

Table 51: FSC processes per stakeholder

Farmer/Producer	Data collection system: internal traceability records.
Process 1	Food fraud risk in pasta products materialises as pesticides' residues and metabolites in the final product
Manufacturer	**Data collection system: internal traceability records.**
Process 2	Register of raw material receipt: quantity, time and date, temperature information, physical condition, transportation information
Process 3	Register of raw material storage: quantity, temperature, storage id, material id

5.8.5 User Needs & Requirements Identification

In this subsection, we present the user needs and requirements for the Alce Nero FSC. Firstly, we present the mapping of the identified problems with the corresponding ALLIANCE technology solutions. In the following Table, we associate the problem with the offered solutions and we link as well as with the respective stakeholder and the emerging need.

Table 52: Identified Problems and Weaknesses of the FSC per stakeholder

Stakeholder	Identified Need	Problem to Tackle	ALLIANCE Technology Offering
Farmer/Producer	Need to check the compliance of raw material to organic production	Problem 1	**Technology Offering 3: AI-enabled Early Warning and Decision Support System** **How:** Use of AI device on field that can check and evaluate the compliance of a farmed field to organic crop
Manufacturer	Need to check the compliance of raw material to "Senatore Cappelli" variety	Problem 2	**Technology Offering 1: Blockchain Platform** **How:** Use of a IoT sensor/AI device, on field, to predict the compliance of durum wheat provided by the farmers to the requirements of the "Senatore Cappelli" variety
Manufacturer	Need to check the compliance of finished product (pasta) to Organic requirements	Problem 3	**Technology Offering 3: AI-enabled Early Warning and Decision Support System** **How:** Application of Quechers and GC/LC paired to MS to several pasta samples and creation of a database of most frequent residues

After having identified an initial mapping of the current problems with the offered solutions, we proceed with the elicitation of specific requirements based on a user needs assessment, we come up with a Requirements Matrix per Technology offering. Each technology offering aims to tackle specific problems and eliminate weaknesses.

Table 53: Requirements Matrix -Technology Offerings 1 & 3 - Blockchain Platform & AI-enabled Early Warning and Decision Support System

Technology Offering 1 & 3			Blockchain Platform & AI-enabled Early Warning and Decision Support System					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1,2	Need to check the compliance of raw material to organic production	At the moment, the evaluation of compliance to organic farming is performed checking the presence of residues in raw material, thus not in a predictive way	1	Reliable and Accurate Allow users to check fast and accurately the compliance of the raw material with the requirements of the organic production	Non-Functional	MUST HAVE	Farmers/Producers, Manufacturer	PUC 1: Stakeholders expecting an innovative Sensing and evaluation of authenticity system In order to be able to Identify the non-organic wheat and the pesticides residues.
			2	Easy to use and low training needed	Non-Functional	SHOULD HAVE		
			3	Reliable data must be generated in order to detect possible alteration in terms of the percentages of soft and durum wheat	Non-Functional	MUST HAVE		
			4	User friendly visualization of the results	Non-Functional	MUST HAVE		
Comments								
	Being able to Identify non-organic production and pesticide residues							

Table 54: Requirements Matrix -Technology Offering 3 - AI-enabled Early Warning and Decision Support System

Technology Offering 3			AI-enabled Early Warning and Decision Support System					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 3	Need to check the compliance of finished product (pasta) to Organic requirements	At the moment, the evaluation of compliance of pasta to organic system is performed analysis many different residues in each sample	5	Reporting and Recommending: Create alerts when a risk has a high probability to occur, evaluate historical data and analyses measurements, allow stakeholders for informed decision making and recommend mitigation strategies to prevent risk from happening.	Non-Functional	MUST HAVE	Manufacturer/ Masoutis	PUC-2: Stakeholders want to be provided with timely information In order to be able to make adjustments and to ensure the control of the process to prevent violating the critical limits. AI analysis on the monitoring data can indicate proactively whether a deviation might occur and provide. warnings that allow them to respond in time.
			6	Reliable and Accurate. Provide quantify risk levels and explain how the outcome has been reached.	Non-Functional	MUST HAVE		
			7	Easy to use: All participants of the value chain should be able to use this service without any special training.	Non-Functional	SHOULD HAVE		
Comments								
Reduce the food fraud in the value chain and protect consumers								

5.9 Demonstrator 7 - PDO Arilje raspberries

5.9.1 Introduction

Due to the high competition in the market, berries are one of the commodities mostly subjected to adulteration. They are usually at risk of a misidentification or addition of a lower quality species for a higher economical gain. Various chemometric and chromatographic technologies are in use to reduce fraud risk, and ensure authenticity, by the identification of the geographical and botanical origin of the berry species (Krstić et al., 2023). It is important to mention that no direct research studies were found about raspberry fruit fraud cases. However, according to Reuters, in 2017, a major frozen raspberry fraud case was reported under mislabelling. The commodity of Chinese origin was shipped to Chile and labelled as "Chilean-grown organics", and sold to Canadian consumers as mentioned. This food fraud case, according to the Canadian authorities, was connected to a norovirus outbreak in Quebec (Reuters, 2020).

5.9.2 Organizations/stakeholders involved

Stakeholder involved in Arilje Raspberries Supply Chain are listed below:

- Farmers that produce raspberries,
- Transporters
- Retailers
- Certificate organisation
- External institutions (competent Authority) in order to apply for PDO labels (Serbian level)

The FSC of PDO Arilje Raspberry and FSC of retailer Migros will be linked to each other in a later stage of ALLIANCE. On the retailer side, Migros is comprised of 2987 stores as of the report date operating in all cities of Turkey. Migros owns, 9 distribution centres, 6 fruits and vegetables production facilities, and 11 wholesale warehouses were independently and externally audited for compliance with IFS Product Safety standards. Migros works with 2,942 active suppliers and 20,000 farmers.

5.9.3 Existing Infrastructure & Operations

Table 55: FSC Processes per stakeholder

Farmer/Producer of Association Arilje raspberry	Data collection system: internal traceability records.
Process 1	Production Register: year, information, location, plant variety, date of planting, quantity, production plot No, traceability number, certification number
Process 2	Storage register: temperature measurements, product id, product quantity
Transporter	**Data collection system: internal traceability records.**

Process 3	- Transportation register: product quantity, date and time, farmer information, location, temperature of the transport, physical condition
Association Arilje raspberry	**Data collection system: internal traceability records.**
Process 4	- Register of product receipt: product description, transporter information, quantity, expiration date, temperature measurements, time and date
Process 5	- Register the certified entities and quantities: product quantity, date and time, farmer information, location, certification id
Process 6	- Register the certified labels: product description, date and time, farmer information, location, certification id
Process 7	- Transportation register: product quantity, date and time, farmer information, location, temperature of the transport, physical condition
Migros	**Data collection system: internal traceability records.**
Process 8	- Register of product receipt: product description, transporter information, quantity, expiration date, temperature measurements, time and date
Process 9	- Register for repackaging: product description, quantity, expiration date, QR code, time, origin DC
Process 10	- Deliveries register: temperature measurements, GPS measurements, product id, product quantity, time and date, origin DC
Process 11	- Storage register: temperature measurements, product id, product quantity, storage id, origin DC
Process 12	- Register of product receipt on the stores: product description, quantity, expiration date, temperature measurements, inspection data on the quality of the product, origin DC

5.9.4 Weaknesses and Problems Identification

Here, we present the stakeholders feedback, where they identified their weaknesses that stemmed from problems occurring in the Arilje raspberry FSC. For each stakeholder, we report those problems and weaknesses.

Table 56: Identified Problems and Weaknesses of the FSC per stakeholder

Farmer – Producer		
Prob. No.	**Structural Problems**	**Weaknesses**
Problem 1	Low educational level - lack of digitalization literacy	Inertia in digital transformation of the FSC: Producers have low level of knowledge over technologies that can facilitate their operations
Problem 2	Low level of digitalization processes (manual records)	Lack of traceability: Printed data may be lost, also data from small producer are hard to be recorded once the raspberries get into freezing phase
Arilje raspberry Association		
Prob. No.	**Structural Problems**	**Weaknesses**
Problem 3	Digital data kept in the cooling chambers might not be easily accessible, or can be lost/jeopardized	Lack of interoperability: The data are not stored properly and therefore may be not utilised. Also, the external traceability systems are not unified.
Problem 4	Sensory analysis is the subject of individual knowledge/experiential knowledge	Lack of reliability: Reliance on human expertise
Migros		

Prob. No.	Structural Problems	Weaknesses
Problem 5	Data associated to fresh products are restricted	Lack of traceability: Missing data can result in fault traceability
Problem 6	Customer awareness	Disinformation regarding the product leading to confidence loss on the company brand.

5.9.5 User Needs & Requirements Identification

In this subsection, we present the user needs and requirements for the Arilje raspberry FSC. Firstly, we present the mapping of the identified problems with the corresponding ALLIANCE technology solutions. In the following Table, we associate the problem with the offered solutions and we link as well as with the respective stakeholder and the emerging need.

Table 57:User needs and requirements for the Lika Potatoes FSC

Stakeholder	Identified Need	Problem to Tackle	ALLIANCE Technology Offering
Arilje raspberry Association	Digitalise the operation processes and build trust among untrusted partners in a chain	Problem 2,3,4,5	**Technology Offering 1: Blockchain Platform**: Digitalize the documents and operational processes. We need also to assure the confidentiality and privacy of the shared data, that will be just use with project related purposes. **How**: Along with Blockchain enable use of IoT to digitalize the data collection processes and automatize the data analysis in critical control points.
Arilje raspberry Association	Need for compatible data and operations	Problem 3	**Tech. Offering 4: Interoperability Mechanism in Complex Food Systems:** interoperability mechanism allows different platforms owned by stakeholders within the food chain to communicate efficiently and allow products, resources and data to be managed in a coherent way. **How**: Create an incompatible software to exchange and compare data.
Migros	Digitalise the operation processes using QR codes and build trust among untrusted partners in a chain	Problem 2	**Technology Offering 1: Blockchain Platform**: Record of every process in the FSC to an immutable platform. **How**: Digitalised processes are recorded and can be easily provided to consumers as a proof of Authenticity.

After having identified an initial mapping of the current problems with the offered solutions, we proceed with the elicitation of specific requirements based on a user needs assessment, we come up with a Requirements Matrix per Technology offering. Each technology offering aims to tackle specific problems and eliminate weaknesses. However, in order to be applicable, each technology offering has been associated with specific requirements (Req. No, Requirements Description). Those requirements have been posed by the stakeholders. Each requirement Is described whether it belongs to a functional or non-functional type and it Is prioritized using the MoSCoW technique with four different classification priorities (must-have, should-have, could-have, and won't-have)

Table 58: Requirements Matrix - Technology Offering 1 - Blockchain Platform

Technology Offering 1			Blockchain Platform					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 2,3,4,5	Automate processes and store data in the Blockchain while building trust among untrusted partners in a chain.	All data is analogue, traceability is designed at cooling chamber level, no or low compatibility with other systems, high level of human engagement	1	Ensure Security and Privacy of the data	Non-Functional	MUST HAVE	Arilje raspberry Accosiation, Migros	PUC-Demonstrator 7: The actors expect to digitalise the Arilje Raspberries FSC with BC and IoT
			2	Ensure availability - uptime 24/7	Non-Functional	MUST HAVE		
			3	Interoperability with other IT tools used in two FSC	Functional	MUST HAVE		
			4	User-friendly and need low training to be used	Non-Functional	SHOULD HAVE		
Comments								
N/A								

Table 59: Requirements Matrix - Technology Offering 4 Interoperability Mechanism in Complex Food Systems

Technology Offering 4			Interoperability Mechanism in Complex Food Systems					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 3	Need for compatible data and operations	There are different database for each operation. The data are not stored properly and therefore may be not utilised. Also, the external traceability systems are not unified.	5	Interoperability with IT tools used in two FSC	Functional	SHOULD HAVE	Arilje raspberry Association, Migros	PUC-7: The two FSCs Arilje raspberry Association and Migros are expected to be linked
			6	Harmonize data in order to be compatible	Functional	MUST HAVE		
			7	Structure data that are not compatible and not easily accessible	Functional	MUST HAVE		
Comments								
N/A								

Table 60: Requirements Matrix - Technology Offering 7 Digital Knowledge Base for Food Fraud

Technology Offering 7			Digital Knowledge Base for Food Fraud					
Problem	**Need**	**Current Status**	**Req. Id**	**Requirements Descr.**	**Type**	**Priority**	**Stakeholder**	**Expectation**
Problem 1,2	Need to link identified food hazards in the FSC with associated food fraud mitigation mechanism	No such a system exists	8	Allow users to perform advanced search in the database	Functional	MUST HAVE	Arilje raspberry Association, Migros	PUC-7: Actors expect to receive updates and reports to ALLIANCE Knowledge database considering risks or Identified Incidences related to adulteration, product tampering Counterfeit, Grey market, as a result of analysis of the continuous monitoring of the FSC.
			9	User-friendly environment that will facilitate the exchange of knowledge	Non-Functional	MUST HAVE		
			10	Suggestive - The Digital Knowledge Base should be able to deduce what a user's knowledge needs are and suggest knowledge associations for fraud incidences with mitigation strategies	Functional	SHOULD HAVE		
Comments								
N/A								

5.10 Mapping of the ALLIANCE Offerings to the PUCs

The following Tables show the mapping of the technology offering of the ALLIANCE project to the PUC-demonstrators.

Table 61: mapping of the technology offerings to PUC-demonstrators

Technology Offerings	Title
Technology Offering 1	Blockchain Platform
Technology Offering 2	Vulnerability Risk Assessment for Critical Control Points Identification in quality-labelled FSCs
Technology Offering 3	AI-enabled Early Warning and Decision Support System
Technology Offering 4	Interoperability Mechanism in Complex Food Systems
Technology Offering 5	Next Generation portable DNA Sequencing for Food Analysis
Technology Offering 6	Advanced Spectroscopy NIR and HSI
Technology Offering 7	Digital Knowledge Base for Food Fraud
Technology Offering 8	Prevent Food Fraud with Predictive Analytics

Table 62: Technology Offerings of each PUC-demonstrator

Pilot Use Case-Demonstrator	ALLIANCE Technology Offerings							
	TO 1	TO 2	TO 3	TO 4	TO 5	TO 6	TO 7	TO 8
PUC 1: PDO-PGI EVOO (IT)	√	√	√	√	√		√	√
PUC 2: PDO Feta Cheese (GR)	√	√	√	√				√
PUC 3: Organic Honey (FR)	√				√			
PUC 4: PGI Asturian Faba Beans (ES)	√					√	√	
PUC 5: PGI Lika Potatoes (HR)	√		√	√			√	
PUC 6: Organic Pasta (IT)	√		√					
PUC 7: PDO Arilje Raspberries (RS)	√			√			√	

Considering the Interoperability of the Food Supply Chains, we plan to interconnect the Food Supply chains of the two retailers (Namely, Masoutis-GR and Migros-TR) with the 5 of the existing PUC-demonstrators as shown in the Table below:

Retailers	Connected FSCs						
	PUC 1	PUC 2	PUC 3	PUC 4	PUC 5	PUC 6	PUC 7
Masoutis (GR)	√	√				√	
Migros (TR)					√		√

6 Conclusion

Food Fraud, one of the most emerging food supply chain challenges, so far, has no widely accepted definition. It is often referred to as an intentional act of misrepresentation, modification, and documentation of food for economic gain. Fraudulent acts are due to the heterogeneity of food products and the complexity of the FSC, as well as the variety of legislation and norms.

Quality, Safety, Authenticity are key elements related to food products all along the FSC. Food products are not limited to one characteristic or criteria, as they are subject to different protocols and process. These protocols ensure food safety during the conception of the final product, to be received by the consumer. The FSC being a multidimensional chain, the food safety and quality issue goes beyond the one sector limitation, with direct and indirect impact on sustainability.

Any product is prone to any type of fraud. Nevertheless, some fraudulent acts can be prominent for a product over the other due to the nature, package and use of it. Each of the presented product in the alliance project is subject to fraud. Olive oil has a wide range of fraudulent acts we can list some such as mislabelling, selling olive oil as PDO when it is not, or alteration, selling vegetable oil with dye as olive oil. Several methods exist to ensure olive oil quality and the reduction of fraud cases. However due to the different legislations and standards the quality measures seem non-sufficient as there is a gap between one norm and another on the global trade market. Potatoes have a recurrent mislabelling problem with a percentage gap between cases that are reported as suspicious fraud acts and cases proven as fraud acts. This is caused by the different origin samples. The lack of traceability application and coherent standards can be concluded as one of the main causes.

Pasta's fraud cases are mainly caused by the discordance between the Italian law and the international quality control measures. As the manufacturer request a more reliable, method to identify durum wheat from non-durum wheat. Knowing that semolina is the main ingredients for past production. this gap between the standards is what increases the risk of mislabelling and adulteration of past. Feta Cheese, listed as PDO, is mostly subjected to milk alteration or ratio alteration. The lack of a well-connected traceability system as well as awareness and information regarding the composition of Feta cheese can be thought as of the reason of fraud. Honey's economic value made it susceptible to fraud varying from packaging fraud cases to substitution and adulteration. The main factor for this wide range of fraudulent activities is again the difference among international standards. There is no clear methodology for honey authenticity quality control. Beans diversity induces the risk of mislabelling and concealment of species. Authenticity as a key element for quality insurance, it is at the outmost need of a methodology improvement for fraud prevention. It can be explained by the lack of traceability engagement. Raspberries are often subject to mislabelling, misidentification or addition of a lower quality product. Not having a common quality norm internationally, alongside the lack of traceability, can be one of the causes of fraudulent acts. Mislabelling, substitution and adulteration seem to be the most common fraud case.

From a consumer perspective, food fraud and food safety cannot be differentiated as a concept. However, consumers are aware and curious about the quality and safety of the commodities they consume. This gap highlights the necessity of awareness towards food fraud, food quality and safety towards the consumers to ensure higher safety measure.

Furthermore, it is clear that there is an utmost necessity to work on the harmonisation homogenization of quality and safety standards as well as the coherence of different international legislation. The gap between the various norms and laws are a primordial cause of food fraud. With the fact that the conception of one common unified concept for quality and safety seems difficult, traceability comes to light. Traceability is a key element for the insurance and prevention of food fraud cases, especially for exported products. It will be able to fill the gaps between the various legislation and track down the source of fraud issues. Finally, consumer awareness and knowledge on food safety is essential, as it serves as a retrospective prevention and assessment of food fraud.

During the preliminary phases of the Delphi technique, members of ALLIANCE contributed their perspectives regarding food fraud, food safety, and quality within their respective food supply chains. A comprehensive questionnaire was devised to encompass diverse facets of the subject matter, and subsequently disseminated among the ALLIANCE partners and their respective FSC's stakeholders responsible for the PUCs. The responses of each partner were gathered and subjected to analysis, which led to the identification of shared patterns, points of concurrence, and points of divergence. The actors' perspectives were summarized and organized into matrices, forming a foundation for further rounds of the Delphi technique to converge on consensus opinions and recommendations.

Next steps, subsequent to the initial round of expert responses, the Delphi technique will proceed to the subsequent stages whereby a feedback report will be generated based on the analysis of the ALLIANCE stakeholders' inputs and will lead to the definition of the particular Pilot Use Case Scenarios. This report will then be disseminated to the ALLIANCE members for further consideration and it will provide a summary of their viewpoints, highlighting areas of agreement and disagreement based on the scope of ALLIANCE. Then they will have the chance to evaluate these viewpoints and provide feedback. Subsequently, the developers will be prompted to assess the significance or soundness of every argument presented in the feedback. Subsequent iterations of the Delphi technique may be employed to enhance precision and agreement among participants, contingent upon the intricacy and degree of consensus attained in the current round. In each successive iteration, the stakeholders will have the opportunity to amend their answers considering the feedback they have received. The overarching objective is to amalgamate the outcomes derived from these successive cycles, encapsulating the discoveries, suggestions, and domains of agreement attained by the proficient group. This all-encompassing report will function as a valuable asset in tackling food fraud, augmenting food safety and quality, and ameliorating consumer consciousness in the food supply chain. Furthermore, this iterative procedure will be used to the definition of the scenarios of the 7 PUC of this project. Technology partners will develop and configure their solutions to meet the needs and requirements of the identified stakeholders in each PUC taking into consideration the description of those scenarios. The utilization of the Delphi technique is expected to yield valuable insights that can be utilized to inform subsequent research, policy formulation, and implementation of strategies aimed at mitigating food fraud and guaranteeing the safety and genuineness of food products.

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ANNEXES

ANNEX-1 QUESTIONAIRE

USER NEEDS AND REQUIREMENTS DEFINITION PROCESS

ALLIANCE GRANT AGREEMENT NUMBER: 101084188

Related to Task2.1 and Task3.1

Dissemination Level: Public

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Executive Summary

The purpose of the Stakeholder Needs and Requirements Definition process is to define the stakeholder requirements for a system that can provide the capabilities needed by users and other stakeholders in a defined environment and specifically for the envisioned use cases for safeguarding food safety, authenticity, traceability in quality-labelled food value chains.

It identifies stakeholders, or stakeholder classes, involved with the system throughout its life cycle, and their needs. It analyzes and transforms these needs into a common set of stakeholder requirements that express the intended interaction the system will have with its operational environment and that is the reference against which each resulting operational

capability is validated. The stakeholder requirements are defined considering the context of the system of interest with the interoperating systems and enabling systems

Outcome

As a result of the successful implementation of the Stakeholder Needs and Requirements Definition process:

a) Stakeholders of the system are identified.

b) Required characteristics and context of use of capabilities and concepts in the life cycle stages, including operational concepts, are defined.

c) Constraints on a system are identified.

d) Stakeholder needs are defined.

e) Stakeholder needs are prioritized and transformed into clearly defined stakeholder requirements.

f) Critical performance measures are defined.

g) Stakeholder agreement that their needs and expectations are reflected adequately in the requirements is achieved.

h) Any enabling systems or services needed for stakeholder needs and requirements are available.

i) Traceability of stakeholder requirements to stakeholders and their needs is established

INTRODUCTION

Before Completing the Questionnaire, please recall the ALLIANCE Objectives.

Objective 1: To provide food producers and retailers with a holistic framework consisting of innovative methods, state-of-the-art technologies, reliable processes, and interoperable systems that ensure data veracity and accelerate transparency and trust throughout the EU quality-labelled food chains.

Objective 2: To investigate the Food Fraud Landscape and propose systemic solutions that move beyond current practices with an aim to enhance traceability, ensure authenticity, preserve quality and eliminate the fraud in food products through novel cost-effective methods and tools that can detect adulteration on the spot and provide trusted interoperable quality-labelled FSCs.

Objective 3: To consolidate international and European links, raise awareness, promote multi-actor cooperation and information-sharing, collaborate with standardisations bodies and EC services and ensure the technology transfer of ALLIANCE results.

Objective 4: Increase transparency in quality-labelled supply chains, of organic, PDO, PGI and GI food, through innovative and improved track-and-trace mechanisms containing accurate, time-relevant, and untampered information for the food product throughout its whole journey from farm to fork.

Objective 5: Equip food actors, farmers, public authorities, and policy makers with meaningful insights to have the complete situational awareness of the food supply chain (in particular organic, PDO, PGI and GI) while at the same time monitoring the financial, nutritional, environmental, social performance of different parts and processes of the food system.

PART 1
QUESTIONNAIRE

NAME OF YOUR USE CASE-PILOT

- ***Briefly introduce your use case***

[example]

What do you have now (systems, infrastructure in terms of traceability and security mechanisms for you food chain), and what do you want from ALLIANCE?

What are the main problems that your food chain faces?

- ***Current mode of operation of your platform***

(Based on a user story description including flow of actions)

1. A BRIEF DESCRIPTION ON YOUR PLATFORM:

[- (a) Identify also Involved stakeholders (producers, distributors, workers, operators etc.)]

- Give your description here based on the presentation that you have already provided.

- Please include a diagram of your food value chain

[example]

The system under evaluation as part of the project, called XXX, supports traceability and quality control In the food chain, and is a vital part in our platform that unlocks advanced insights. . The system streams a wealth of critical quality control performance data to an operations monitoring center, which is where an IoT sensing network is used.

2. MAIN OPERATIONS FLOW OF THE SYSTEM:

[Please provide the (b) required characteristics and context of the use of capabilities and concepts in the life cycle stages of the product, including operational concepts (for Food Authenticity, Safety, Traceability) e.g, The system operates in such way to comply with the Quality Standards, or it is dependent on the operation of another subsystem]

[example: the system will do XXX first, second, third, …, at last do YYY.]

- The system gathers Information considering the orders and monitors the performance of specific critical points
- It gathers and transmits measurements using standard data formats on the using interfaces and mobile devices
- It can connect to any communications link with internet access.

3. DATA FLOW OF THE SYSTEM:

[example: what is the original data, generated from where and by who/what; and then this data is handled by who\what, and it is changed to be another data form and handled by others.]

The original data is collected from the IoT devices, the data further goes to data hub and later are transferred to the database. While data analysis is required to predict an action, the data will be taken to the data analysis center and then after analysis, the results of the analysis will be sent back to notification system.

4. ANY INFRASTRUCTURE, DEVICES, SOFTWARE, HARDWARE FACILITIES AND THEIR SETTINGS IN THE CURRENT SYSTEM:

[c)Constraints on a system are identified.]

[example]

Logistics, IoT Sensors, Wireless Communication Infrastructure and Sensing and Monitoring Technologies

5. WHAT ARE THE WEAK POINTS AT THE SYSTEM THAT YOU WANT TO ENHANCE?

[f) Weaknesses in your food value chain system are identified in terms of Food Authenticity, Safety, Traceability.]

[f)Critical performance measures are defined.]

[example: identify where and what are the weak points]

All clients' data are stored on a cloud server and so far we only use access control on the server, and we think the data stored on data hub could be exposed to network attackers.

6. WHAT DO YOU NEED FROM ALLIANCE (BASED ON THE ABOVE SECURITY/PRIVACY/OTHER RELATED CHALLENGES) AND WHAT YOU THINK ALLIANCE CAN GIVE TO THE USE CASE.

[d) Stakeholders Needs are defined e) Stakeholder needs are prioritized and transformed into clearly defined stakeholder requirements

h) Any enabling systems or services needed for stakeholder needs and requirements that are available.]

[example: provide what kind of technique or features on where under what kind of condition]

ALLIANCE platform will be used in order to provide effective resiliency against possible fraud Incidences aiming to exploit a series of vulnerabilities of the food chain (procedures, lack of infrastructure etc.). ALLIANCE should be able to help us to enhance security and safeguard our products in what context and under what condition.

the following part will be completed later at a second stage]

PART 2

7. Description on potential Pilot Scenario (Please include the type of specific services to be tested) (work with technical partners)

[g) **Stakeholder agreement that their needs and expectations are reflected adequately in the requirements is achieved.**

-Any enabling systems or services needed for stakeholder needs and requirements are available.]

[**example**]

We plan to the XXX to setup the pilot. In the context of the project we will deploy a wireless sensor network in our warehouse to monitoring climatic storage conditions and cameras to apply Image processing to recognize fraud products. Testing and validation of ABC-like architectures and systems for safeguarding PDO-PGI products to available device resources available for exploitation. Specific security services to be tested again as part of ALLIANCE will be defined in the first few months.

8. Requirements for merging the techniques (work with technical partners)

[Confirm all the techniques below under this use case]

[i) Traceability of stakeholder requirements to stakeholders and their needs is established]

MUST HAVE (Necessary):

SHOULD HAVE (important but not necessary):

COULD HAVE (wish and nice to have):

WILL NOT HAVE (not a priority):

9. Requirements Elicitation Matrix

Business Requirements explain "What" and "Why" while functional requirements explain how

ID	Business Require-ments ID	Business Require-ments Description	Functional Require-ments ID	Functional Require-ments Description	Current Status	Architectural/ Design Document:	Department/ Business Unit Impacted	Test Scenario ID	Test Case ID	Defect ID	Current Status	Tracking Comments
A	B	C	D	E	F	G	H	I	J	K	L	M
1	BR1	Need to monitor storage humidity and temperature conditions	FR1	Use of sensing devices that can monitor the storage conditions 24/7 and transmit the data to a server for archiving and further processing	The current monitoring of storage condition relies on a sensing device that is installed in the warehouse. It cannot offer continuous monitoring capabilities to a remote data center. It Is reliant on human operation, where a worker visits every 4 hours the warehouse and records the conditions by hand	Refer here at what stage according to your supply chain this can happen and link it with the functional requirement. e.g According to the supply chain system management design, the raw product --upon reception at the warehouse from the responsible worker -- is examined and quality control is conducted and then it is stored under controlled conditions of humidity and temperature in a warehouse which is monitored using conventional	In the case of a risk being issued please describe which departments or units of your supply chain are being affected either directly or directly. Since the records of temperature and humidity storage conditions are done by hand, it is possible that a failure in the cooling system might not be detected on time, and that can impact the storage (direct) and quality control (indirect) operations.	Scen 1	TC1: Sensing and collection of storage condi-tions data	D1	Record of storage conditions is done by hand. The current infra-structure requires improvement/upgrades to enable a continuous 24/7 monitoring .	Use of IoT sensing devices to enable 24/7 monitoring of storage conditions with automated collection of data and transmission to remote data centered for further processing

						temperature and humidity sensing devices.						
2	BR2	Need to record storage conditions using Blockchain, in order to track and trace historic data In a secure and untampered manner	FR2	Use of Blockchain for storage and tracking the reports of storage conditions monitoring	No Blockchain technology is used.	Same as the previous one	Same as the previous one	Scen 1	TC2: Use of Blockchain for the data recording	D2	Same as the previous one.	Enable the use of Blockchain Technology along with the use of IoT sensing devices.

INSTRUCTIONS FOR COMPLETING THE REQUIREMENTS TRACEABILITY MATRIX

Column	Instructions for completing this document
	Complete the below details in the following columns
A	**ID:** A unique ID number used to identify the requirements in the requirements traceability log.
B	**Business Requirements ID #:** This column should be populated with a unique ID number used to identify business requirements linked to functional requirements
C	**Business Requirements Description:** This column should be populated with a description of the business requirements linked to the functional requirements.
D	**Functional Requirements ID #:** This column should be populated with a unique ID number used to identify functional requirements.
E	**Functional Requirements Description:** This column should be populated with a description of the functional requirements.
F	**Architectural/Design Document:** This column should be populated with a description of the architectural/design document linked to the functional requirement.
G	**Date Identified:** This column should be populated with the date each requirement was identified and recorded.
H	**Department/Business Unit Impacted:** This column should be populated with the department/business unit impacted by the requirement.
I	**Test Scenario ID:** This column should be populated with the test scenario number linked to the functional requirement.
J	**Test Case ID:** This column should be populated with the test case number linked to the functional requirement.
K	**Defect ID:** This column should be populated with a unique defect ID for a test case.
L	**Current Status:** This column should be populated with the functional requirement's current status. o **Open**: The requirement is currently open. o **Closed**: The requirements is currently closed.
M	**Tracking Comments:** This column should be populated with any comments associated with each requirement