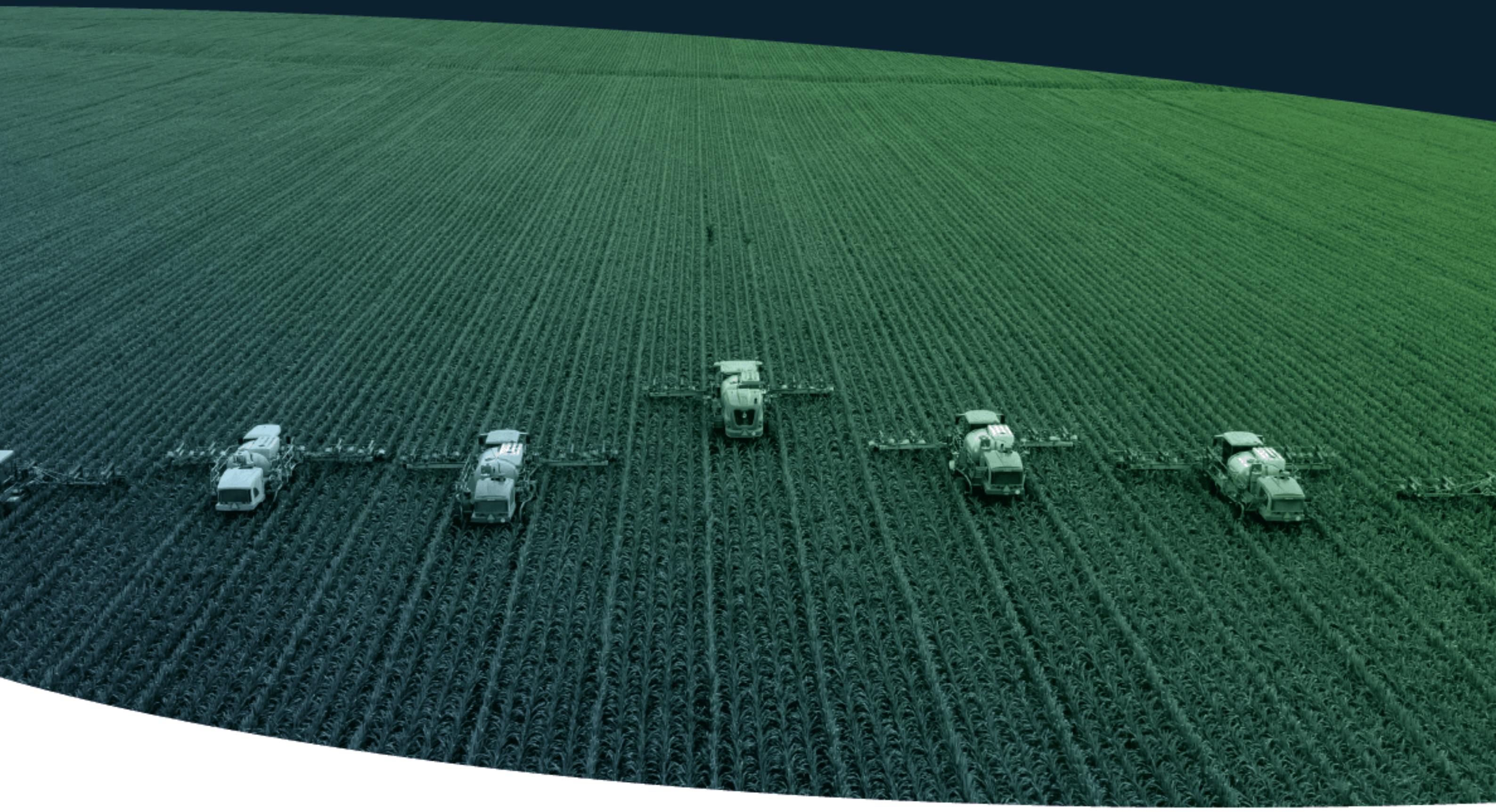
ALLIANCE

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



DELIVERABLE 2.2
FINAL DISTRIBUTED LEDGER TECHNOLOGY FOR IMPROVED TRACEABILITY

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List of Abbreviations

Abbreviation	Description
AI	Artificial Intelligence
CBV	Core Business Vocabulary
DoA	Description of Action
EPCIS	Electronic Product Code Information Services
EWDSS	Early Warning Decision Support System
FSC	Food Supply Chain
HSI	Hyperspectral Imaging
IoT	Internet of Things
NIR	Near-Infrared
PDO	Protected Designation of Origin
PGI	Protected Geographical Indication
VRAMF	Vulnerability Risk Assessment Management Framework

Executive Summary

This deliverable, D2.2 (“Final Distributed Ledger Technology for Improved Traceability”), provides an updated and comprehensive overview of the implementation status and results achieved up to M30 for the Blockchain technological components developed under WP2. It incorporates significant updates and advancements reflecting the progress made since the initial submission of D3.1. This deliverable focuses also on the following tasks:

- T2.2 – Resilient Food Supply Chain Systems using Blockchain

The deliverable details the work completed, and results achieved from M06 to M30. The Blockchain implementation is documented with a structured analysis for all the steps of each Food Supply Chain. Since the initial version, the technical developments have transitioned from early implementations to more mature forms. This final version highlights the following advancements:

- Completeness of the Blockchain implementation for every FSC, reaching operational maturity suitable for testing and demonstration.
- Key functionalities have been tested in real-world scenarios, enhancing their utility for practitioners.
- Initiation of evaluations at pilot sites, providing critical feedback to improve the components and ensure alignment with practical needs.

In summary, this deliverable D2.2 concludes with a consolidated report of the achievements within WP2 related to Blockchain technology, showcasing the readiness of its components for integration and real-world application. These results represent a significant step toward delivering innovative tools for food traceability that can safeguard the food value chains, fulfilling ALLIANCE’s scope.

1. Introduction

1.1. Document purpose & scope

WP2 belongs to the core technical work packages of ALLIANCE. It provides key technical components and solutions for the implementation of the ALLIANCE platform. This deliverable D2.2 *Final Distributed Ledger Technology for Improved Traceability,* describes the results of WP2 pertaining to the development and implementation of the Blockchain platform and apps and achieved within the period of M19-M30 of the project with an aim to attain the following objectives (according to the Description of Action (DoA)):

- **WP2.Obj.1:** To create the Blockchain framework for providing increased traceability in organic, PDO, PGI and GI food products.
- **WP2.Obj.2:** To provide food actors with increased visibility and situational awareness about the performance of the quality labelled FSC against the strict organic, PDO, PGI and GI standards.

Attaining the aforementioned objectives has been accomplished so far by the progress made within the activities carried out within the following Task:

- **Task 2.2** - Resilient Food Supply Chain Systems using Blockchain

The following Table summarizes how Task 2.2 has contributed to the WP2 objectives.

Tasks	*Contribution to attain to the WP2 Objectives*
T2.2	**WP2.Obj.1:** Apart from the digital transformation of the current FSCs, the use of the Blockchain Technology in the ALLIANCE platform offers also increased traceability allowing stakeholders to trace back the origin of the food products, verify and justify the data accompany the food products, confirm food sources and ensure quality standards for PDO, PGI, and GI food products. **WP2.Obj.2:** Utilizing Blockchain technology provides transparent and immutable data records, allowing food actors (and according to their roles) access to authenticated and trustworthy information considering the journey of the food products in real-time. Data integrity is ensured through cryptography, which allows information related to production dates, packaging numbers etc. to be accessed only by the authorised users in a secure way.

1.2. Relation to project work

Relevance to ALLIANCE Use Cases: The technical components and solutions of Blockchain integral part of the ALLIANCE use cases. The Blockchain implementation will be included and used in each Pilot demonstrator.

Relevance to ALLIANCE objectives: From a technical point of view, the outcomes from the Blockchain development in WP2 are highly relevant for implementing and achieving various ALLIANCE objectives.

Obj.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.

Obj.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.

Obj.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.

Obj.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.

Relationship to ALLIANCE milestones: Besides the importance of the WP2 results for implementing the ALLIANCE Blockchain platform and achieving the project's objectives, the outcomes presented in this deliverable are also a key component of Milestone MS2 ("ALLIANCE technology tools") at M15, following the project start (M01) and the delivery of D3.1.

1.3. Document Structure

The document is structured in 5 major Sections.

- **Executive summary** provides a summary of the whole document.
- **Section 1** " Introduction" introduces the main purpose and scope, the relation to project work and the structure of this deliverable.
- **Section 2** "System Architecture" provides an overview of the ALLIANCE concept and introduces the ALLIANCE Reference Architecture that provides a comprehensive overview encompassing all the different technology solutions of WP2 and WP3.
- **Section 3** "The Blockchain App" presents the Blockchain App for each quality labelled FSC that the project deals with, namely, *Olive Oil, Feta Cheese, Organic Honey, Faba Bean, Lika Potatoes, Organic Pasta and Arilje Raspberries*.
- **Section 4** "Resilient Food Supply Chains" describes the effort towards the digital transformation of the food value chains utilizing the Blockchain technologies.
- Lastly, **Section 5** "Conclusion" concludes the document and provides an overview of the next steps.

2. System Architecture

2.1. Overview

The ALLIANCE architecture consolidates key technologies and data processing layers, such as the **Data Acquisition**, **Data Management** and **Application** layers, as depicted in Figure 1. It is a wholistic approach for FSCs that encompasses the entire process of gathering and utilizing data related to them, from data harvesting to data consumption.

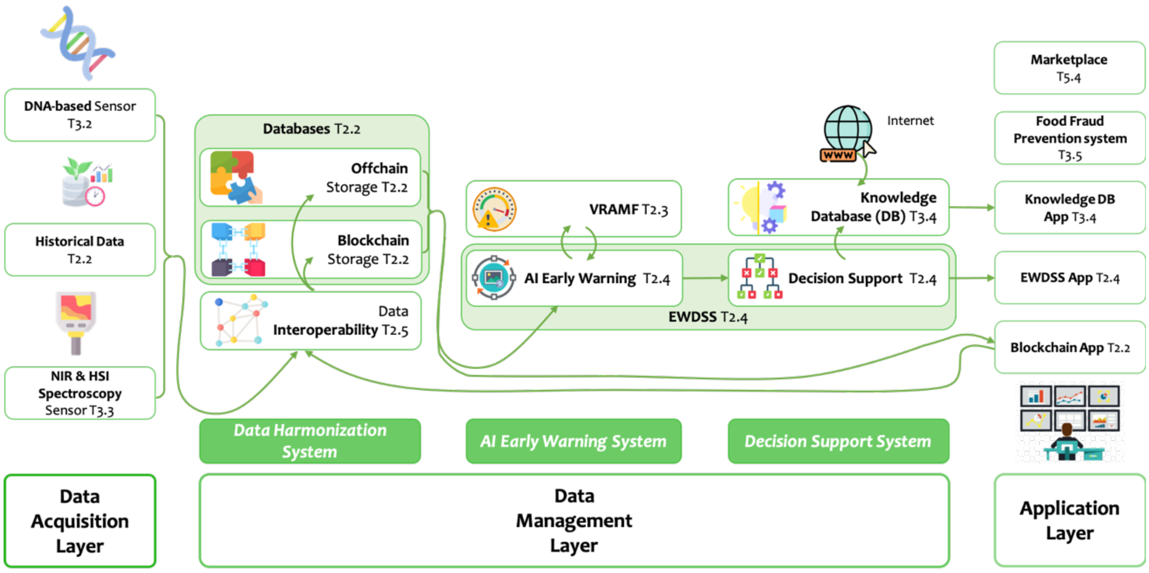

Figure 1: The ALLIANCE Logical Architecture from DoA.

Below, we present the components existing at the three layers of the ALLIANCE architecture, as well as their interactions. All components are mature and completed, apart from the result of T5.4 that will go until M36. We follow a bottom-up approach, according to which:

1. The first layer is the **Data Acquisition** layer. It includes the data sources, which are of three types. It is modular and allows for dynamic extension with additional data sources during the project lifetime or even after its expiration. The two types of data sources are the **DNA-based** and the **NIR & HSI** (Near-Infrared & Hyperspectral Imaging) **Spectroscopy sensors** (results of T3.2 & T3.3, presented in D3.3), and the third type is the **Historical data** that is retrieved from the local databases of the actors involved in the FSCs (result of T2.2).
2. The second layer is the **Data Management** layer, which is responsible for data processing and consists of three systems: **Data Harmonization, AI Early Warning** and **Decision Support** systems. In turn,
   2.1. The **Data Harmonization** system consists of the **Data Interoperability** process (result of T2.5) that harmonizes the data, which are stored right after in the **Blockchain** and **Off-chain** databases (results of T2.2).
   2.2. The **AI Early Warning** system mainly consists of the **AI Early Warning** process that is the first half of **EWDSS** (Early Warning Decision Support System, result of T2.4). This process is facilitated by **VRAMF** (Vulnerability Risk Assessment Management Framework, result of T2.3). The AI Early Warning process uses the stored data in the Blockchain and Off-chain databases to detect potential food frauds and interacts with **VRAMF**, which continuously exploits the produced warnings to identify the critical control points in the FSCs.

2.3. The **Decision Support** system (result of T2.4) consists of the **Decision Support** process that is the other half of **EWDSS**, which is fed by the AI Early Warning system and suggests actions to the administrator to mitigate the possibilities of food frauds. This system also includes the **Knowledge Database** (result of T3.4), which uses data retrieved by the Blockchain and Off-chain databases and the Internet open datastores to create a broader collection of information that is related to food fraud.

3. Finally, the third layer is the **Application** Layer that includes Mobile/Web Applications, which enable end users to interact with the FSCs. These applications include the **Blockchain App** (result of T2.2), the **Decision Support App** (result of T2.4), the **Knowledge Database App** (result of T3.4), the **Food Fraud Prevention system** (result of T3.5) and the **Marketplace** (result of T5.4). The Blockchain App is used for interacting with the databases, the Decision Support App exports the results of the data analysis, the Knowledge Database App interacts with external sources from the Internet and the Marketplace handles the industrial data.

2.2. Architecture Layers and Components

This section provides a more comprehensive explanation of the three levels of the ALLIANCE architecture and their components. It continues with a more detailed presentation of the ALLIANCE components, providing also references to the following sections for additional specific information. Whenever it is necessary, the FSC of Feta Cheese is used as an illustrative example to demonstrate the role of each component.

2.2.1. Data Acquisition Layer

In the Data Acquisition Layer, data is primarily generated and collected automatically through the utilization of distributed IoT sensing devices, rather than being manually injected by users. The generated data either refers to performance metrics from the FCS operations or testing scores of the authenticity and the origin of the food products. Apart from these data collected currently by **DNA-based** and **NIR & HSI Spectroscopy sensors**, there are also **Historical data**, which are datasets of historic metrics from the FSC operations, which are necessary for the data analytics. The Historical data will be updated during the project's lifetime with the information produced by the developed FSCs. The architecture is designed to be flexible and modular, allowing it to easily adapt to any type of IoT device. D3.3 presents in detail the two types of IoT devices that currently are integrated in the architecture. Synthetic datasets have also been generated in the context of Food Prevention System with Predictive Analytics for the Feta Cheese use case.

2.2.2. Data Management Layer

The Data Management Layer is tasked with the storage and processing of data received from the lower layer. It is composed of a centralized service that has the data storage capabilities to the entire dataset. Additionally, it utilizes a Blockchain distributed ledger for the most critical data. The data are firstly harmonized and then stored in a standardized manner, mitigating their variability and heterogeneity. Simultaneously, there exists a procedure at the same level for utilizing this data to uncover, via AI, methods to improve the performance of the FSCs. The Data Management layer comprises three distinct systems:

a) The **Data Harmonization System**

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This system is responsible for harmonizing the heterogeneous data coming from different FSCs, allowing their common processing to simplify and enrich their analysis. The data are stored and shared according to the **EPCIS** (Electronic Product Code Information Services) standard of GS1 [1], which is a flagship data sharing standard for enabling visibility within the stakeholders even of different FSCs. EPCIS helps provide the "what, when, where, why and how" of food products, enabling the capture and sharing of interoperable information about their status, location, movement and chain of custody. Together with the **CBV** (Core Business Vocabulary) [2] that is a companion standard to EPCIS, both standards provide definitions of data values that can be used within the data structures used in the data storage.

Part of the data is stored in parallel in the **Blockchain** distributed ledger [3] by leveraging a private permissioned Blockchain network that supports multiple channels, one for each FSC, which can be bridged through cross-chain and data sharing to support interoperability between different FSCs. More details about the utilization of the Blockchain technology are presented later in Section 3. At this point, we would like to highlight that the storage of the whole dataset on Blockchain would be inefficient, since there are big data that could introduce high delays for their Blockchain storage without being critical to be misused or intentionally manipulated. Thus, Blockchain is exclusively used for the storage of the data that need to be secured, and the centralized storage, called **Off-chain** (as the opposite of Blockchain that is the On-chain database), is used in parallel for the storage of the whole dataset [4].

b) The **AI Early Warning System**

The main component of this system is the **AI Early Warning** process, which is one of the two components of **EWDSS**, the product of T2.4. This process uses AI and the harmonized data to predict and determine with increased probability possible food fraud incidences within the FSCs. It reactively monitors the FSC operational performance to assess the fraud risk factors and the actual fraud vulnerability of the food products. By harnessing the capabilities of AI [5], it proactively recommends interventions, enabling faster and adaptable decision-making processes crucial for mitigating food fraud. As part of the proposed solution, employing a Mamdani Fuzzy Inference System for early warning demonstrates the effectiveness of AI technologies in detecting anomalies within the complex food supply chain. Crucially, this process will be demonstrated in real-life case studies through rigorous testing, with a focus on a practical use case centered around the FSC of Feta Cheese, Organic Honey and Organic Pasta.

VRAMF is a concurrent parallel component that functions as a supplement to the previous process. The result of T3.1, which ended in M6, was the basis for identifying a first set of critical control points [6] in each FSC for mitigating the food fraud incidences. Specifically, each FSC's stakeholders responded to questionnaires, refined through the Delphi technique [7, 8] as it was presented in D2.1, to identify the initial set of critical control points. These control points are mainly the points in each FSC that samples are generated and used for quality control. During the lifetime of ALLIANCE, the effectiveness of the results of the AI process, which relies on the samples and the data produced by the current control points, will be improved by redefining this set of control points. In turn, the change in the control points will affect the AI process, thus, an interacting relationship exists between these two processes.

c) The **Decision Support System**

Early warning signals generated by the AI-enabled Early Warning System can serve as critical criteria in the decision-making process, supporting recommendations under conditions of uncertainty or risk. The Decision Support System plays a dual role: it (i) supports a human-in-the-loop approach where expert opinions and preferences are evaluated for consistency and also (ii) facilitates a more automated approach for ranking machine learning algorithms based on performance metrics such as accuracy, precision, and recall. These algorithms are used within ALLIANCE for detecting fraud incidents in the food supply chain. The Decision Support System will be demonstrated through real-world use cases involving various FSCs, including Feta Cheese, Fava Beans, Organic Honey and Organic Pasta, among others. Notably, the human-in-the-loop methodology offers a generic tool applicable across all pilot scenarios. For further information, see deliverable D2.4.

The **Knowledge Database** is conceptualized as an all-inclusive repository, well-designed with the assimilation of processed data, insights, and inferences derived from the analysis of food products along with their supply chains in an immaculate manner. The integration of external data (standards, certificates, PDO/PGI CoPs, scientific articles, links to related websites, etc.) with the data originating from the project makes it easy to take a thorough examination and extraction of valuable insights and reports by each product. More details are given D3.3.

2.2.3. Application Layer

The Application Layer provides interactive **Web Apps** for comparing and filtering the data analytics and the suggested decisions of the Data Management layer. These user-friendly applications can support multiple roles of end users (such as farmers, producers, processors and retailers), who are informed about the analytics or the decisions of their interest. Moreover, the policy makers and authorities can access this information to design countermeasures for food fraud mitigation.

There are the 4 Web Apps developed in ALLIANCE:

1. the **Blockchain App**, which is presented in detail in Section 3 of this deliverable,
2. the **Knowledge Database App,** which is presented in deliverable D3.3,
3. the **EWDSS App,** which is presented in deliverable D2.4 and
4. the **Marketplace**, which will be presented in deliverable D5.6.

3. The Blockchain App

3.1. Overview

The Blockchain web-app is operated by administrators and personnel in the FSCs to oversee the supply chains, monitor the state of food product processing, and input data pertaining to their actions. Workers have limited access to relevant data based on their function within FSC. Ultimately, the online application facilitates the tracing of the product and the demonstration of its journey to prospective consumers, thereby persuading them of the authenticity and superior quality of the food products. The seven FSCs of ALLIANCE are as follows:

- *PDO/PGI Extra Virgin Olive Oil* (referred from now on as ***Olive Oil*** for simplicity reasons)
- *PDO Feta Cheese* (referred from now on as ***Feta Cheese*** for simplicity reasons)
- ***Organic Honey***
- *PGI Asturian Faba Beans* (referred from now on as ***Faba Beans*** for simplicity reasons)
- *PGI Lika Potatoes* (referred from now on as ***Lika Potatoes*** for simplicity reasons)
- ***Organic Pasta***
- *PDO Arilje Raspberries* (referred from now on as ***Arilje Raspberries*** for simplicity reasons)

In the following sub-sections, we present how this web is visualized for each FSC, as well as the data generated and stored at each step of the FSC.

3.2. Olive Oil FSC

The Olive Oil supply chain consists of multiple stages from the fruit (olive) harvesting up to the point of the bottling of the produced olive oil. Once the administrators have logged in to the web-app, they can view all the stages as well as to submit data regarding each stage. In more detail the stages are:

3.2.1. Olive Harvesting

In this view of the web-app, users can view data regarding olive harvests as well as submit data to add a new harvest by clicking on the 'Add new olive harvest' button at the top-left corner of the dashboard. A form is displayed where users need to fill in all the required data including the producer and field code, the harvested variety, the pigment of the harvested olives, the estimated harvested quantity in kilograms, the collection date, and a DNA result and the testing date as shown in Figure 2.

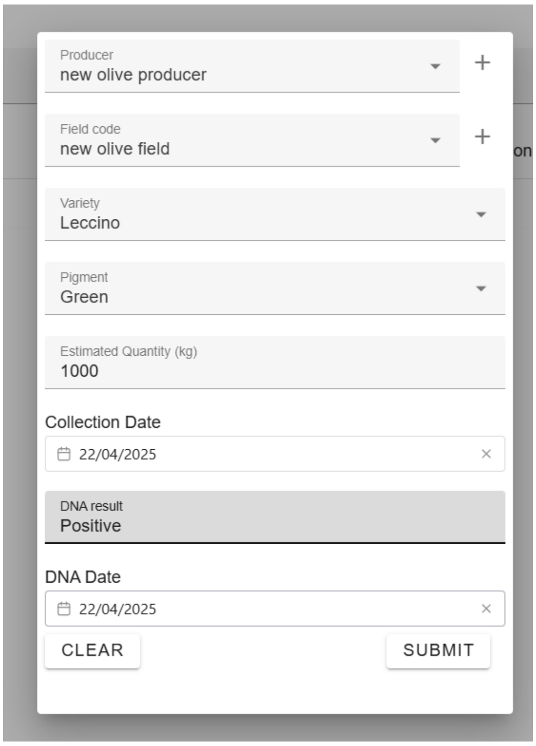


Figure 2: The form for uploading a new harvest of olives.

If the desired producer or field code are not present, the user can click on plus button next to each of the mentioned fields and add a new producer and/or field code by filling out the forms shown below in Figure 3.

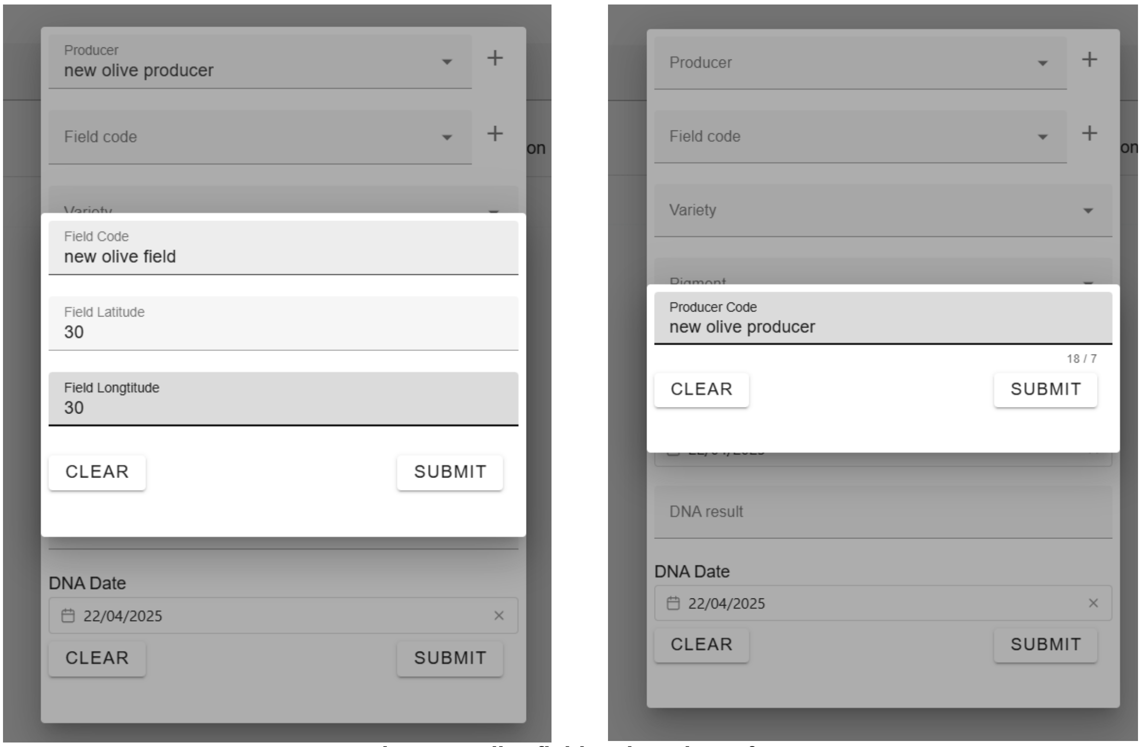


Figure 3: Olive field and producer forms.

Once the form is submitted the new olive harvest is visible on the 'Olive Harvesting' view of the Blockchain app, as it is depicted in Figure 4.

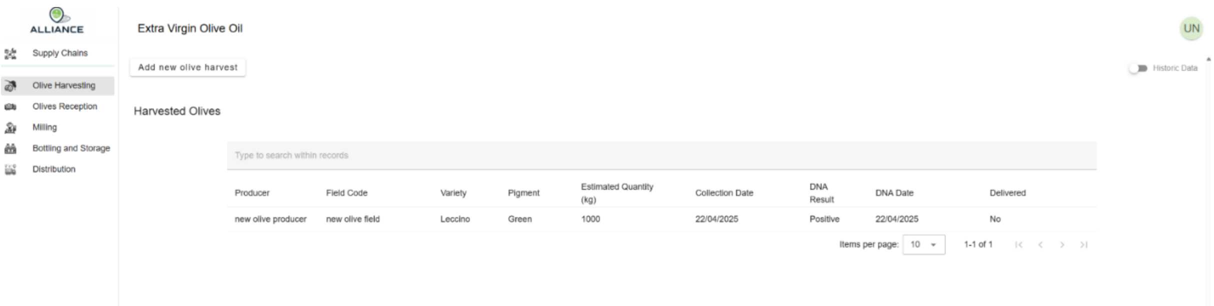


Figure 4: The 'Olive Harvesting' view.

3.2.2. Olives Reception

The next stage includes the reception of the harvested olives at a facility to be processed. As shown in Figure 5, on the upper half of the dashboard olive harvests awaiting reception are displayed. Once the reception manager is ready to submit a new reception he must click on 'Receive Olives' button on each olive harvest and submit data as shown in the left side of Figure 6. Regarding the facility code, if the desired facility code is not available the user can click on the plus button and create a new one through the form shown in the right side of Figure 6. Once a reception has been reported, it is displayed on the bottom half of the screen, as it is depicted in Figure 7.

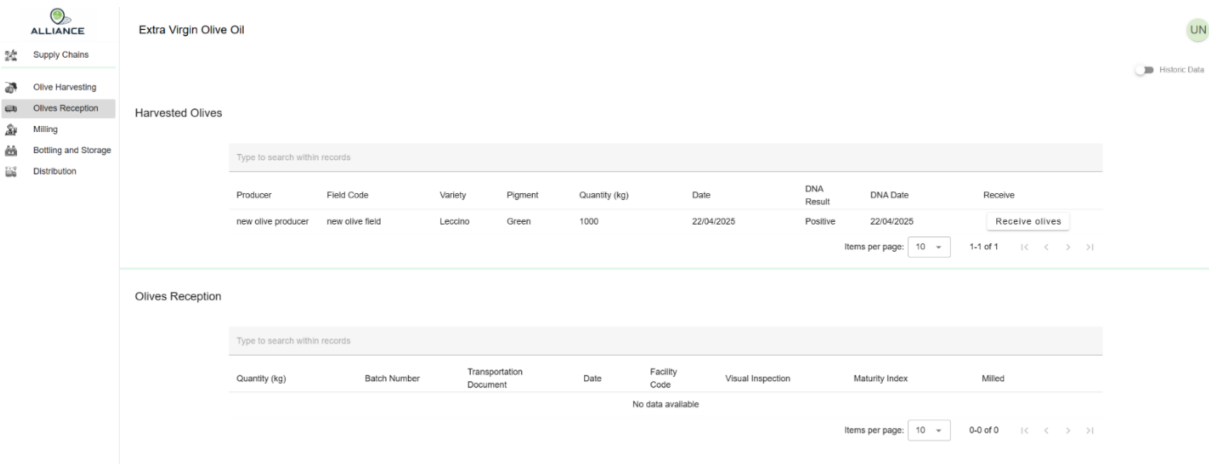


Figure 5: The 'Olive Reception' view.

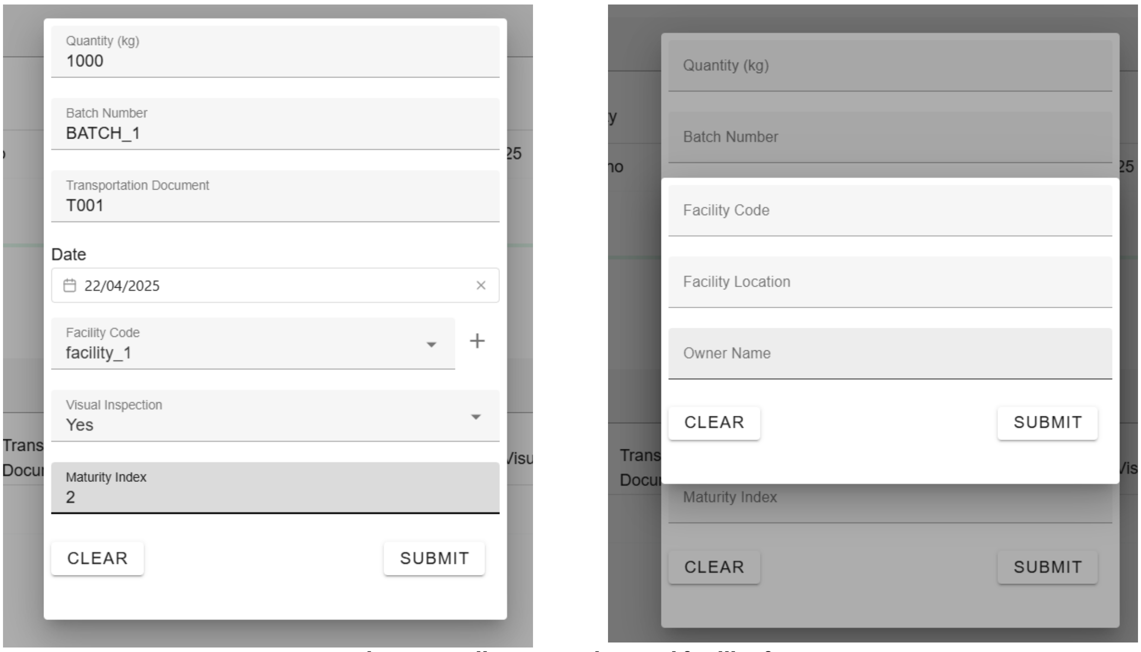


Figure 6: Olive reception and facility forms.

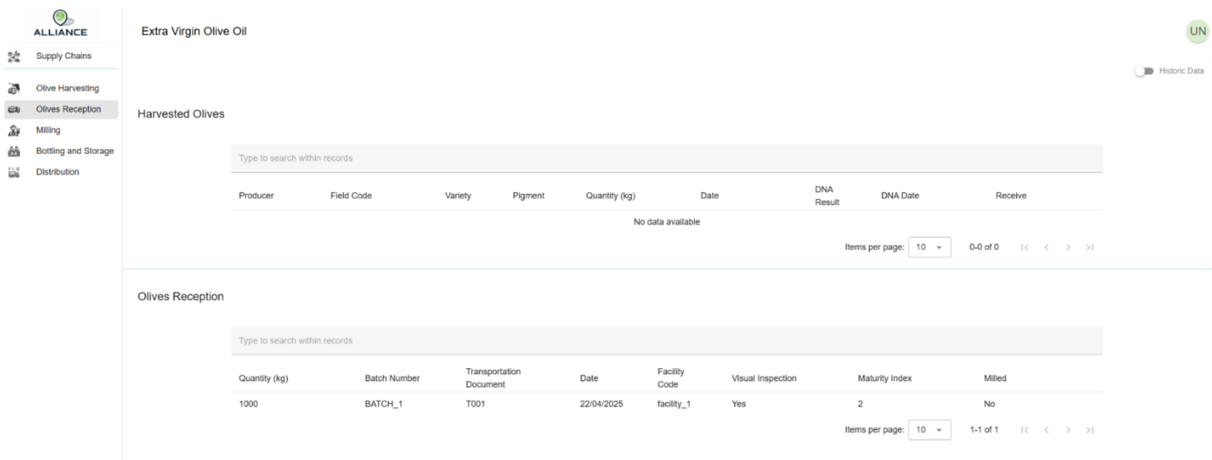


Figure 7: The 'Olive Reception' view after inserting a new reception.

3.2.3. Milling

On the milling page the worker responsible for processing the olives and producing olive oil can choose a reception to mill by clicking on 'Mill Olives' button on the upper half of the web app as shown in Figure 8. By filling in the displayed form, shown in Figure 9, the produced olive oil is stored in the desired tank and is ready to proceed to the next stages. On the lower half of the web-app the olive oil produced is shown, Figure 10, and the user can submit data regarding its quality control results, the DNA testing and also chemical analysis as shown in Figure 11.

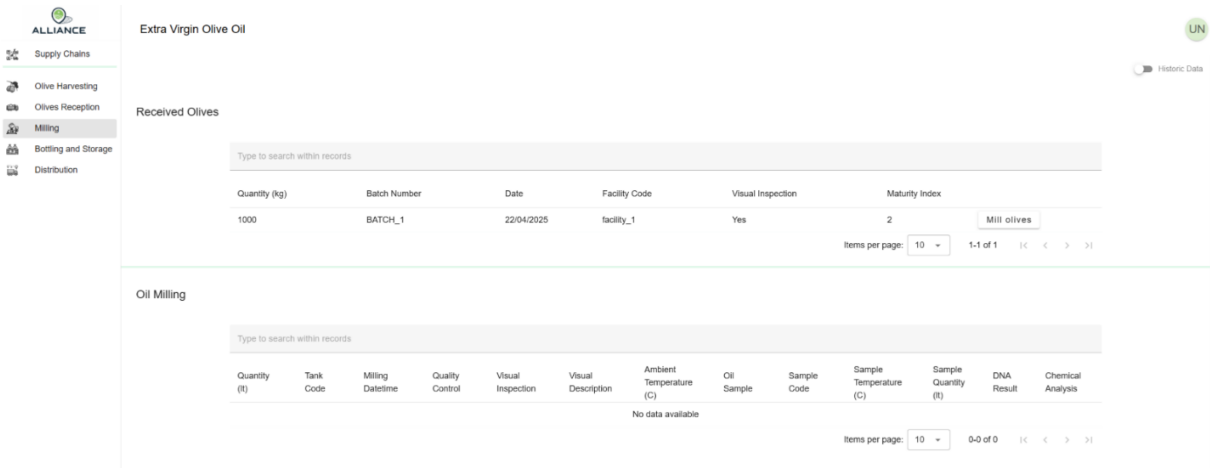


Figure 8: The 'Milling' view.

Figure 9: The milling form.

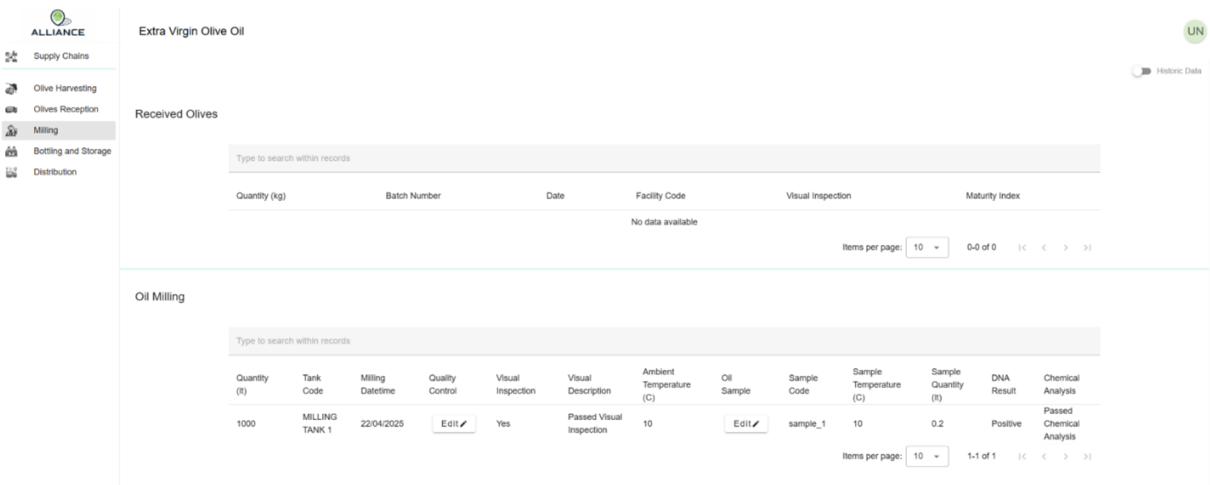


Figure 10: The 'Milling' view after the insertion of a milled oil.

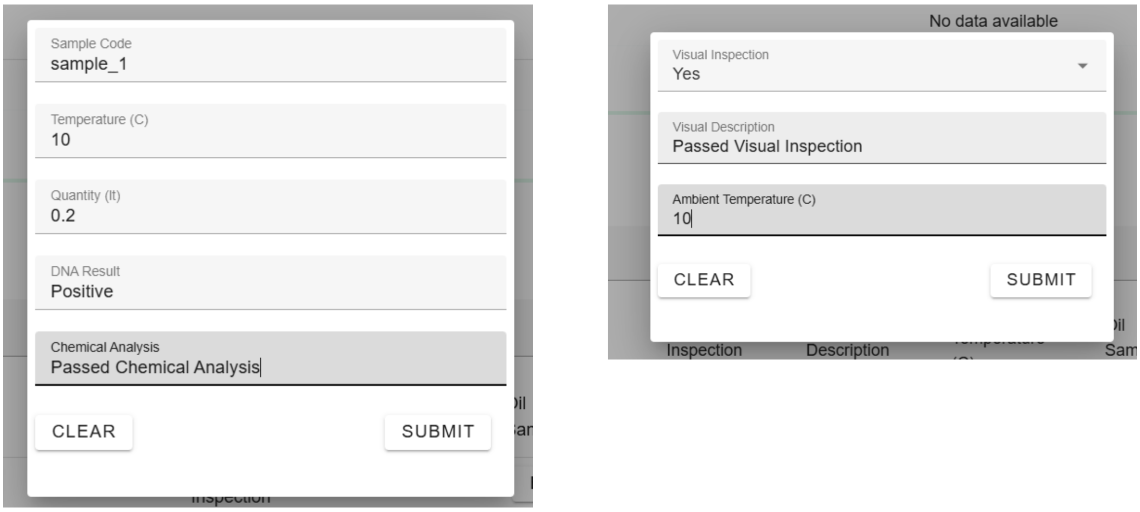


Figure 11: Quality control and sample forms for olive oil.

3.2.4. Bottling and Storage

The next stage is the storage and the bottling of the olive oil until it is distrusted to the retailer. On the upper half of the web-app the stored olive oil waiting to be stored in a bottling tank and subsequently be bottled is shown, Figure 12. To store a portion or the whole of the milled oil the user must click on the 'Store Milled Oil' button at the top left side of the current view. Once the form is displayed, as shown in Figure 13, the user must click on the plus icon and select one, or more, olive oils to store, the tank code and date of storage must also be filled. Once the form is submitted the new storage is shown on the lower half of the view as shown in Figure 15. From there the user can click on the 'History' button to view the olive oils that were stored in this tank, Figure 16, as well as submit DNA test results information. The next step is to package the stored quantity into bottles, with specific LOT numbers. This is achieved by clicking on the 'Lots' button and filling out the information required as shown in Figure 17. Once a LOT has been produced and is ready to be distributed the 'Distribute' button is enabled and by clicking on it the user can submit information regarding the distribution to the retailer as shown in Figure 18. Regarding the distribution form, if the desired driver id or truck numberplate are not available the user can create them by clicking on the plus icon of each field accordingly as shown in Figure 19 andFigure 20 respectively.

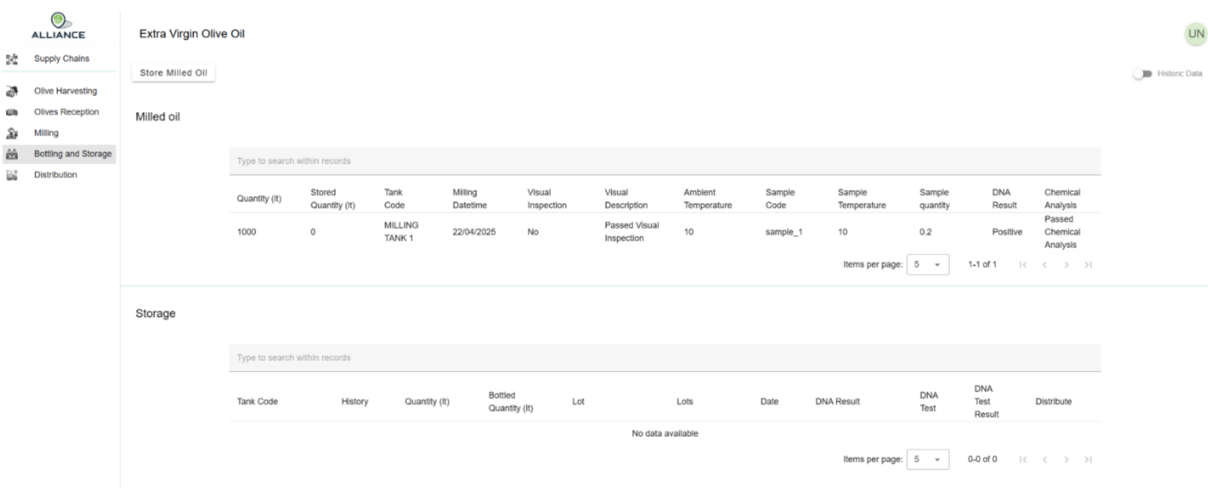


Figure 12: The 'Bottling and Storage' view.

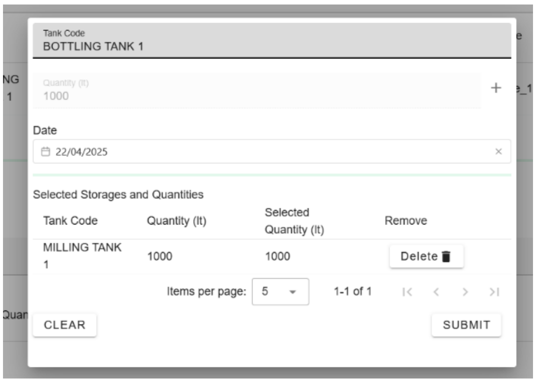


Figure 13: The storage form.

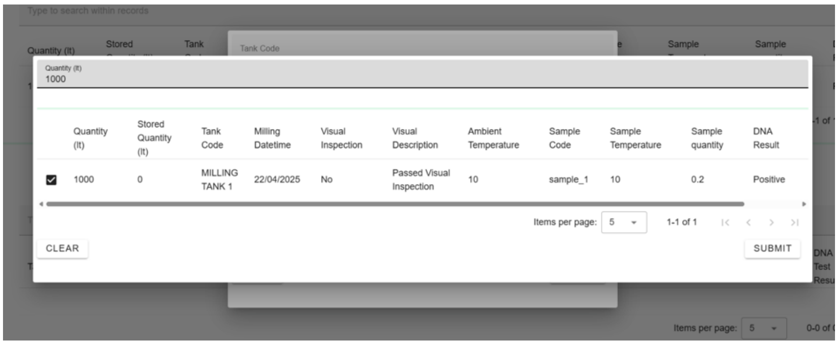


Figure 14: Form where the user selects oils for storage.

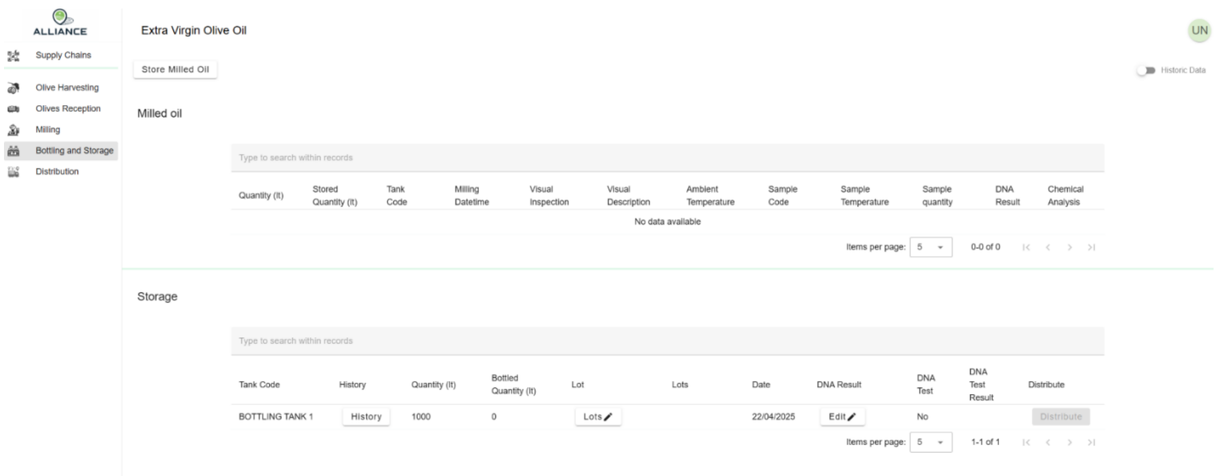


Figure 15: Stored oils view.

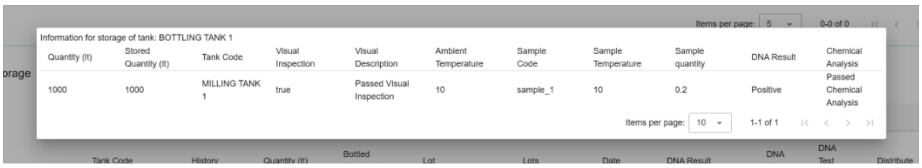


Figure 16: History View, user can view the oils stored in each tank.

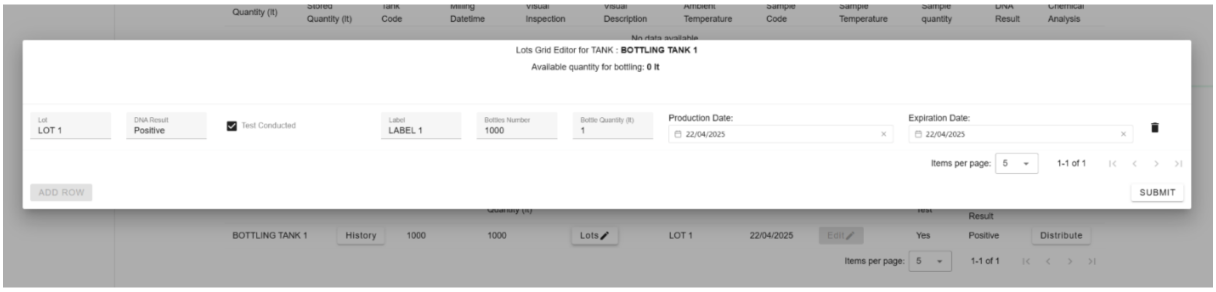


Figure 17: The Lots form for olive oil.

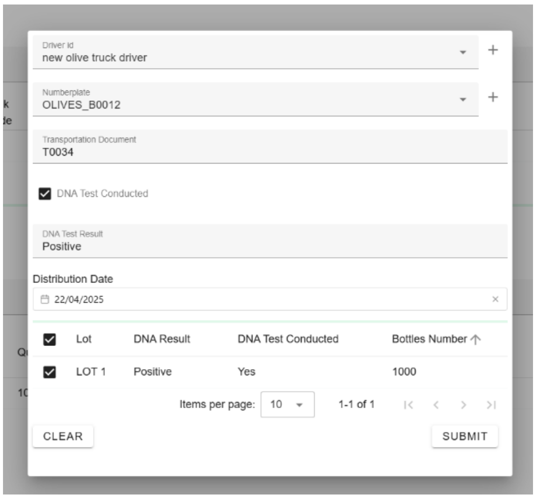


Figure 18: The distribution form for olive oil.

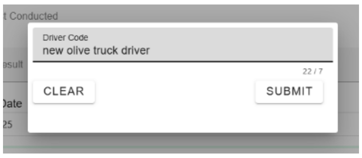


Figure 19: The driver form for olive oil.

Figure 20: The truck form for olive oil.

3.2.5. Distribution

The next and final stage of the supply chain is the distribution. By filling out the distribution form mentioned above a new distribution entry is created in the 'Distribution' view, as shown in Figure 21, and the user can click on each row to view the contents of each distribution as shown in Figure 22.

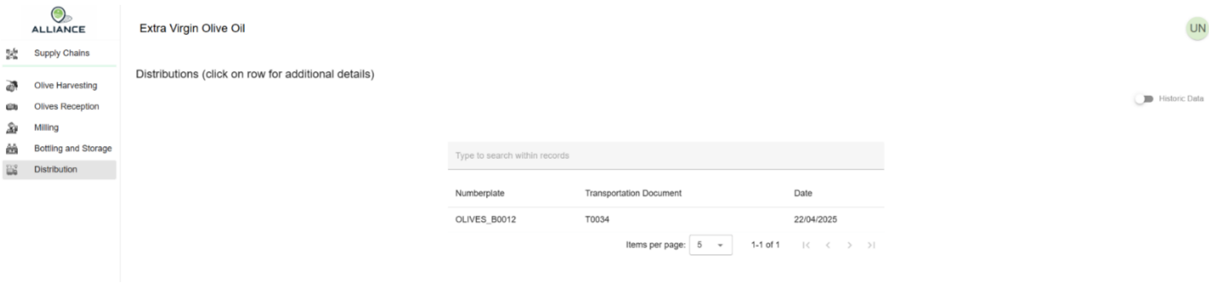


Figure 21: The Distribution view of olive oil.

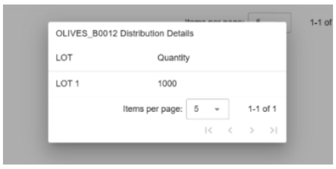


Figure 22: The Distribution information of olive oil.

3.3. Feta Cheese FSC

The Feta Cheese supply chain from Greece is supported within the scope of the Alliance project. The supply chain consists of the following stages:

3.3.1. Milk Collection

The first stage is the Milk Collection. Drivers collect fresh milk from farmers and load it to their trucks. First the driver should report a new milk collection. This is done through clicking on the 'Add new milk collection' button at the top left side of the web-app, shown in Figure 23, and filling out the required information as shown in Figure 25. If the desired producer is not available a new one can be created by clicking on the plus button next to the producer code field and filling out the information, shown in Figure 24. Note the sample code field as it will be explained later. Once a new milk collection record has been created, the driver can load one or more milks to their truck by clicking on the 'Add new milk transportation' button, shown in Figure 26, filling out the required information and choosing which milk he uses to load onto the truck shown in Figure 27. If the truck numberplate is not available, the user can create a new one by clicking on the plus button next to the field.

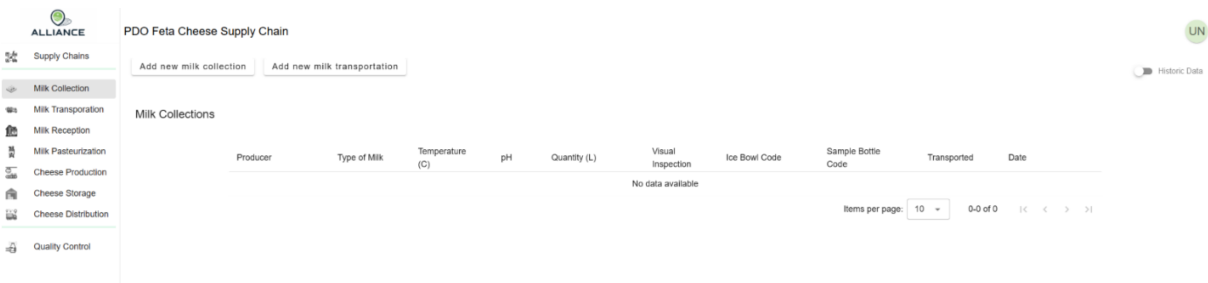


Figure 23: The 'Milk Collection' view.

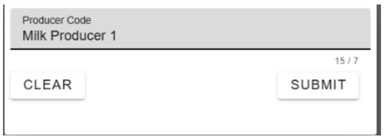


Figure 24: Producer form, from which a new producer can be created.

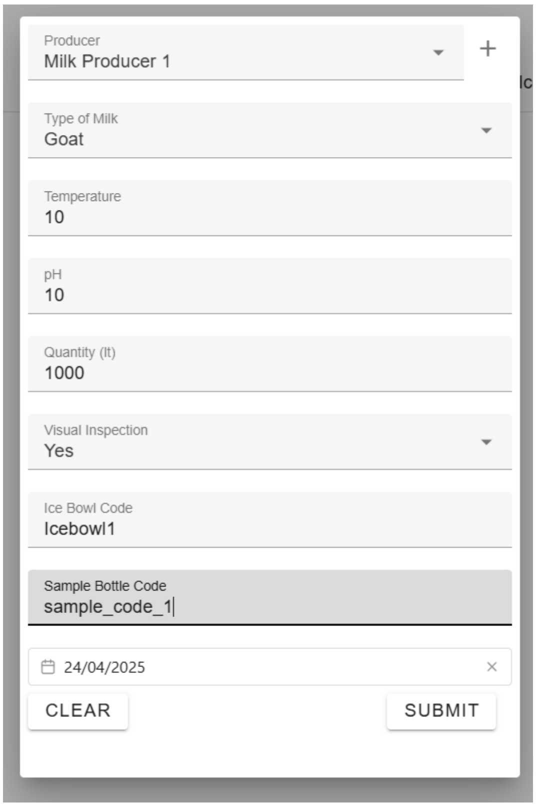


Figure 25: The milk collection form.

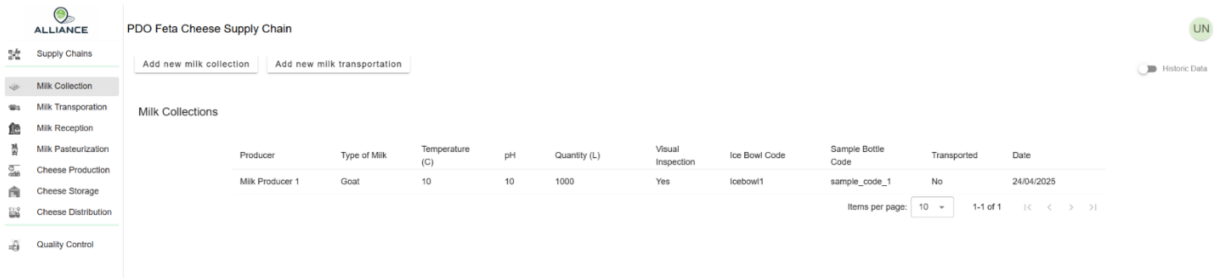


Figure 26: The 'Milk Collection' view, with one collected milk.

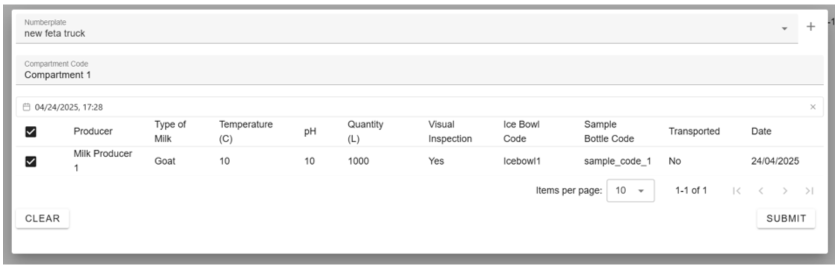
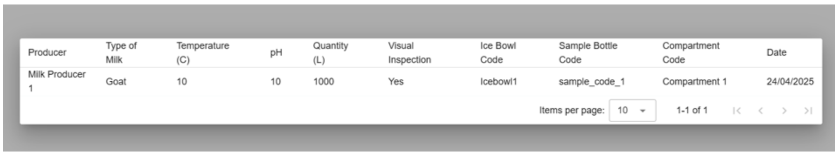


Figure 27: The milk loading form for the truck driver.

3.3.2. Milk Transportation

In the milk transportation's view shown in Figure 28, the user can view active transportation and the contents of each transportation by clicking on the desired record as shown in Figure 29.

Figure 28: The 'Milk Transportation' view.



Producer	Type of Milk	Temperature (C)	pH	Quantity (L)	Visual Inspection	Ice Bowl Code	Sample Bottle Code	Compartment Code	Date
Milk Producer 1	Goat	10	10	1000	Yes	Icebowl1	sample_code_1	Compartment 1	24/04/2025

Items per page: 10 1-1 of 1

Figure 29: Transportation information, available by clicking on each active transportation.

3.3.3. Milk Reception

In the Milk Reception view, the user should declare a new reception at the facility. This is done through clicking on the 'Add Milk Reception' button (top left of the web-app, see Figure 30). Once the user selects a truck, (s)he also provides the required information through the reception form, Figure 31, and the contents are uploaded and displayed on the web-app, Figure 32. By clicking on reception record the user gains access to a variety of choices. She or he can conduct quality control tests on the compartments by clicking on the 'Log Sample Results' and filling out the required information and later view it on demand, as shown in Figure 33 and Figure 34 respectively. For the supply chain to proceed to the next stage the user should store the received milk by clicking on the 'Store Milk' button and by reporting the required information as shown in Figure 35. If the desired silo code is not available, there is the option to create a new one by clicking on the plus button, next to the field as shown in Figure 36. Finally, by clicking on the 'Log Milk Sample' button on the receptions view the user can submit results from quality control tests, as shown in Figure 37, conducted on the samples taken from the driver on the initial stage. The quality control outcomes can be viewed on demand in the Quality Control page, as shown in Figure 38.

Figure 30: The 'Milk Reception' view.

Figure 31: The reception form for milk.

Figure 32: Milk receptions view, with one current reception.

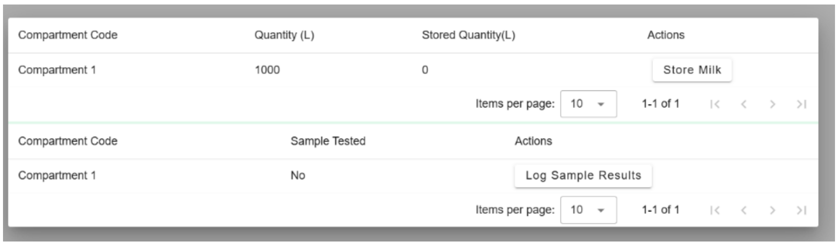


Figure 33: Information of each reception, available by clicking on each reception.

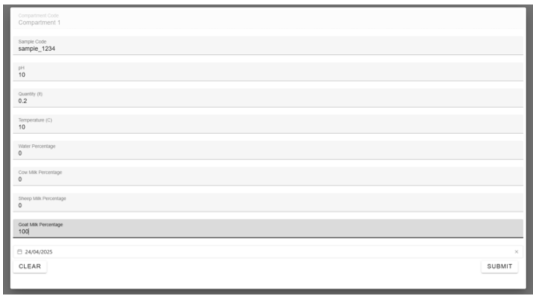


Figure 34: The compartment Quality Control form.

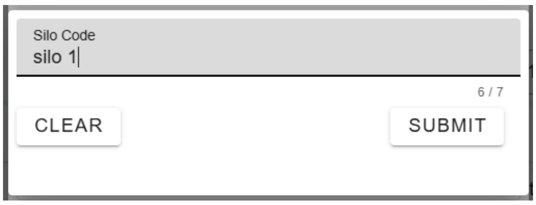


Figure 35: New silo form.

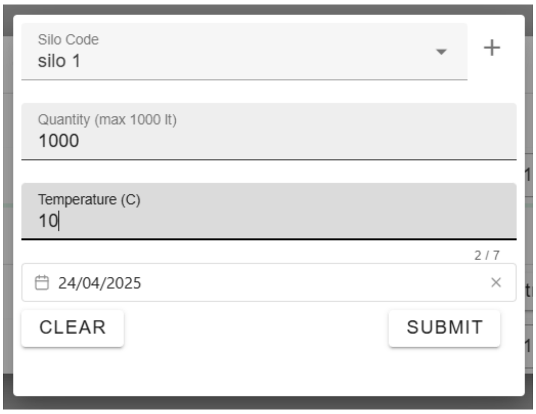


Figure 36: Milk storage form.

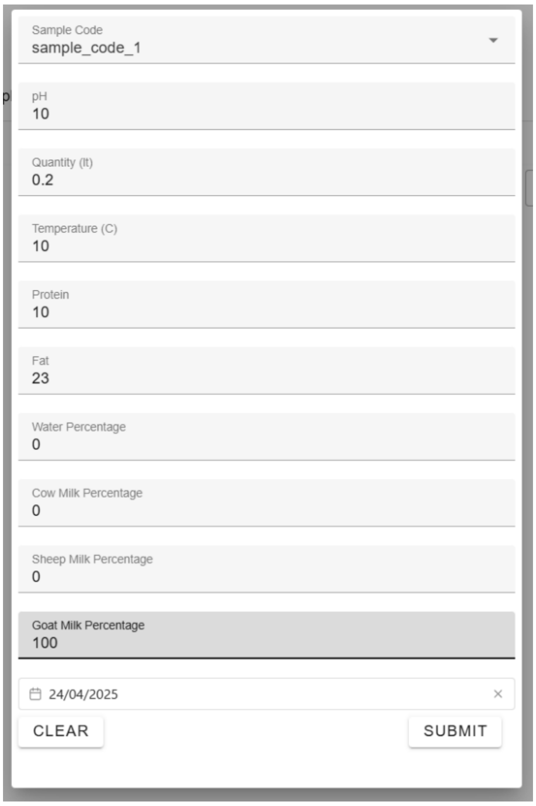


Figure 37: Samples quality control form.

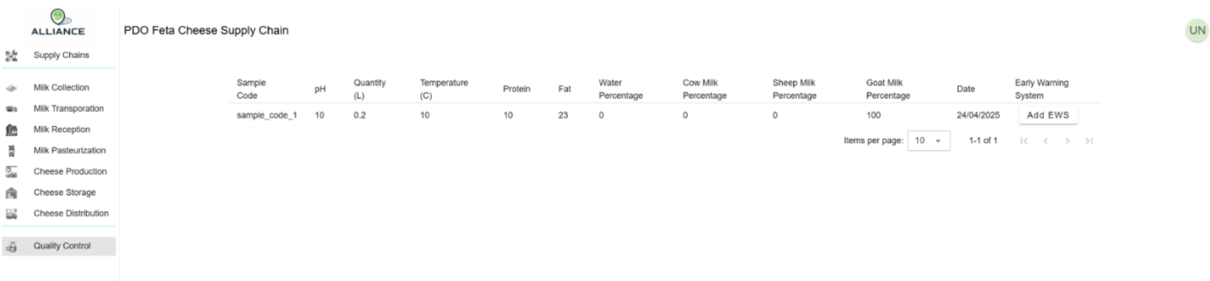


Figure 38: The 'Quality Control' view for Feta cheese.

3.3.4. Milk Pasteurization

The next step is Milk Pasteurization. On the upper half of the web-app the user can view non-pasteurized stored milks as shown in Figure 39. To declare a pasteurization process, the user must click on the 'Add Pasteurization' button at the top left side of the view and fill out the required information as shown in Figure 40. If the silo code where the pasteurized milk will be stored is not available, the user can create it by clicking on the plus button next to the field as shown in Figure 41. Once the pasteurization process has been successfully submitted the record of it is displayed on the lower half of the dashboard, Figure 42.

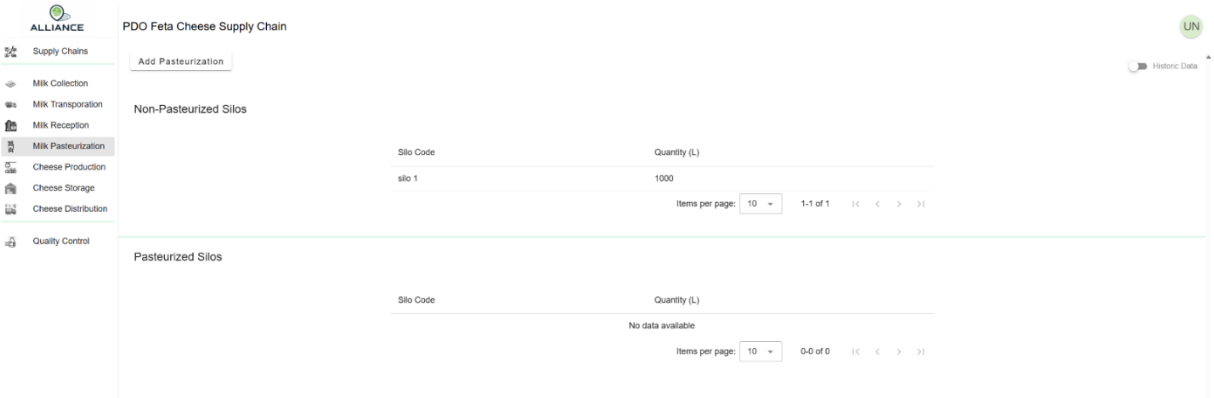


Figure 39: The 'Milk Pasteurization' view.

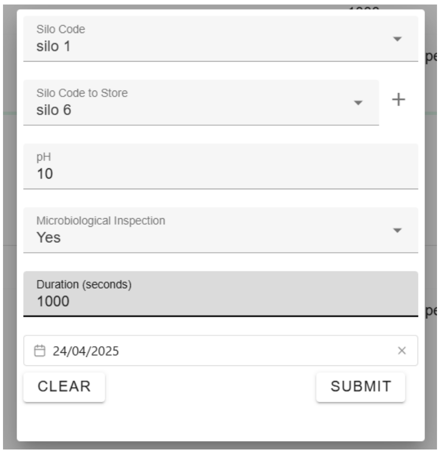


Figure 40: Milk pasteurization form.

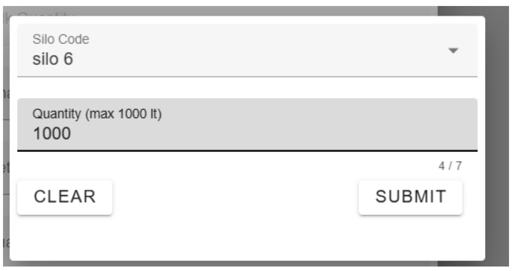


Figure 41: Form to create a new silo for pasteurization.

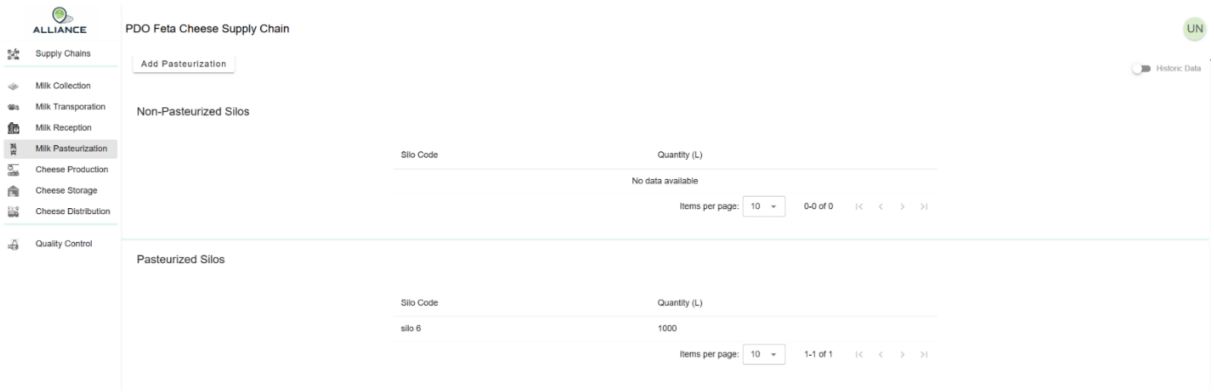


Figure 42: The 'Milk Pasteurization' view with pasteurized milks.

3.3.5. Cheese Production

The next stage is Cheese Production. To declare a new production, the user must click on the 'Add Cheese Production' button on the top left side of the web-app as shown in Figure 44. In the displayed form the user must click on the 'Add Silo' button to choose from which pasteurized silo storage the milk came from. After that the user should also fill out the required fields and a new cheese production record will be created (Figure 43). On each record, by clicking on the 'Package and Store' button the user is displayed with a form where information regarding the packaging and storage of cheese should be supplied as shown in Figure 45. On the form once the packages quantity the user can click on the 'Add Pallets' button and submit information regarding the pallets, boxes codes and the number of packages per box as shown in Figure 46. Once the packaging information has been submitted the user can click on the 'Store Cheese Pallets' button on the upper left side of the current view and fill out the required information by choosing an available Lot for storage as shown in Figure 47.

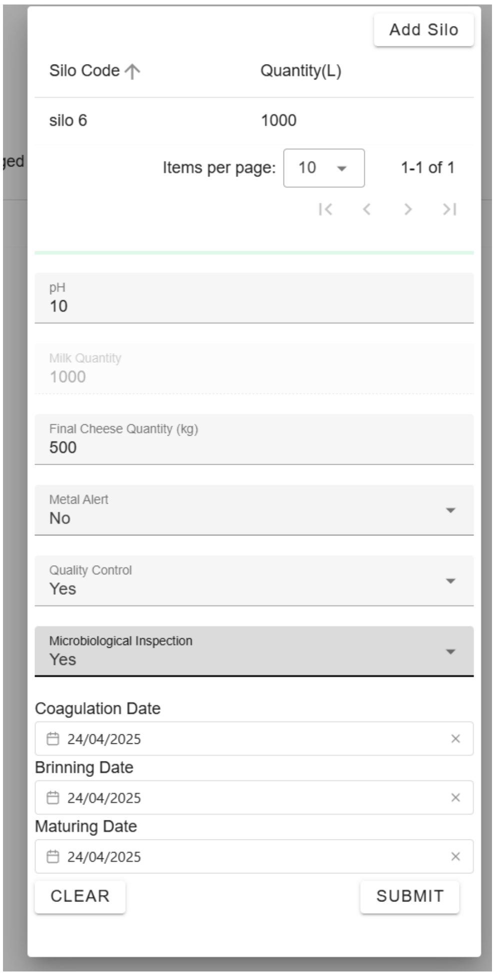


Figure 43: Cheese production form.

Figure 44: The 'Cheese Production' view.

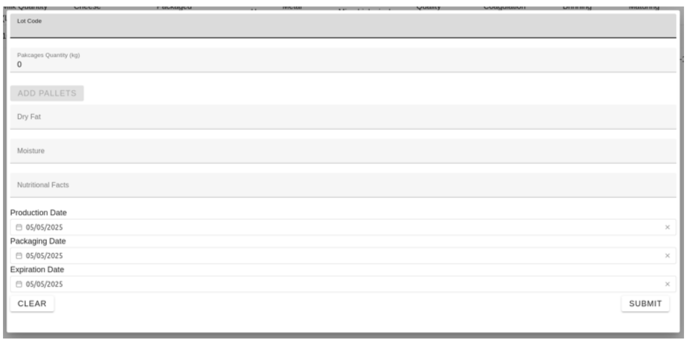


Figure 45: Packaging form.

Figure 46: Pallets and Boxes form.

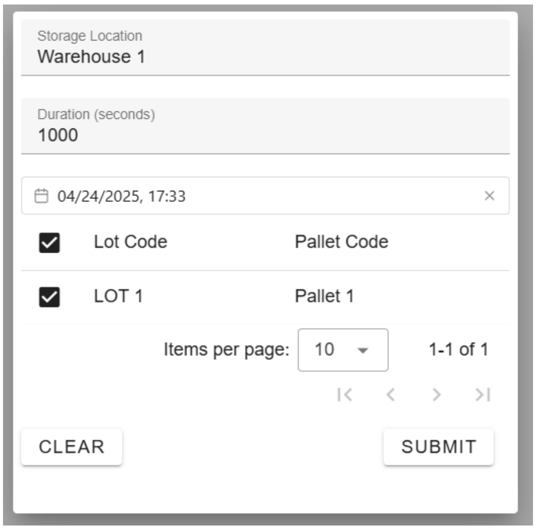


Figure 47: The packaging form after Lot addition storage form.

3.3.6. Cheese Storage

On the Cheese Storage view, the user can view stored Lots and additional information, as well as to add distribution information by clicking on the 'Add Distribution' button on the upper left side of the web-app as shown in Figure 48. By filling out the required information and choosing which Lots to distribute, Figure 50, a new distribution record is created. If the desired driver id or numberplate are not available new ones can be created by clicking on the plus button next to the corresponding field, Figure 49.

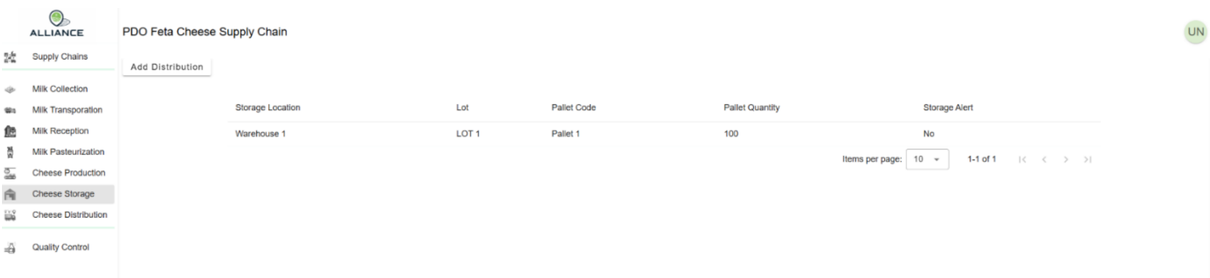


Figure 48: The 'Cheese Storage' view.

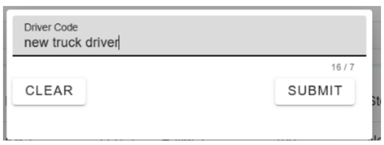


Figure 49: The new driver form.

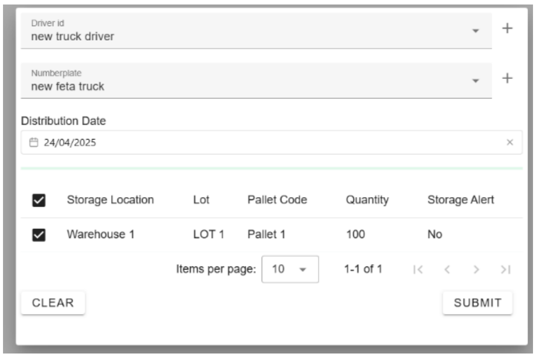


Figure 50: The distribution form for feta cheese.

3.3.7. Cheese Distribution

On the Cheese Distribution view of Figure 51, distribution records are displayed and by clicking on each record additional information regarding the content of each distribution are displayed, as shown in Figure 52.

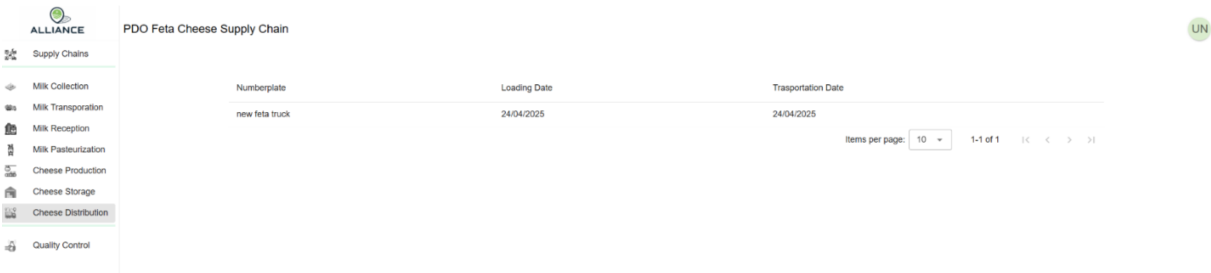


Figure 51: The 'Cheese Distribution' view.

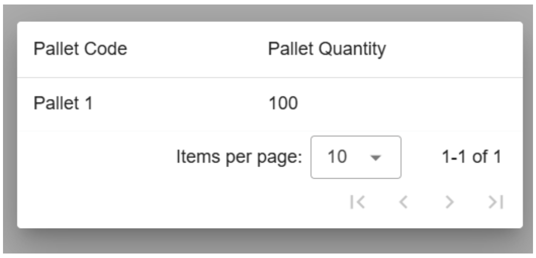


Figure 52: Cheese distribution information.

3.4. Organic Honey FSC

The Organic Honey supply chain consists of multiple stages from the honey production up to the point of packaging. Once the user has logged in to the Alliance dashboard, he can view all the stages as well submit data regarding each stage. Details on the pages are presented in the following sub-sections.

3.4.1. Apiary Management

In the view of Figure 53, the user can observe and edit information regarding the available Apiaries. The user can create a new Apiary by clicking on the 'Add new Apiary' button on the top left side of the view as shown in Figure 54. Once the user submits the data, Figure 55, a new apiary is created, which can edit by clicking on the 'Edit' button of each apiary or add a Quality Control test result that was conducted, as shown in Figure 56. Finally, the user can view the Quality Control results by clicking on the 'View QC' button, see Figure 57.

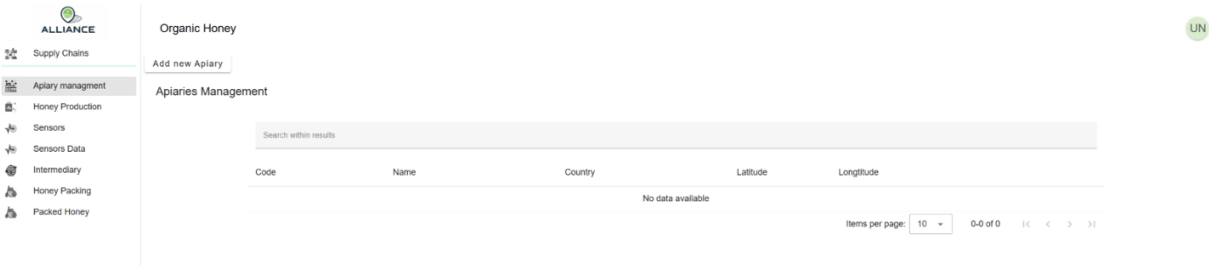


Figure 53: The 'Apiary Management' view.

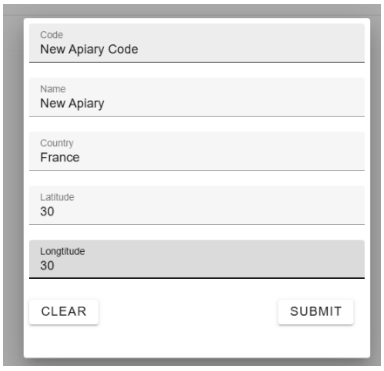


Figure 54: New apiary form.

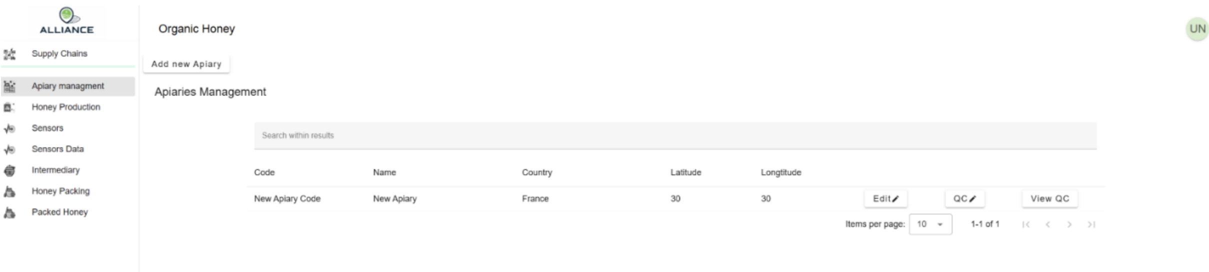


Figure 55: The 'Apiary Management' view with one new apiary.

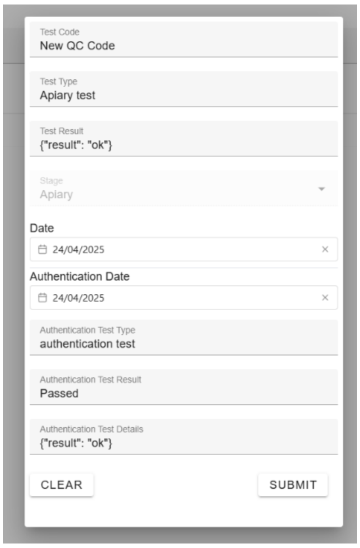


Figure 56: Apiary Quality Control form.

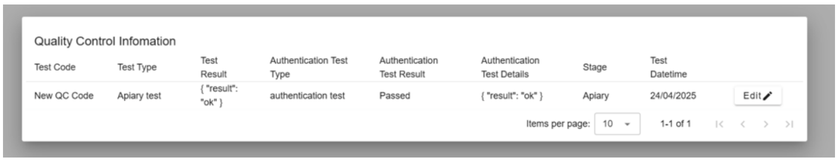


Figure 57: Apiary Quality Control information.

3.4.2. Honey Production

The next step of the supply chain is Honey Production and the corresponding view is depicted in Figure 58. The user can create a new production record by clicking on the 'Add new Production' button at the top left side of the web-app as shown in Figure 59. Once a production record has been created by filling the form shown Figure 60, the user can edit its information by clinging to the 'Edit' button or/and add crop data related to this production by clicking on the 'Crop Data' button and filling out the form shown in Figure 61.

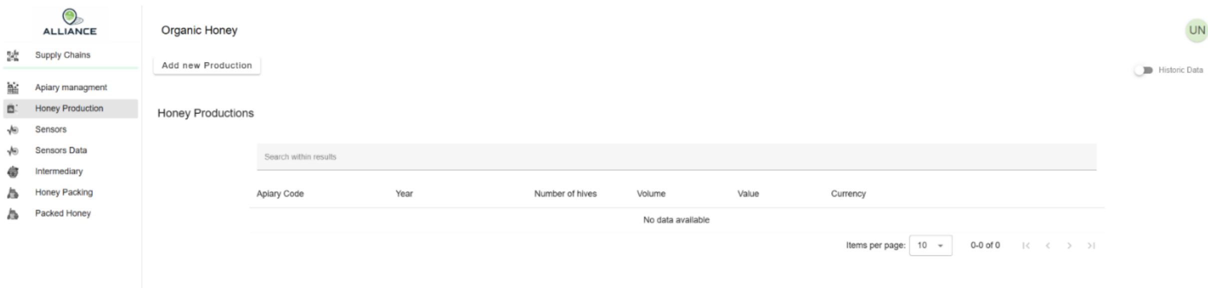


Figure 58: The 'Honey Production' view.

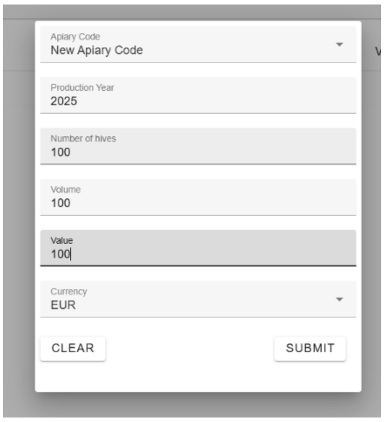


Figure 59: New honey production form.

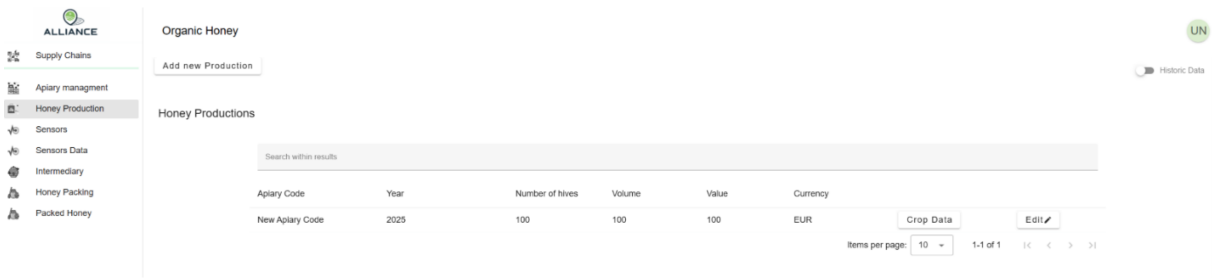


Figure 60: The 'Honey Production' view with one new production.

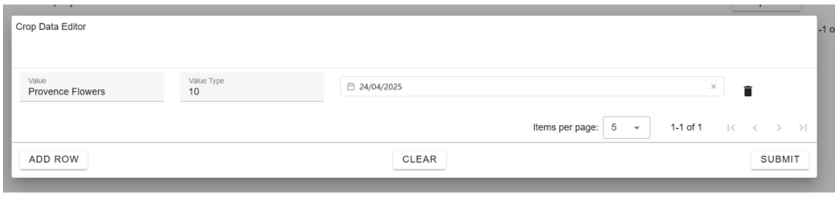


Figure 61: Crop data form.

3.4.3. Sensors

Some Apiaries are equipped with several sensors to monitor various parameters. In the Sensors view of Figure 62, the user can view and/or add a new Sensor related to an apiary by clicking on the 'Add new Sensor' button (Figure 63). After a sensor has been created, by filling out the form shown in Figure 64, the user can edit the information by clicking on the 'Edit' button.

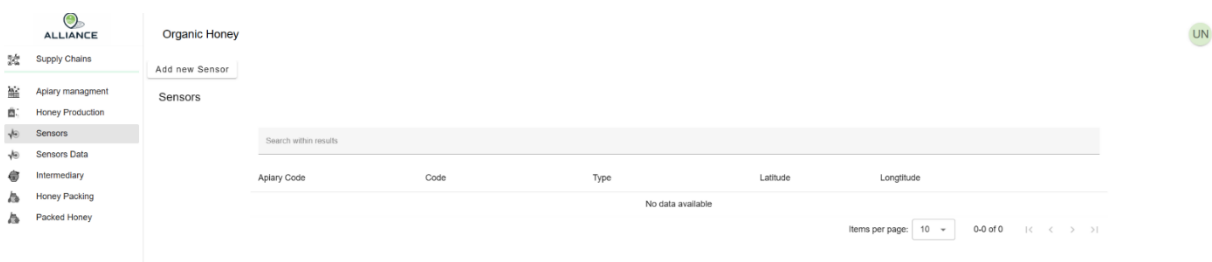


Figure 62: The 'Sensors' view.

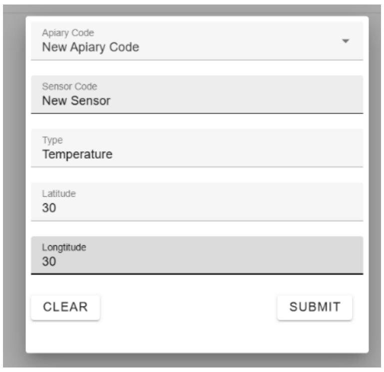


Figure 63: New sensor form.

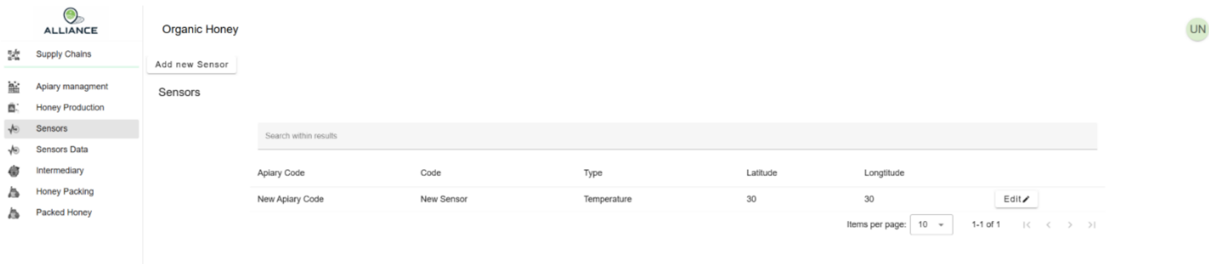


Figure 64: The 'Sensors' view with one new sensor.

3.4.4. Sensors Data

The sensors gather data that are visible on the Sensors Data view of Figure 65. The user can submit a new sensor measurement by clicking on the ‘Add New Sensor Data’. Once the measurement has been created, by filling out the form shown in Figure 66, its information can be edited via the ‘Edit’ button. Furthermore, the user can search for a specific measurement using the search fields above the data table as shown in Figure 67.

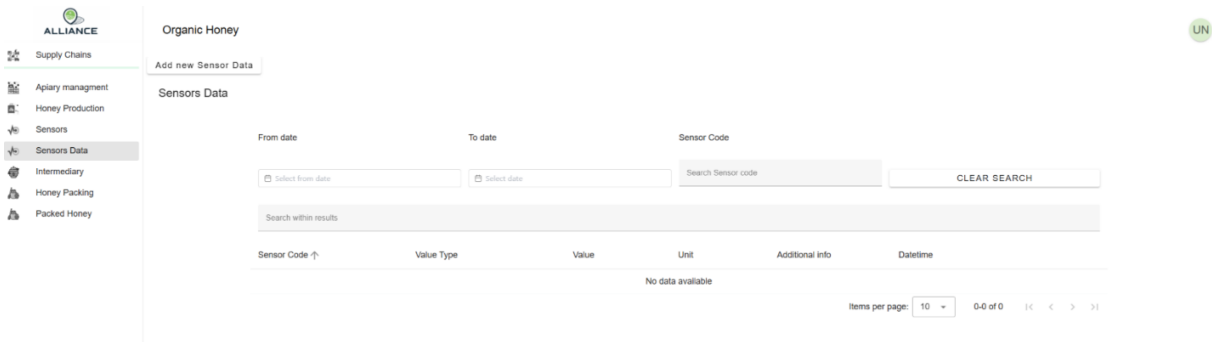


Figure 65: The 'Sensor Data' view.

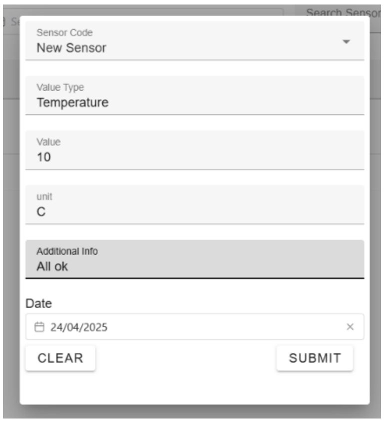


Figure 66: Sensor data form.

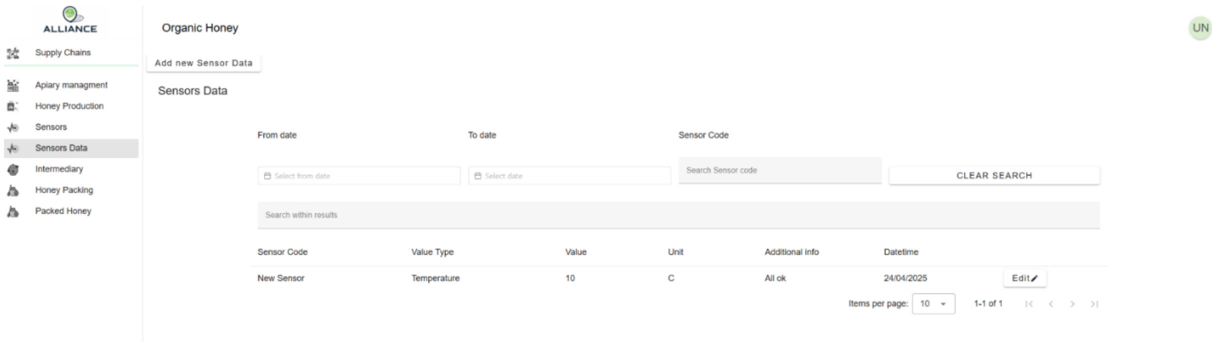


Figure 67: The 'Sensor Data' view with a new record of data.

3.4.5. Intermediary

In some cases, between the Honey production and Honey packing, different intermediaries can be involved. The user can report the involvement of an intermediary to a honey production by clicking on the ‘Add Intermediary’ button, Figure 68, and filling out the form, Figure 69. If the desired intermediary is not present, the user can create a new one by clicking on the plus button next to intermediary field and fill out the required information as shown in Figure 70. By clicking on a honey production at the upper half of the web-app, the intermediary data will be displayed at the bottom half, Figure 71, and the user can submit Quality Control results that were carried out by clicking on the ‘QC’ button and view these results by clicking on the ‘View QC’ button as shown in Figure 72 and Figure 73 respectively.

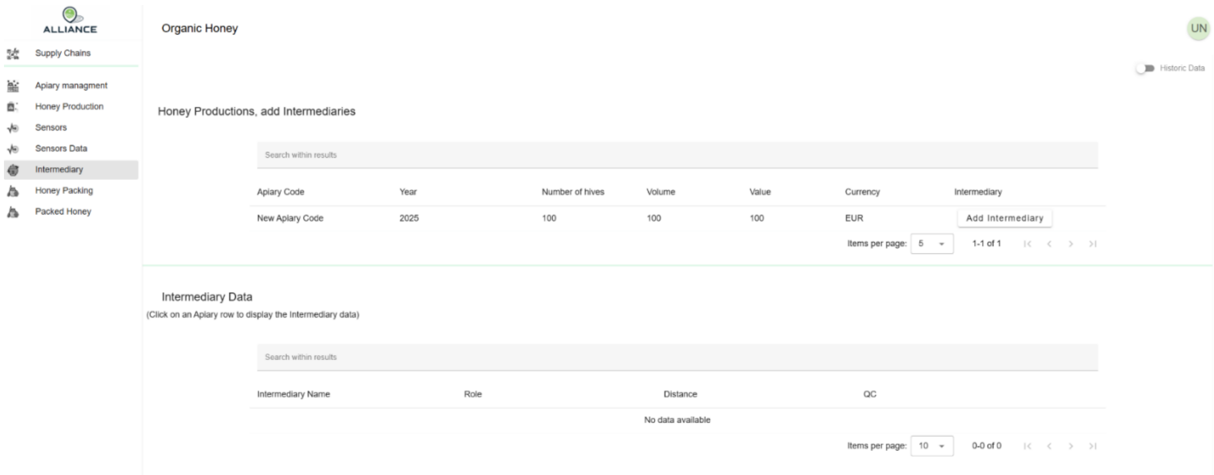


Figure 68: The 'Intermediary' view.

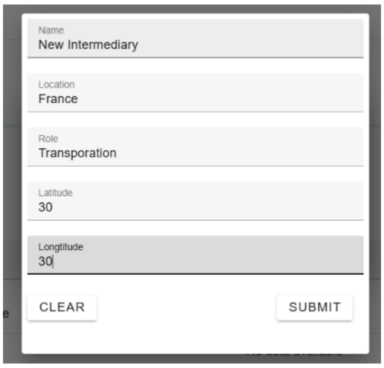


Figure 69: New intermediary form.

Figure 70: Form for creating new intermediary.

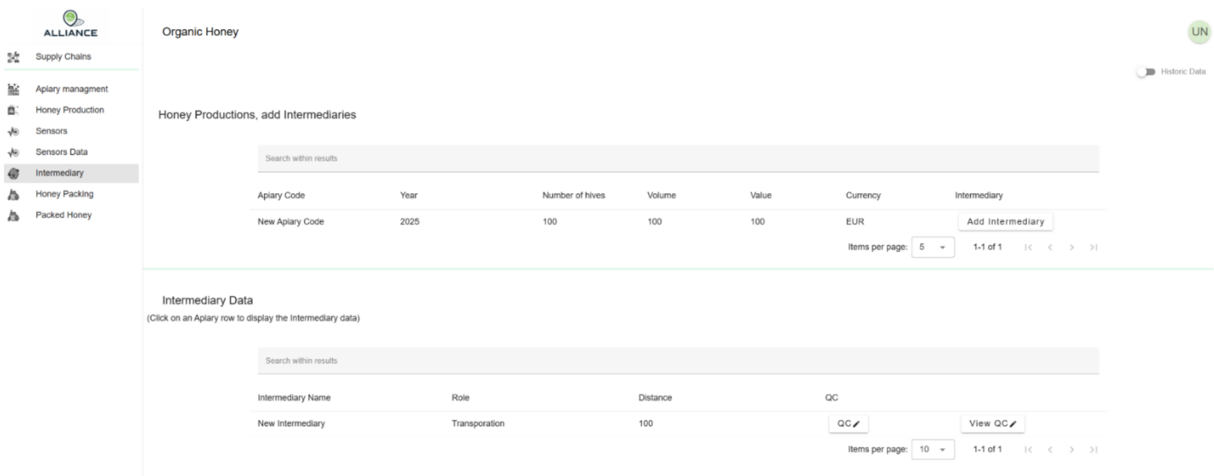


Figure 71: The 'Intermediary' view after creating a new intermediary.

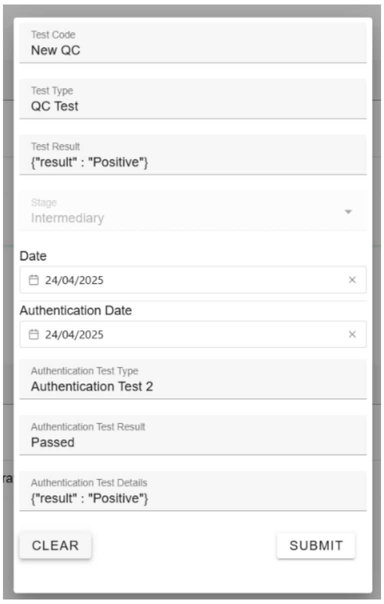


Figure 72: Intermediary quality control form.

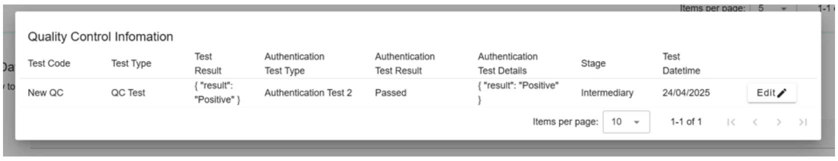


Figure 73: Intermediary quality control information.

3.4.6. Honey Packing

On the Honey Packing page, the user is provided with information related to the honey productions that have not been packed. The user is able to package each production by clicking on the 'Pack' button, Figure 74, and filling out the form shown in Figure 76. If the desired producer code is not available, the user can create it by clicking on the plus button, and next to the producer field fill out the form shown in Figure 75.

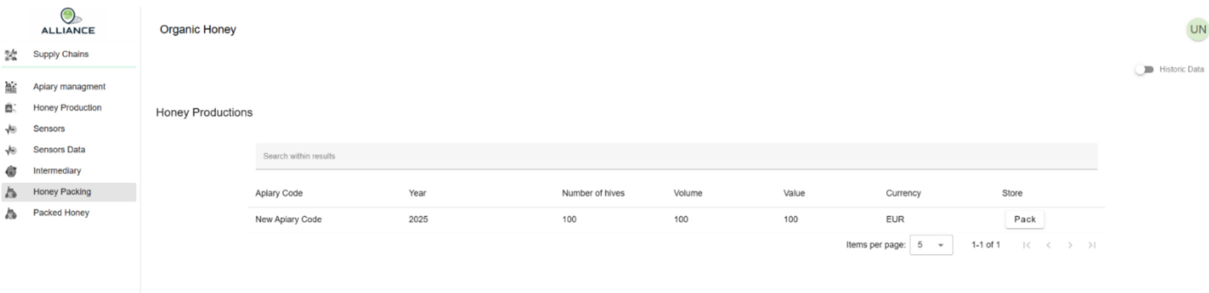


Figure 74: The 'Honey Packing' view.

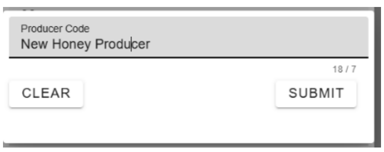


Figure 75: New honey producer form.

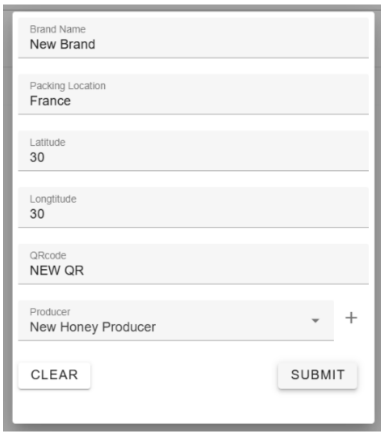


Figure 76: New honey packing form.

3.4.7. Packed Honey

On the last page of the Organic Honey supply chain the user can view the packed honey, as shown in Figure 77, edit the information of each packaging by the 'Edit' button, add metrics, Figure 78, sales, and Quality Control results, Figure 79, and view Quality control results, Figure 80, by clicking on the corresponding buttons.

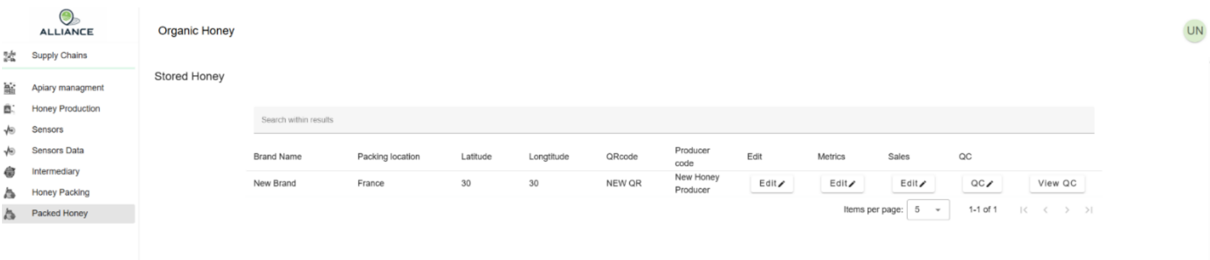


Figure 77: The 'Packed Honey' view.

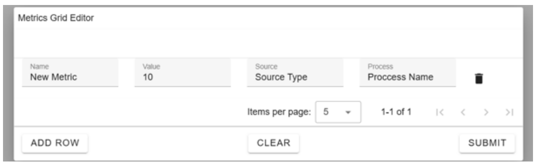


Figure 78: Honey-related metrics form.

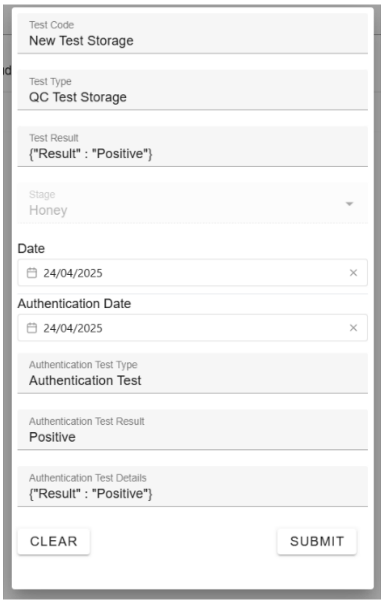
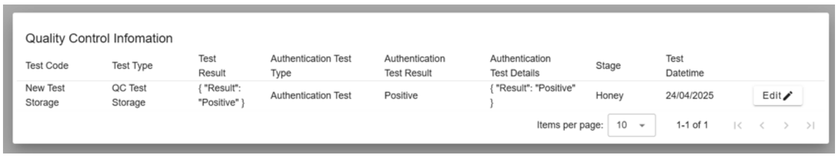


Figure 79: Honey Quality Control form.


Quality Control Infomation

Test Code	Test Type	Test Result	Authentication Test Type	Authentication Test Result	Authentication Test Details	Stage	Test Datetime	
New Test Storage	QC Test Storage	{ "Result": "Positive" }	Authentication Test	Positive	{ "Result": "Positive" }	Honey	24/04/2025	Edit

Items per page: 10 1-1 of 1

Figure 80: Honey Quality Control information.

3.5. Faba Beans FSC

The PGI Faba Beans originating from Asturias is a complex supply chain supported in the Alliance platform. The stages the product goes through are presented in the following sub-sections.

3.5.1. Faba Fields

In the Faba Fields view, the user can create and view Faba Fields. The creation of a new field is done through clicking on the 'Add new Faba Field' at the top left side of the web-app, Figure 81, and fill out the required information (see Figure 82). If the desired producer is not present, the user can create a new one by clicking on the plus button next to producer field and fill the required information (see Figure 83). Once the Faba Field has been created, the user can edit its information by clicking on the 'Edit' button as shown in Figure 84.

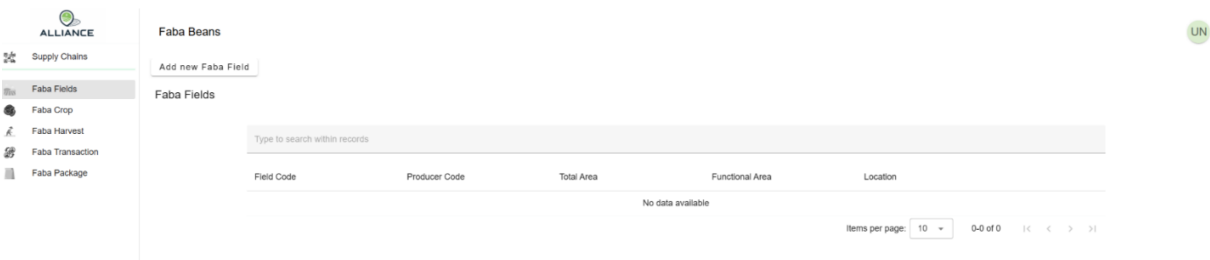


Figure 81: The 'Faba Fields' view.

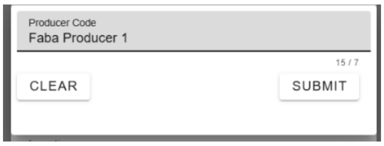


Figure 82: New faba beans producer form.

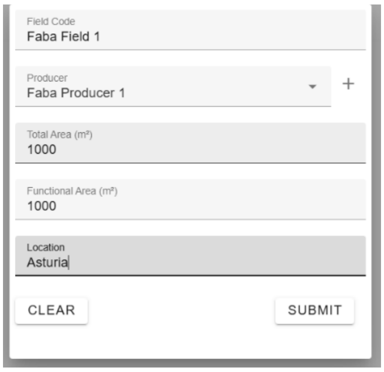


Figure 83: Faba beans field form.

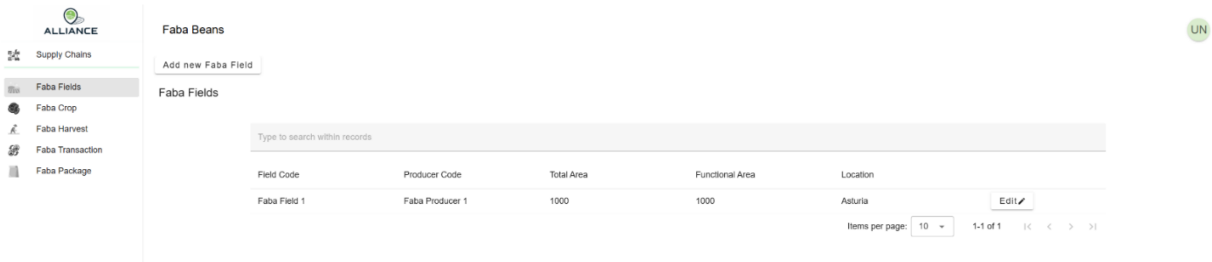


Figure 84: The 'Faba fields' view with a new field.

3.5.2. Faba Crop

The next step of the supply chain is Faba Cropping. The user can view, edit, create and delete a faba cropping record. The creation of a new record is achieved by clicking on the 'Add new Faba Crop' button at the top left side of the web-app, Figure 85, and to fill out the required information as shown Figure 86. Once a new record has been created the user can edit its information or delete it by clicking on the corresponding buttons (see Figure 87).

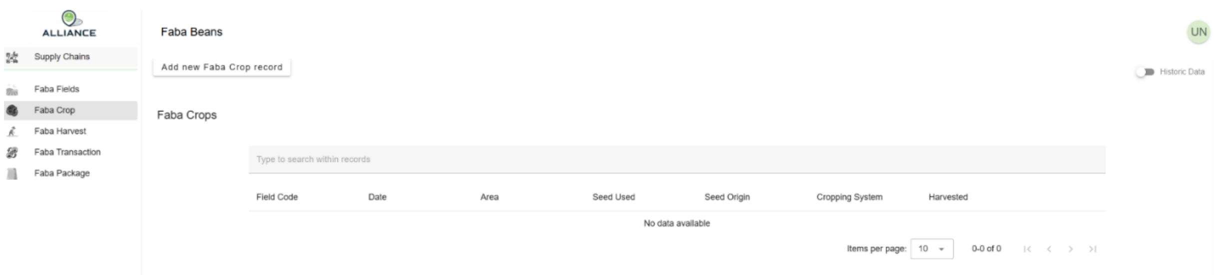


Figure 85: The 'Faba Crop' view.

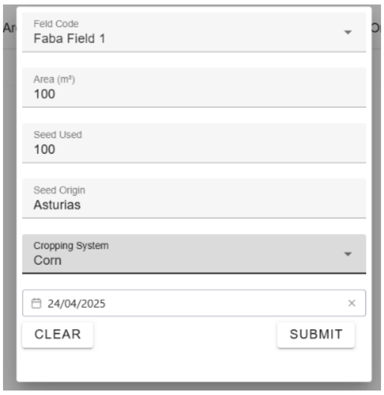


Figure 86: New crop form.

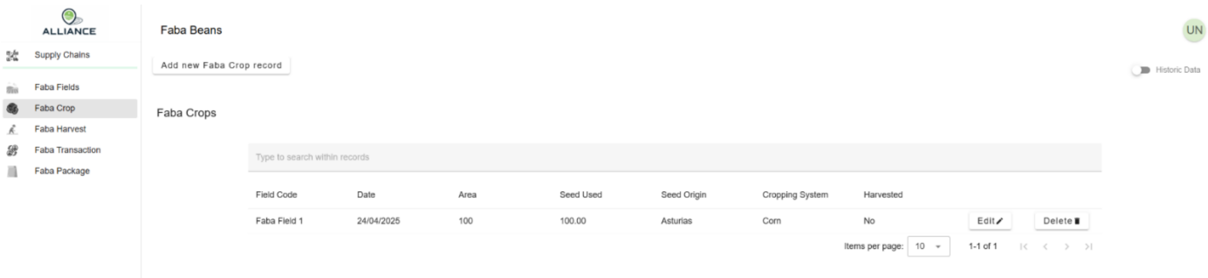


Figure 87: The 'Faba Crop' view with a new cropping record.

3.5.3. Faba Harvest

The harvest of the recorded crops is the next step within the supply chain. The user declares a new harvest by clicking on the 'Add new Faba Harvest' button at the top left side of the view Figure 88, and fill out the required information as shown in Figure 89. Then, the user adds crops by clicking on the plus button within the form in the crops field, and selects a cropping system and one or more of the available cropping records created in the previous stage, as shown in Figure 90. Once a harvest record has been created the user can edit its information through the 'Edit' button. The user could also add authenticity results by clicking on the 'Authenticity' button on each record, and filling out the required information as shown in Figure 91. Finally, the user can sell the harvest through clicking on the 'Sell' button of each record and filling out the required fields as shown in Figure 92.

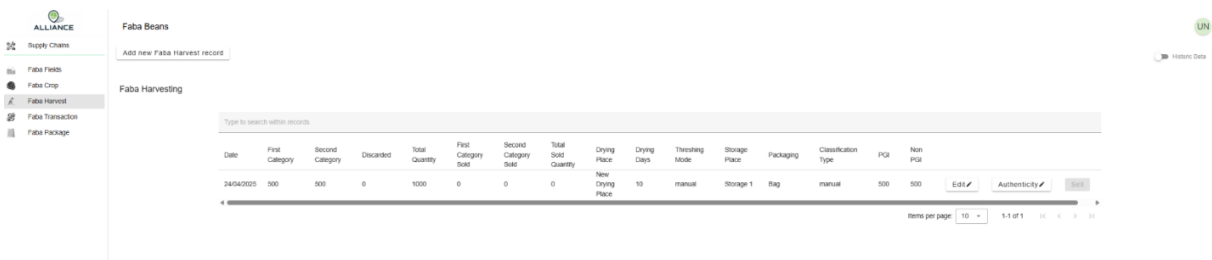


Figure 88: The 'Faba Harvest' view.

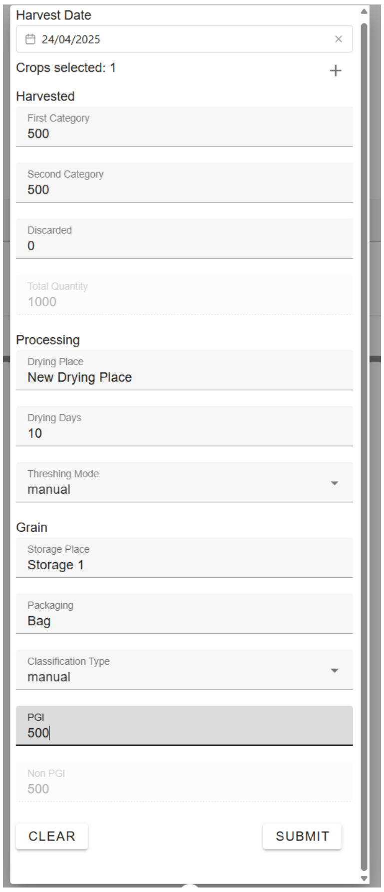


Figure 89: Faba harvest form.

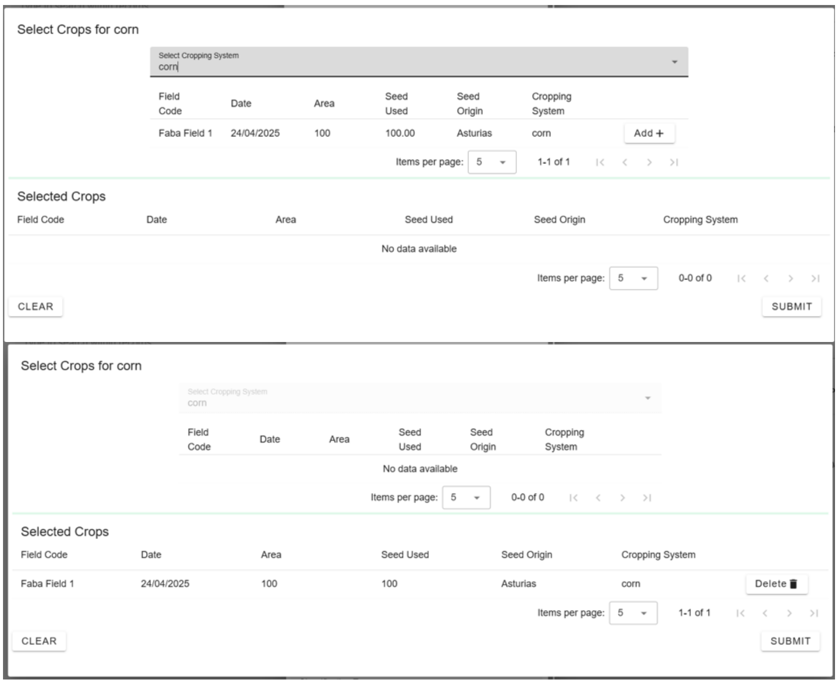


Figure 90: Crops selection forms for harvest.

Figure 91: Authenticity form at Faba Harvesting stage.

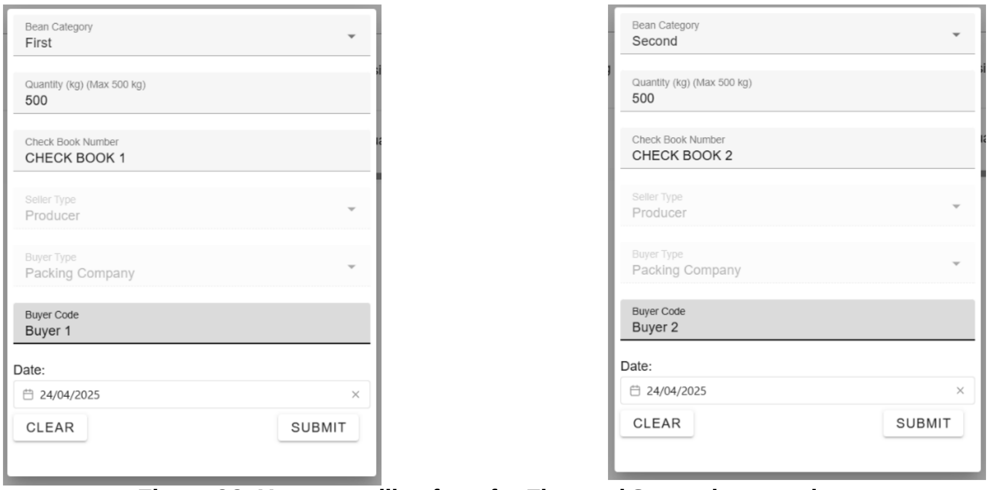


Figure 92: Harvest selling form for First and Second categories.

3.5.4. Faba Transaction

Faba Transaction is the next step of the supply chain. On the upper half of the web-app the sold harvests created from the previous step are displayed as shown in Figure 93. The user can either resell or pack each record by clicking on the corresponding buttons on each record as shown in Figure 94. Transactions that have been resold to third parties are displayed on the lower half of the dashboard as shown in Figure 95.

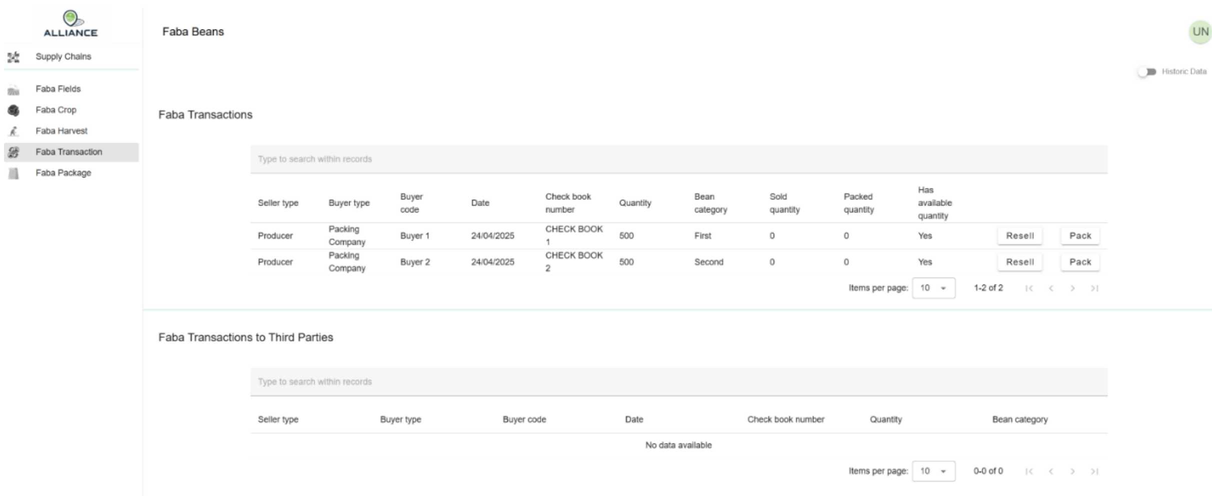


Figure 93: The 'Faba Transaction' view.

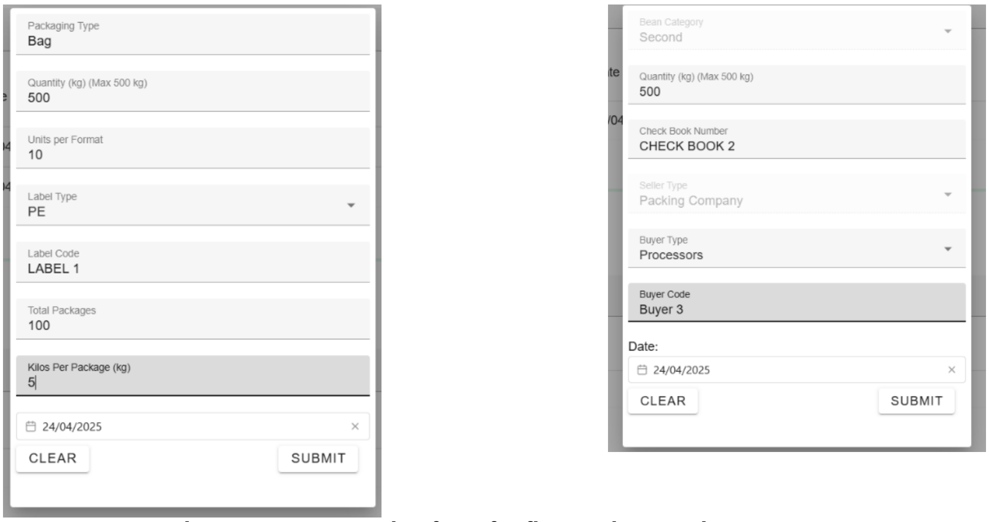


Figure 94: Transaction form for first and second category.

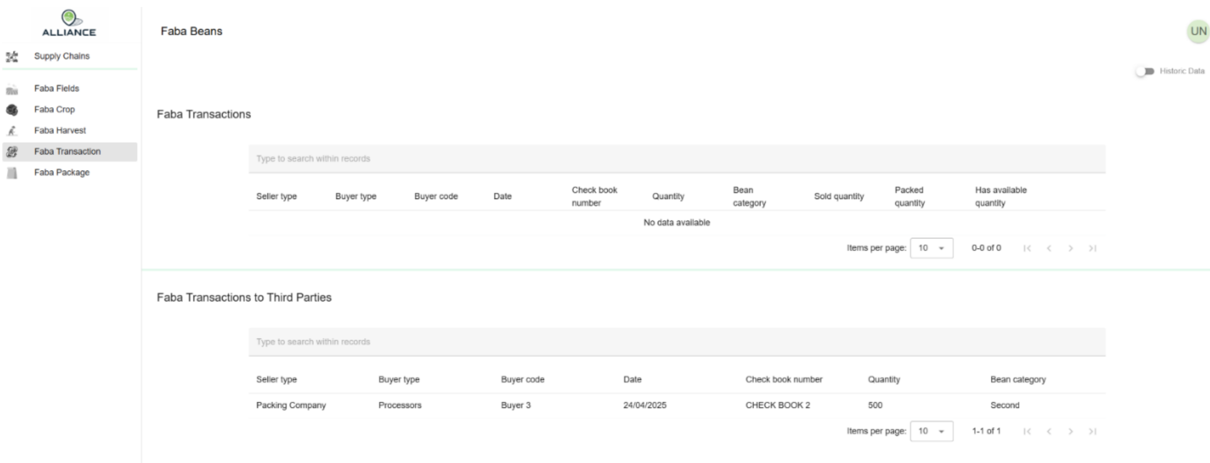


Figure 95: The 'Faba Transaction' view with transactions to third parties.

3.5.5. Faba Package

On the last page of the PGI Faba Beans supply chain the user can view packaging records created on the previous stage, as shown in Figure 96, and submit authenticity results conducted either before or after packaging by clicking on the corresponding buttons, filling out the required information as shown in Figure 97.

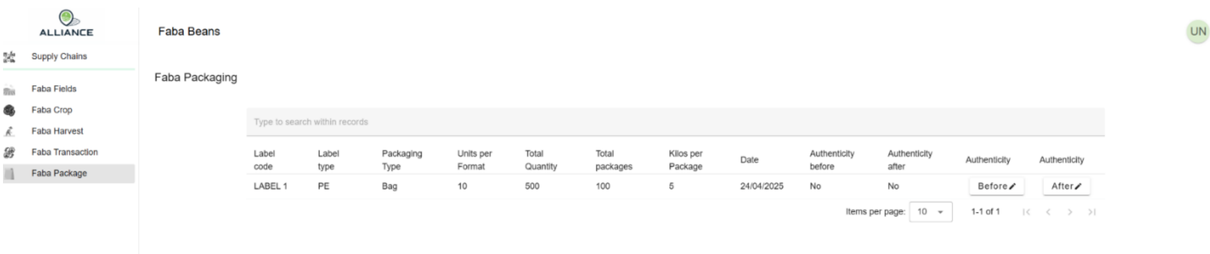


Figure 96: The 'Faba Package' view.

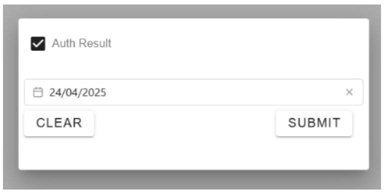


Figure 97: Authenticity form at Faba Packaging stage.

3.6. Lika Potatoes FSC

The Lika Potatoes supply chain is supported within the Alliance Platform. The user can view the stages of the supply chain through the implemented web-app. In more detail, the stages are presented in the following sub-sections.

3.6.1. Potato Fields

The first page of the PGI Lika Potatoes supply chain is the Potato Fields view. The user can create a new potato field by clicking on ‘Add new Potato Field’, as shown in Figure 98, and filling out the information as shown on Figure 99. If the desired producer is not available, the user can create a new producer by clicking on the plus button next to the producer field and fill out the required information as shown in Figure 100. Once a field has been created, Figure 101, the user can click on the ‘Edit’ button to edit the submitted information and add Quality Control results by clicking on the ‘QC’ button and filling out the required information, Figure 102, and finally view this information through the ‘View QC’ button as shown in Figure 103.

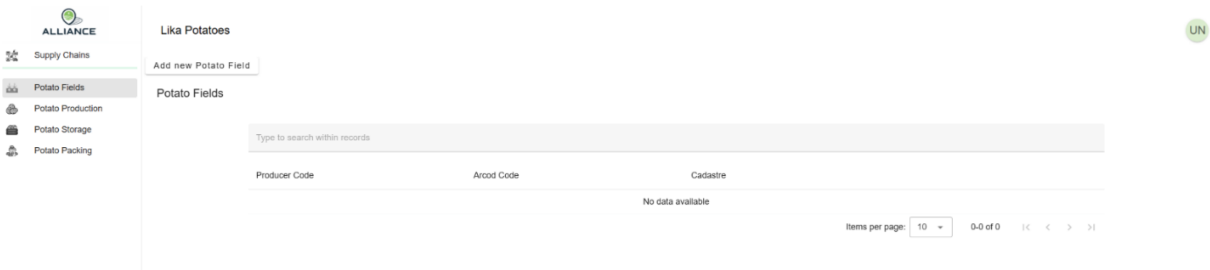


Figure 98: The 'Potato Fields' view.

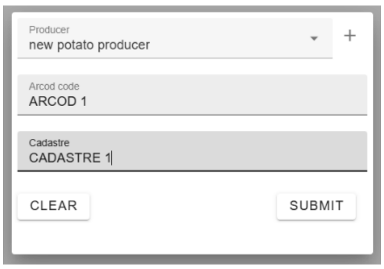


Figure 99: New potato-field form.

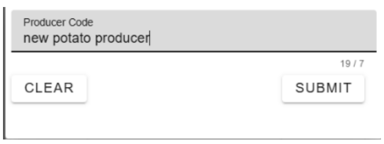


Figure 100: New potato-producer form.

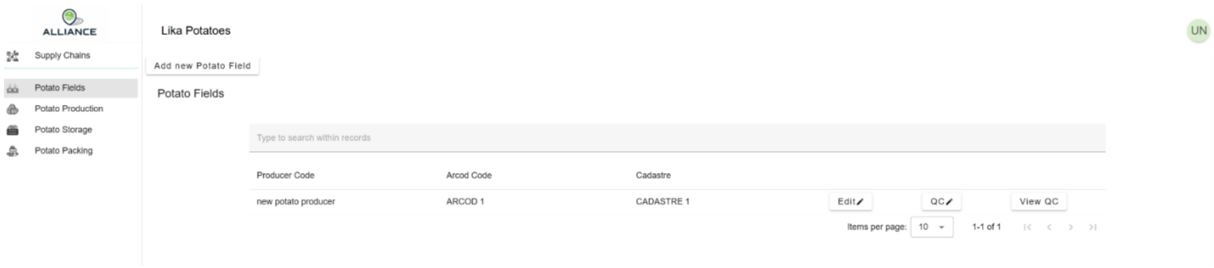


Figure 101: The 'Potato Fields' view with a new field.

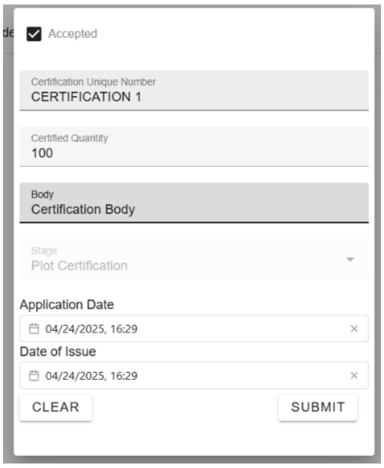


Figure 102: Field Quality Control form.

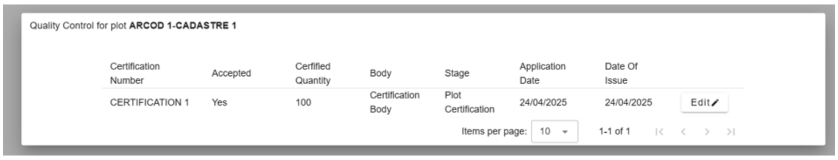


Figure 103: Field Quality Control results display.

3.6.2. Potato Fields

The next stage is the declaration of potato production. The user can create a new production record through clicking on the 'Add new Potato Production' button, shown in Figure 104, and filling out the required information as shown in Figure 105. Regarding the Total Production field, the user should click on the plus icon next to the field and submit data regarding the production quantities of each month of the year (Figure 106). Once the information has been submitted a new production record is created and the user can edit the information by clicking on the 'Edit' button as well as submit Quality Control results through the 'QC' button and view these results by clicking on the 'View QC' button (all buttons are shown in Figure 107). Finally, the user can submit data regarding the procedures each production went through, Figure 108, as well as the boxes each production was packaged, Figure 109, by clicking on the corresponding buttons.

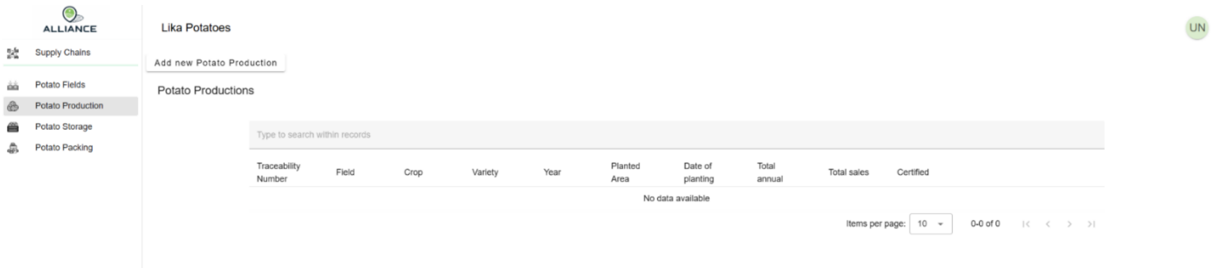


Figure 104: The 'Potato Production' view.

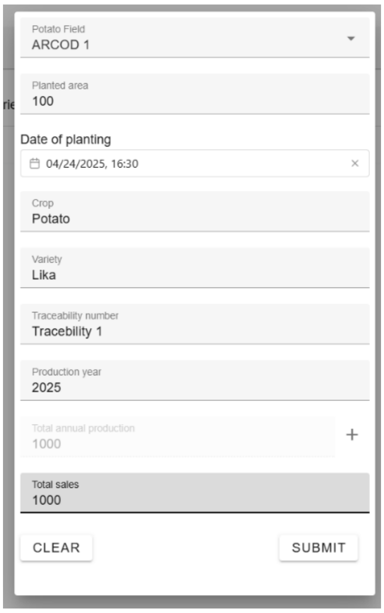


Figure 105: New potato production form.

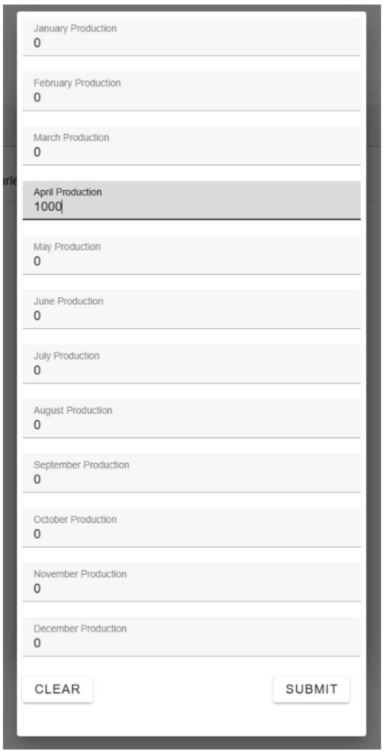


Figure 106: Form for annual potato production.

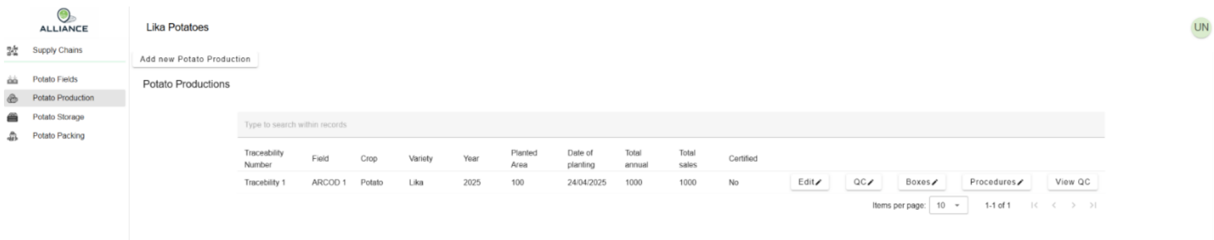


Figure 107: The 'Potato Production' view with a new potato production.

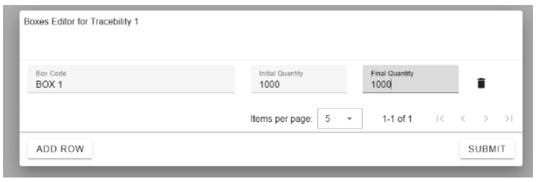


Figure 108: Potato boxes form.

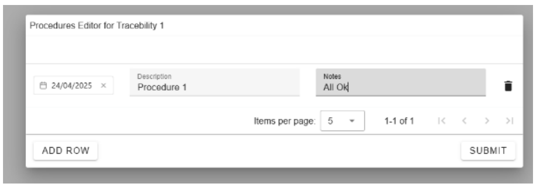


Figure 109: Potato procedures form.

3.6.3. Potato Storage

The next step of the supply chain includes the storage of the boxes until the packaging stage. On the upper half of the Potato Storage view the user can view all the potato production and store the boxes as shown in Figure 110, if there is an available one for storage, by clicking on the 'Store' button and filling out the required information as shown in Figure 111. If the desired chamber is not available, the user can create a new chamber by clicking on the plus button next to the chamber field and fill out the required information as shown in Figure 112. By clicking on a production record at the upper half of the web-app the storage information of this production will be displayed at the lower half and the user can either edit the storage information by clicking on the 'Edit' button or proceed to package the contents of each box by clicking on the 'Pack button' and filling out the required information as shown in Figure 113.

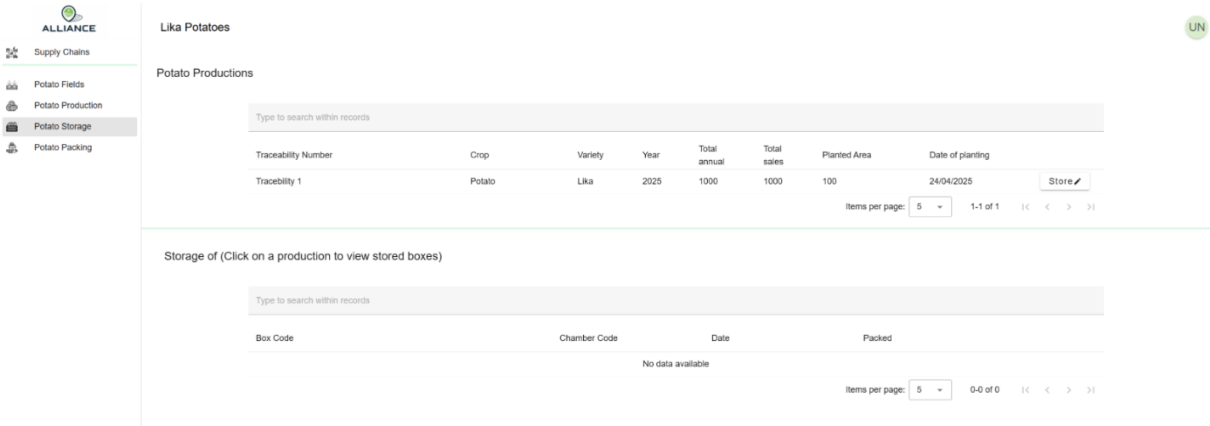


Figure 110: The 'Potato Storage' view.

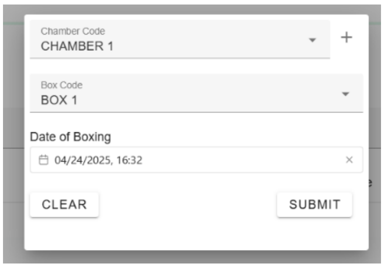


Figure 111: New potato-storage form.

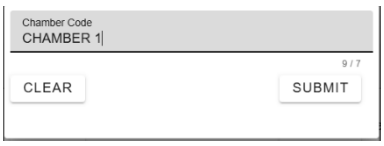


Figure 112: New potato-chamber form.

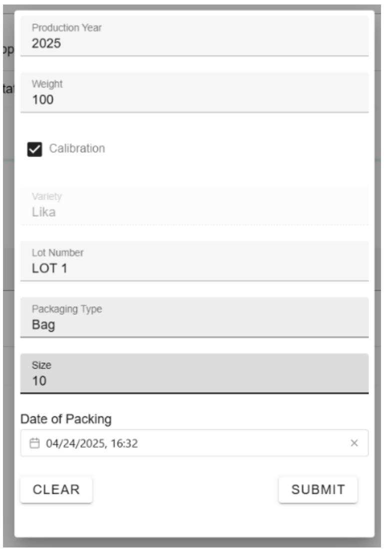


Figure 113: Form for parking for potato boxes.

3.6.4. Potato Packing

On the final page of the supply chain, which is the Potato Packing view, the user can view information regarding the potatoes packaging and edit the data of each packaging record through the 'Edit' button as shown in Figure 114.

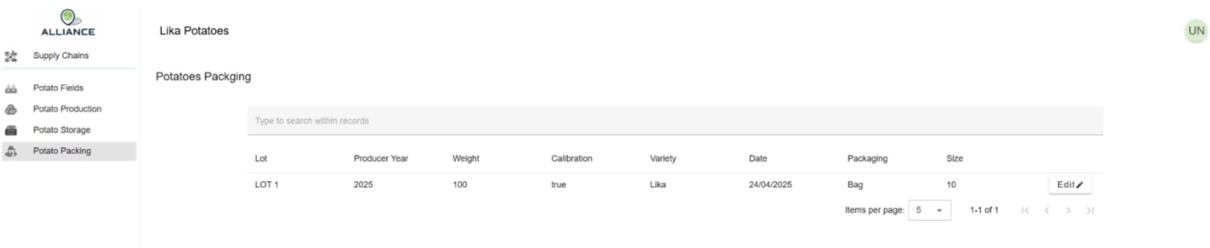


Figure 114: The 'Potato Packaging' view.

3.7. Organic Pasta FSC

3.7.1. Wheat Fields

The first stage of the organic pasta supply chain is the registration of the wheat fields. The user can create a new wheat field by clicking on the 'Add new Wheat Field' button, as shown in Figure 115, and fill out the required information (see Figure 116). If the desired producer is not available a new one can be created by clicking on the plus button next to the producer field, and filling out the producer code as shown in Figure 117. Once a new field has been created the user can view all the available fields and edit its information through the edit button, Figure 118.

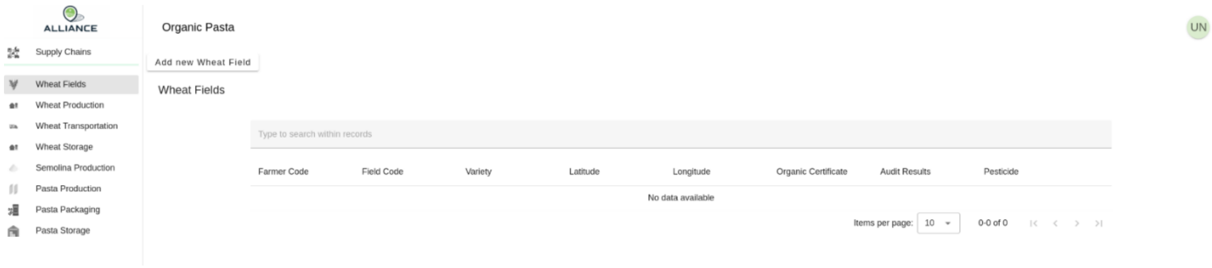


Figure 115: The 'Wheat Fields' view.

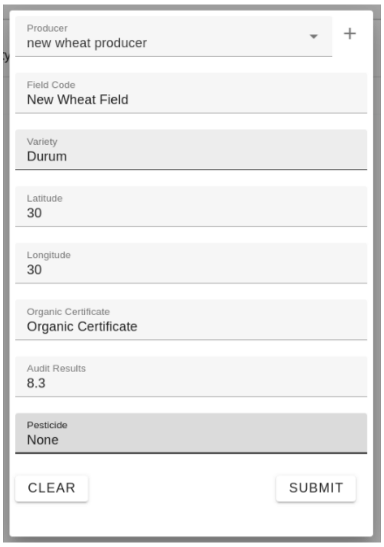


Figure 116: New wheat field form.

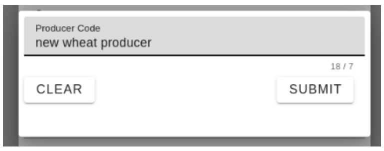


Figure 117: Wheat producer form.

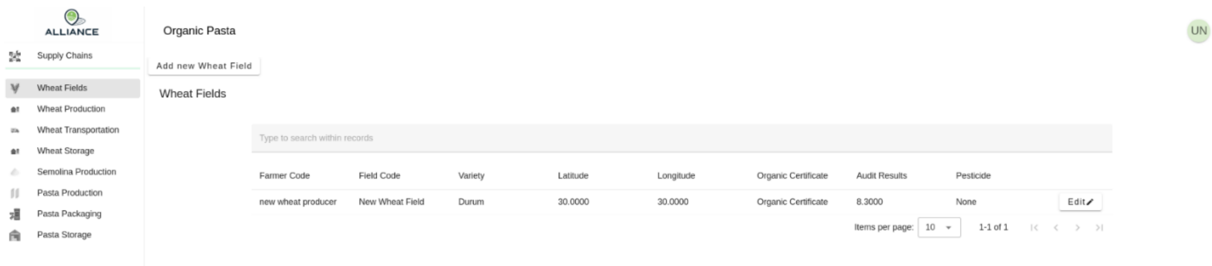


Figure 118: The 'Wheat Fields' view with one new field.

3.7.2. Wheat Production

The next step is the wheat production. The user can submit a new wheat production by clicking on the 'Add new Wheat Production' on the upper left side of the web-app as shown in Figure 119 and fill out the required information as shown in Figure 120. Once the data is submitted the wheat production record is displayed and the user can edit its information through the edit, Figure 121. To proceed to the next step of the supply chain the user should click on the 'Add new Wheat Transportation' button and fill out the required information and filling out the required information as shown in Figure 122. To fill out the total quantity field the user should click on the plus button and select productions, and the quantity of each production, he wishes to transport as shown in Figure 123.

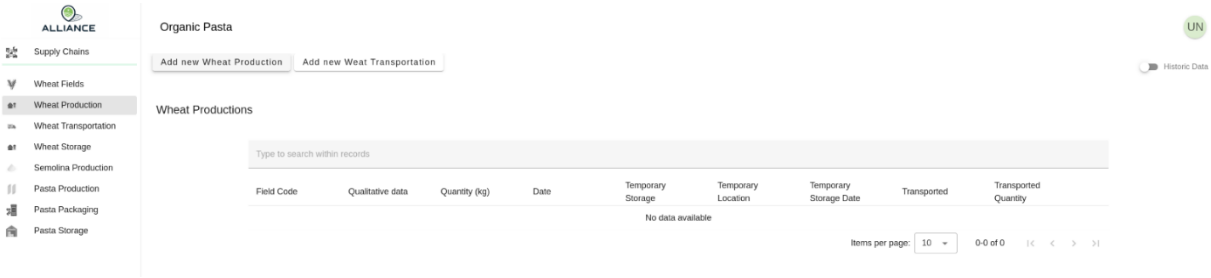


Figure 119: The 'Wheat Production' view.

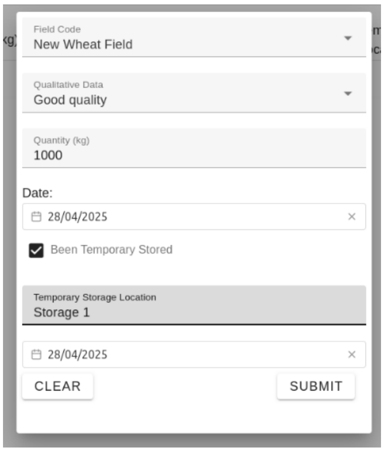


Figure 120: Wheat production form.

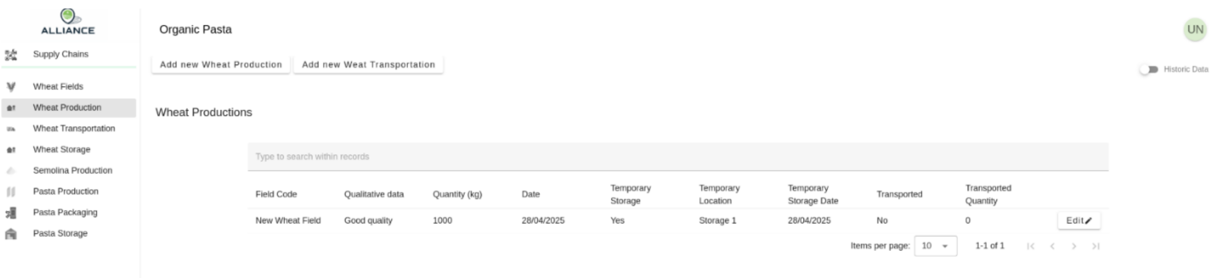


Figure 121: The 'Wheat Production' view with one new production.

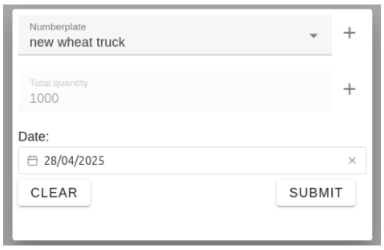


Figure 122: Wheat transport form.

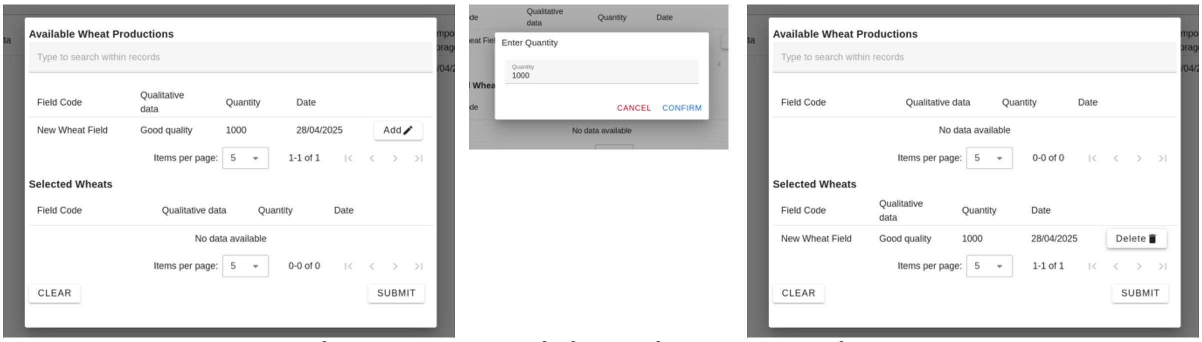


Figure 123: Forms relative to wheat transportation.

3.7.3. Wheat Transportation

In the wheat transportation page, the user can view all the active transportations and conduct quality control, Figure 124, test and receive each transportation, Figure 125, by clicking on the corresponding button available on each record as shown in Figure 126. To proceed to the next stage the received wheat should be stored, and this is done by clicking on the 'Add new Wheat Storage' button on the upper left side of the web-app and filling out the required information as shown in Figure 127. To fill in the total quantity the user must click on the plus button and select the wheat and the quantities he wishes to store (see Figure 128).

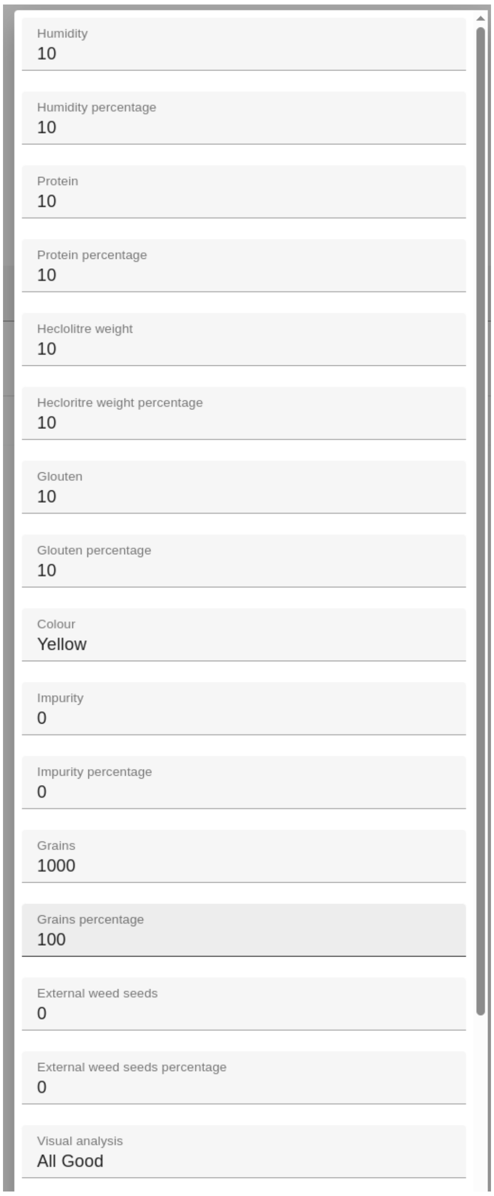


Figure 124: Quality control form for wheat.

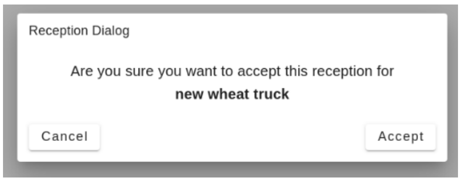


Figure 125: Wheat reception form.

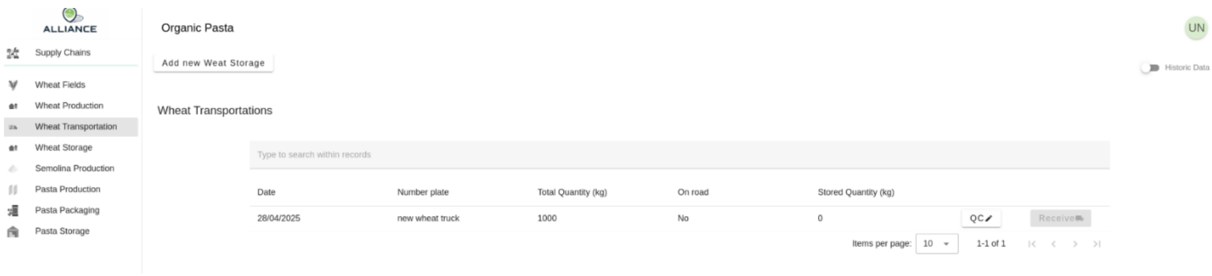


Figure 126: The 'Wheat Transportation' view.

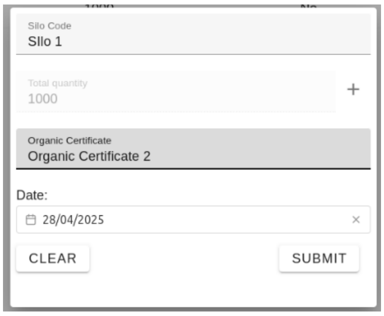


Figure 127: Wheat storage form.

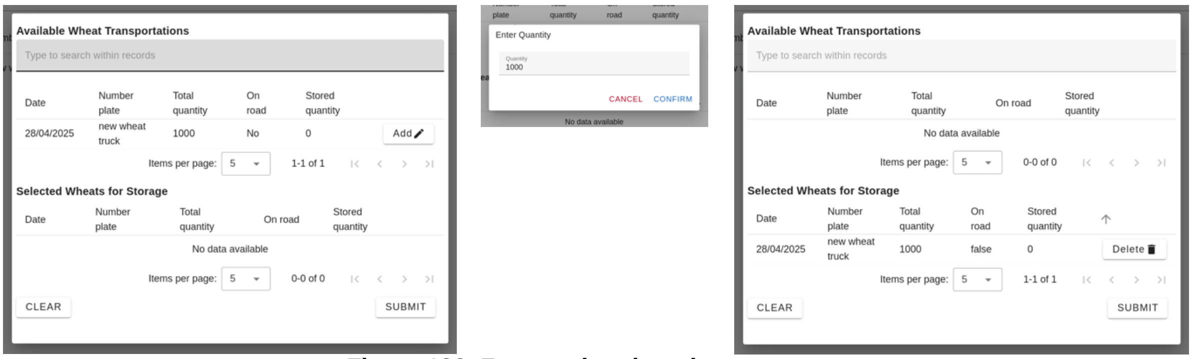


Figure 128: Forms related to wheat storage.

3.7.4. Wheat Storage

On this page the wheat storages are displayed as shown in Figure 129. The user can conduct analysis on the storages by clicking on the corresponding button on each record and fill out the required information as shown in Figure 130. The user can also initiate a new semolina production by clicking on the 'Add new Semolina Production' button (upper left side of the dashboard) and fill out the necessary information as shown in Figure 131. To fill the incoming quantity, the user must click on the plus button and select the wheat storages and quantities for the semolina production, as shown in Figure 132.

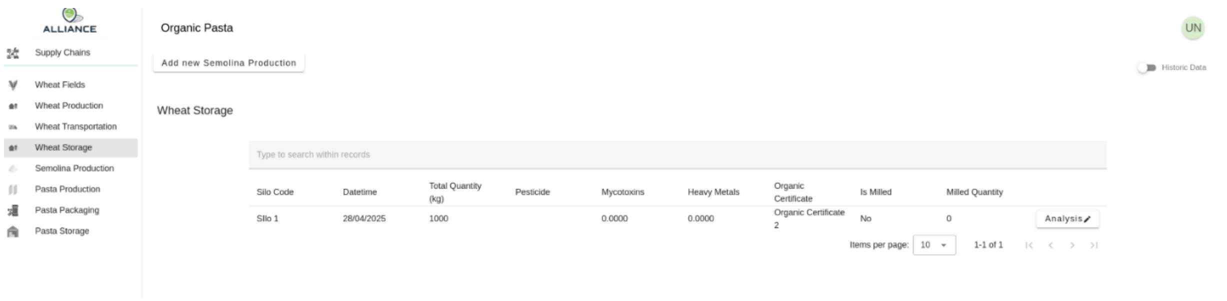


Figure 129: The 'Wheat Storage' view.

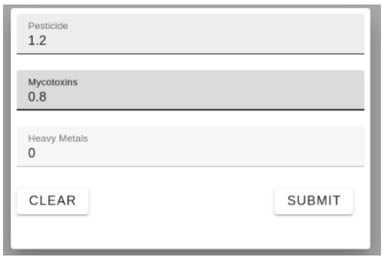


Figure 130: Wheat analysis form.

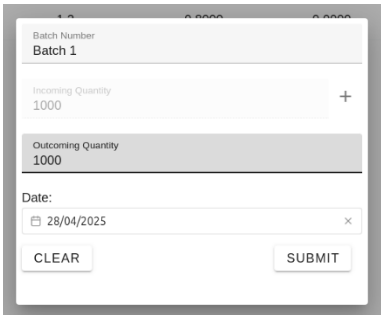


Figure 131: Semolina production form.

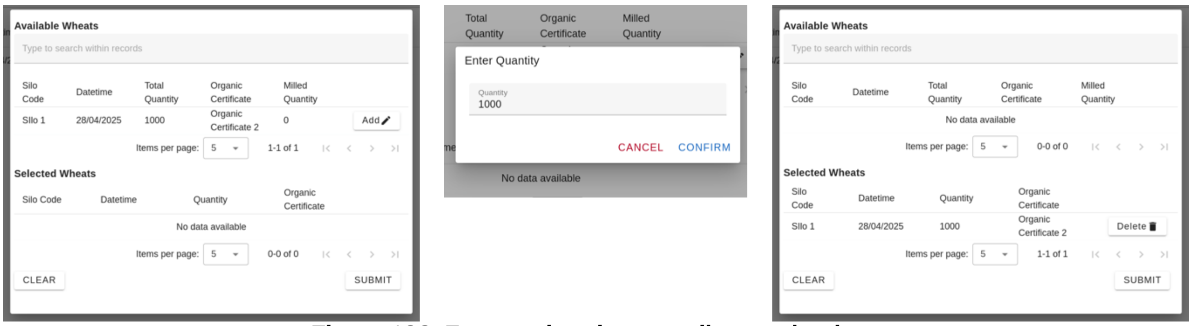


Figure 132: Forms related to semolina production.

3.7.5. Semolina Production

On the upper half of this view the user can be provided with the semolina production that are in the milling stage, as shown in Figure 133, and can conduct analysis on each production by clicking on the 'Semolina Analysis' button and filling out the required information as shown in Figure 134. Once the analysis has been completed the user can transport the semolina to Factory by clicking on the 'Transport' button and choosing the truck that participated in the transportation process as shown in Figure 135. Once a transportation has been initiated, on the lower half of the web-app the user can accept the reception, Figure 136, at the factory by clicking on the ‘Receive’ button and once it has been received conduct analysis on it as shown in Figure 137.

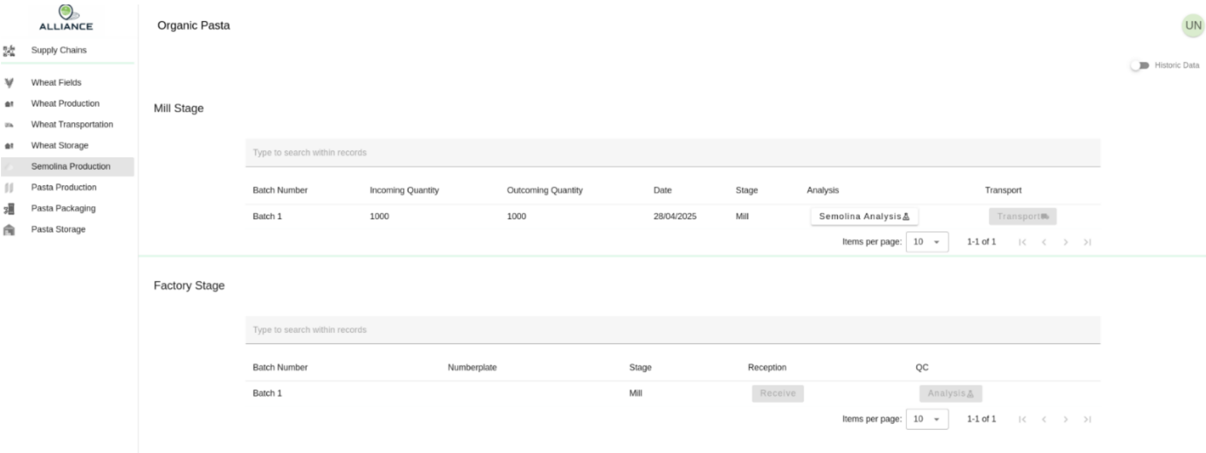


Figure 133: The 'Semolina Production' view.

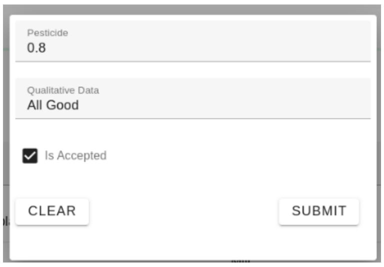


Figure 134: Semolina analysis form at the milling stage.

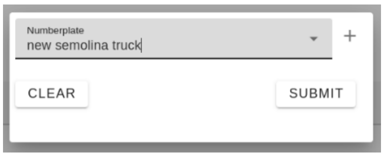


Figure 135: Semolina transportation form.

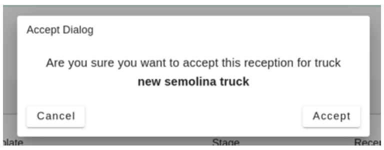


Figure 136: Semolina reception form.

Figure 137: Semolina analysis form at the factory stage.

3.7.6. Pasta Production

On the upper half of the web- app the user can view the semolina productions and create new pasta production form them by clicking on the 'Add Pasta Production' button, Figure 138, and filling out the required information as shown in Figure 139. Once a new pasta production has been created the user can view it on the lower half of the current view as shown in Figure 140.

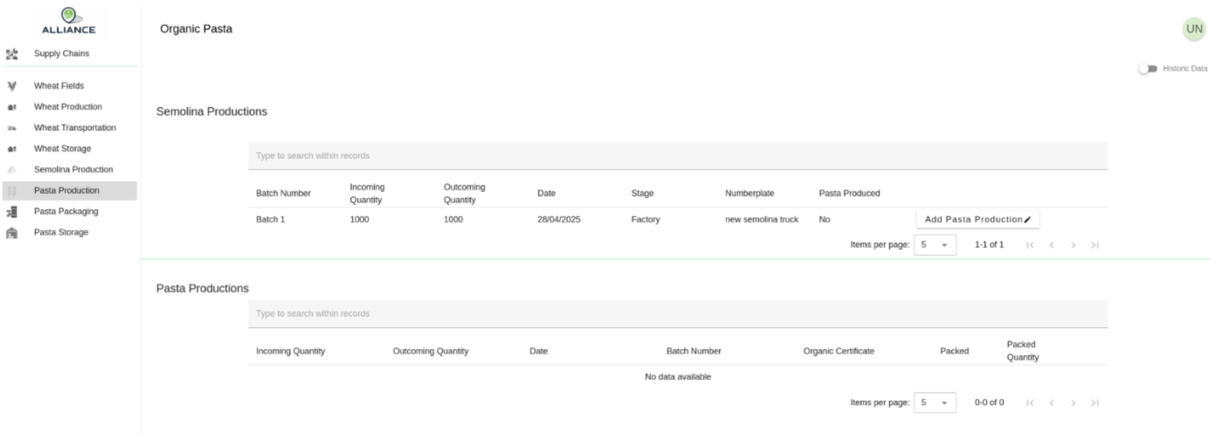


Figure 138: The 'Pasta Production' view.

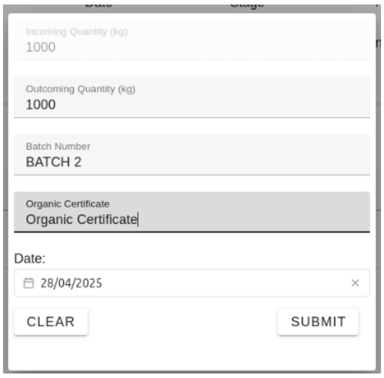


Figure 139: Pasta production form.

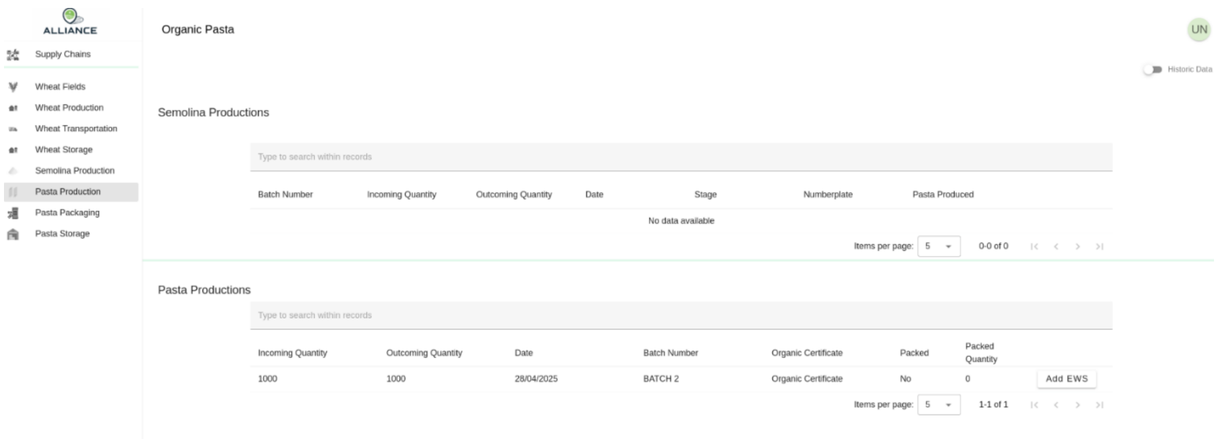


Figure 140: The 'Pasta Production' view with one new production.

3.7.7. Pasta Packaging

On this page the user can package the produced pasta. On the upper half of the web-app the user can pack a pasta production by clicking on the 'Add Pasta Packing' button, Figure 141, and filling out the required information as shown in Figure 142 and once it has been created, it is displayed on the lower half of the dashboard.

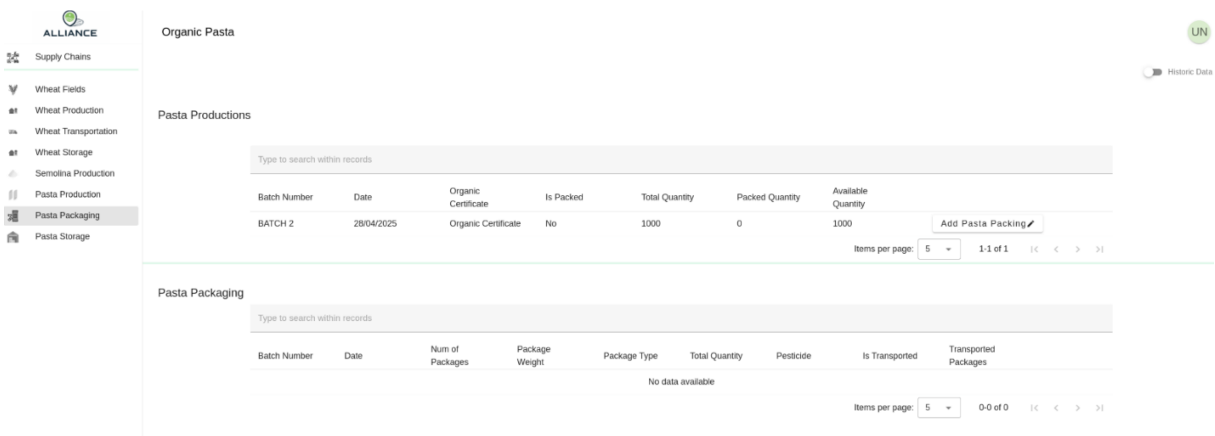


Figure 141: The 'Pasta Packaging' view.

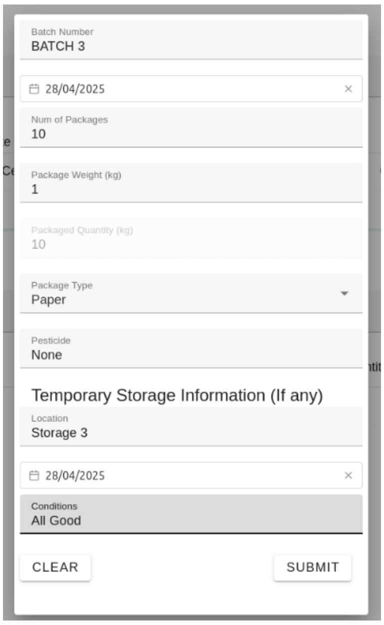


Figure 142: Pasta packaging form.

3.7.8. Pasta Storage

The last step in the supply chain is the storage of packed pasta. On the upper half of the web-app the user can view the packaged pasta available for storage and store them by clicking on the 'Store' button, Figure 143, and fill out the required information as shown in Figure 144. Once a storage record has been created, it is displayed on the lower half of the web-app, Figure 145, and the user can submit analysis results by clicking on the 'Analysis' button and fill out the required information, Figure 146, and/or distribute it to the retailers via the 'Distribute' buttons, and filling out the required information as shown in Figure 147.

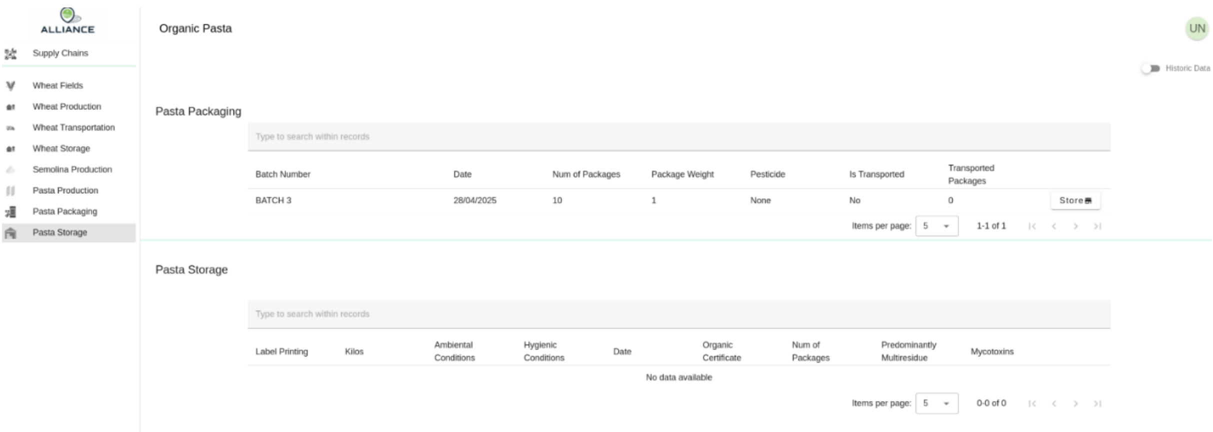


Figure 143: The 'Pasta Storage' view.

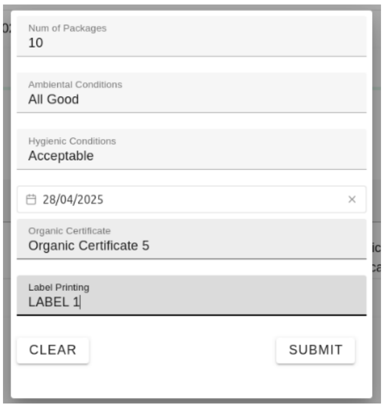


Figure 144: Pasta storage form.

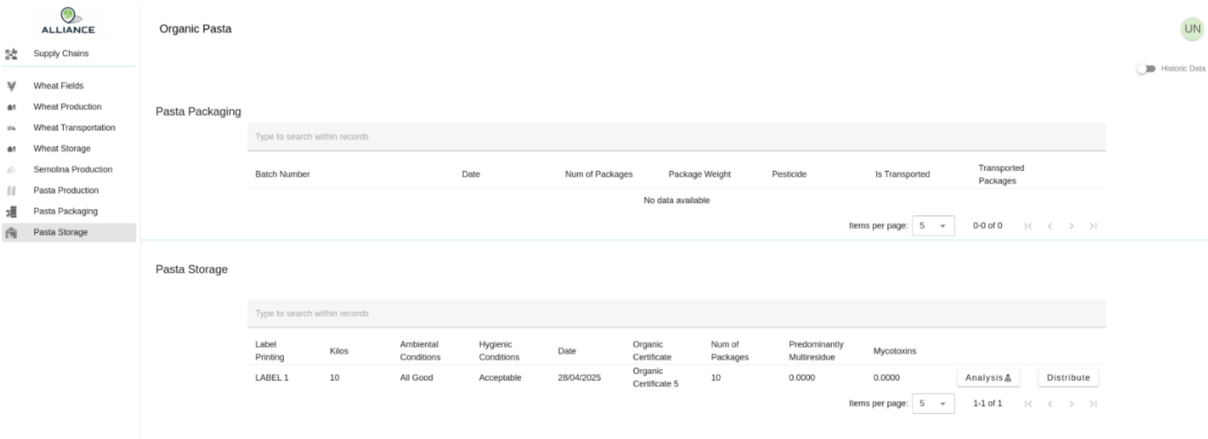


Figure 145: The 'Pasta Storage' view with one new stored package.

Figure 146: Pasta analysis form.

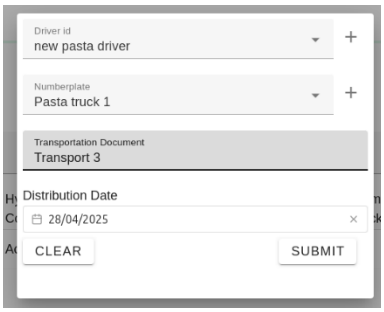


Figure 147: Pasta distribution form.

3.8. Arilje Raspberries FSC

3.8.1. Raspberry Fields

The first page of the Arilje Raspberries dashboard is the Raspberries Fields. The user can view and create new fields by clicking on the 'Add new Raspberry Field' button (top left side of the web-app, Figure 148), and fill out the required information (see Figure 149). If the desired producer is not available, the user can create one by clicking on the plus button next to the producer code field and filling out the producer code field, Figure 150. Once a field has been created, Figure 151, the user can edit its information, submit data regarding the planted varieties, Figure 152, and historic information, Figure 153, by clicking on the corresponding buttons on each field record.

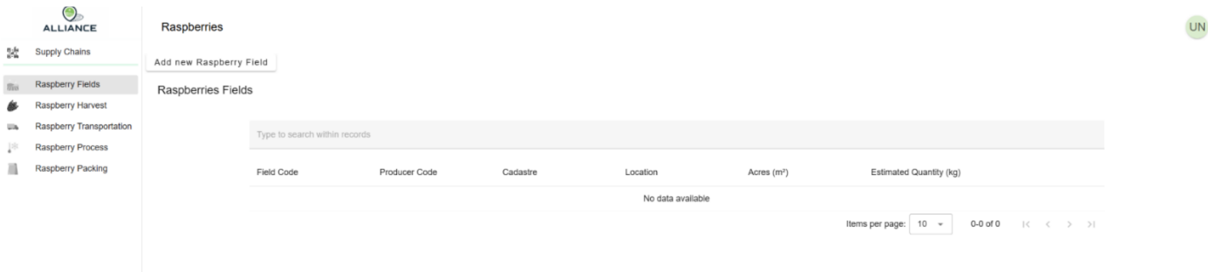


Figure 148: The 'Raspberry Fields' view.

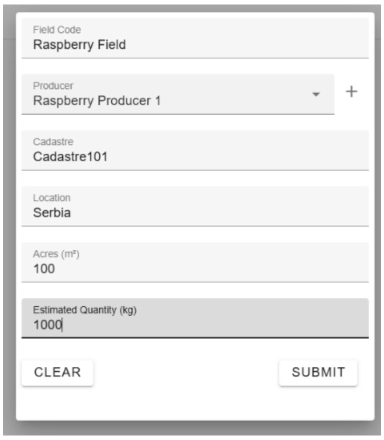


Figure 149: New raspberry field form.

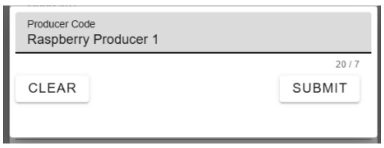


Figure 150: Raspberry producer form.

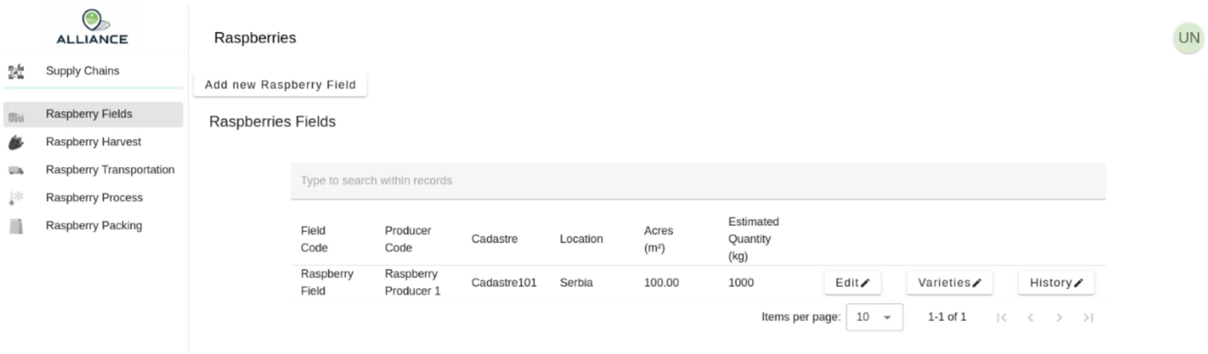


Figure 151: The 'Raspberry Fields' view with new entries.

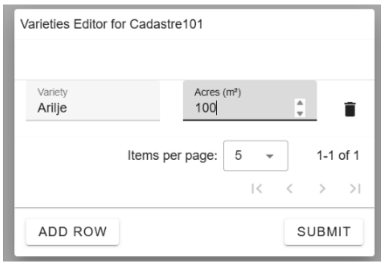


Figure 152: Raspberry varieties form.

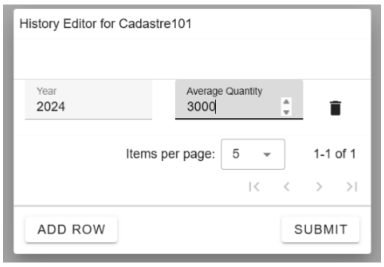


Figure 153: History form for raspberries.

3.8.2. Raspberry Harvest

The next step is the Raspberries Harvesting. The user can view past harvests and create a new one through clicking on the 'Add new Raspberry Harvest' button on the top left side of the web-app, Figure 154, and filling out the required information as shown in Figure 155. Regarding the total quantity the user must click on the plus icon next to the field and fill out information regarding the harvesting days as shown in Figure 156. Once a new harvest record has been created, Figure 157, the user can edit its information and harvest days by clicking on the corresponding buttons. Finally, the user should declare a transportation for this harvest by clicking on the Transportation button and filling out the required information as shown in Figure 158. If the desired numberplate is not available, the user can click on the button next to field and create a new one as shown in Figure 159.

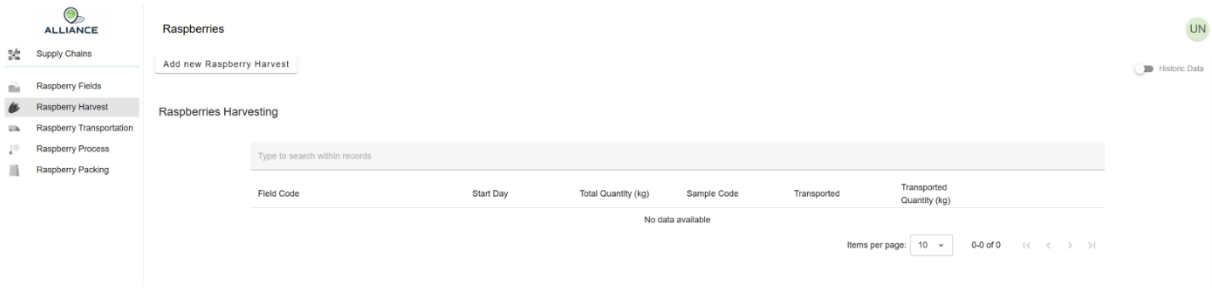


Figure 154: The 'Raspberry Harvest' view.

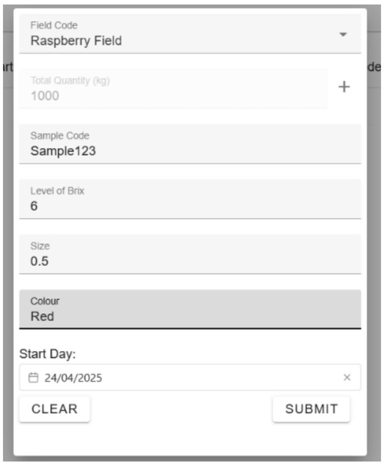


Figure 155: Raspberry harvest form.

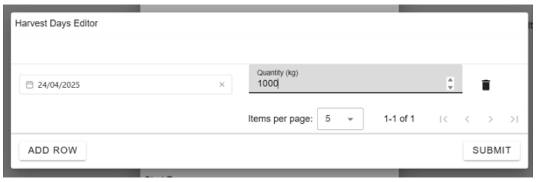


Figure 156: Raspberry harvest days form.

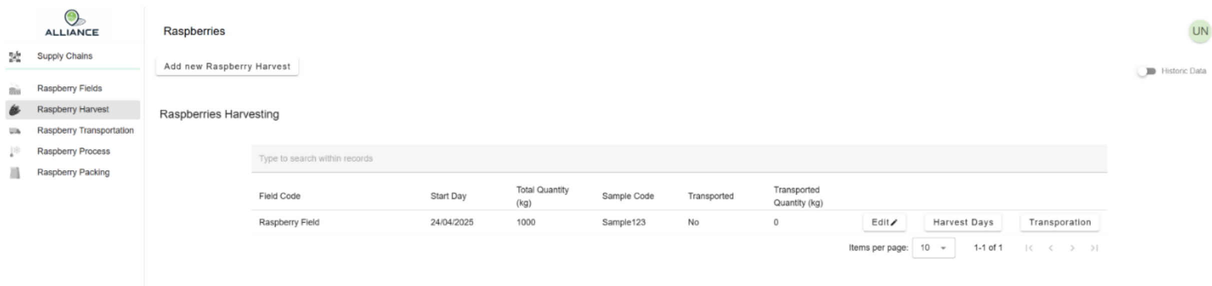


Figure 157: The 'Raspberry Harvest' view with one new harvest.

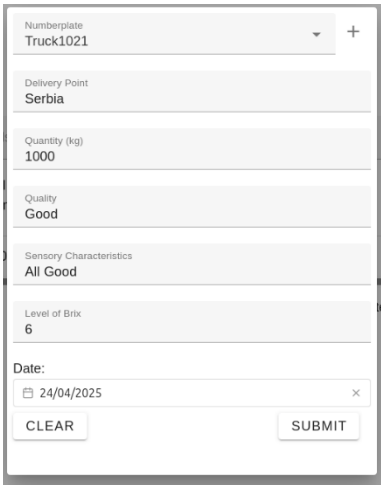


Figure 158: Raspberry transportation form.

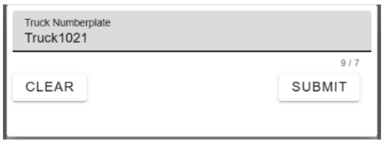


Figure 159: Form for new truck used for raspberry transportation.

3.8.3. Raspberry Transportation

In the Raspberry Transportation view, the user can manage and accept transportation and receptions. On the upper half of the web-app active transportation awaiting acceptance are displayed as shown in Figure 160. The user can accept transportation by clicking on the 'Accept' button available within each transportation record as shown in Figure 161. Once transportation has been accepted the transported products are waiting to be processed and are displayed on the lower half of the web-app, Figure 162. The user can either edit the displayed information or begin the process by clicking on the corresponding buttons. On the process form the user can declare the First- and Second-class quantities and other information shown in Figure 163 and submit the information to proceed to the next stage.

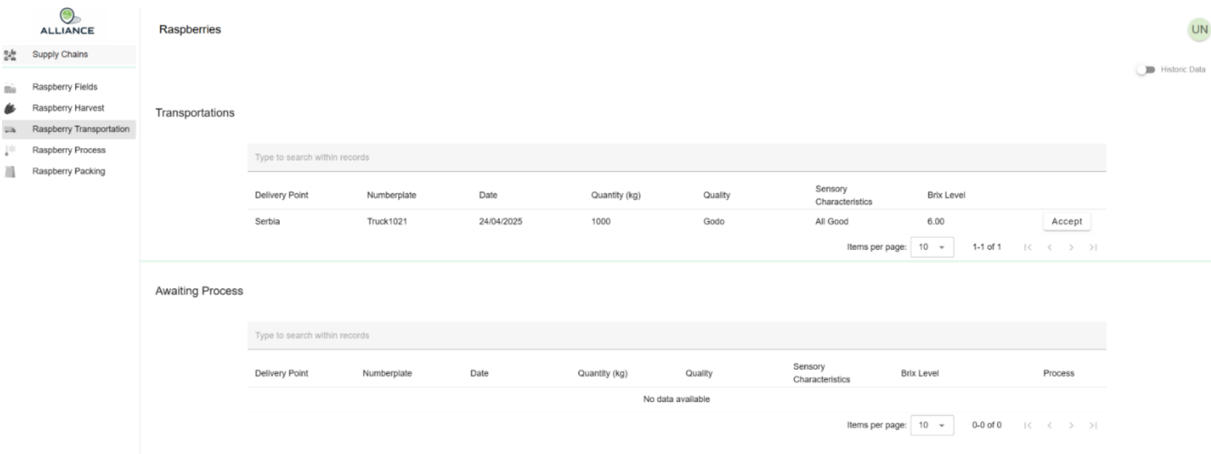


Figure 160: The 'Raspberry Transportation' view.

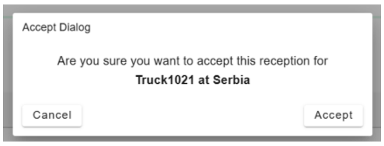


Figure 161: The form for accepting raspberry reception.

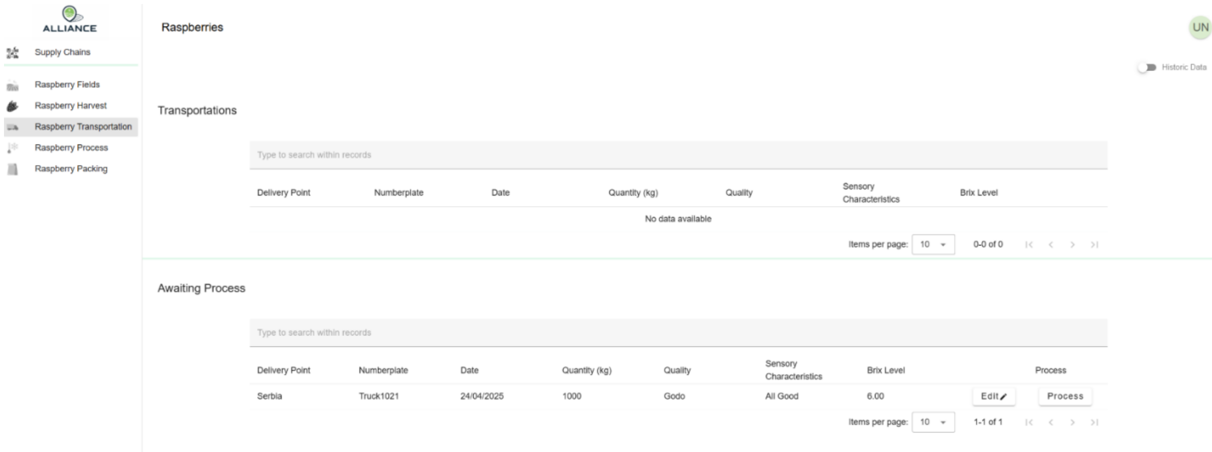


Figure 162: The 'Raspberry Transportation' view with one new reception.

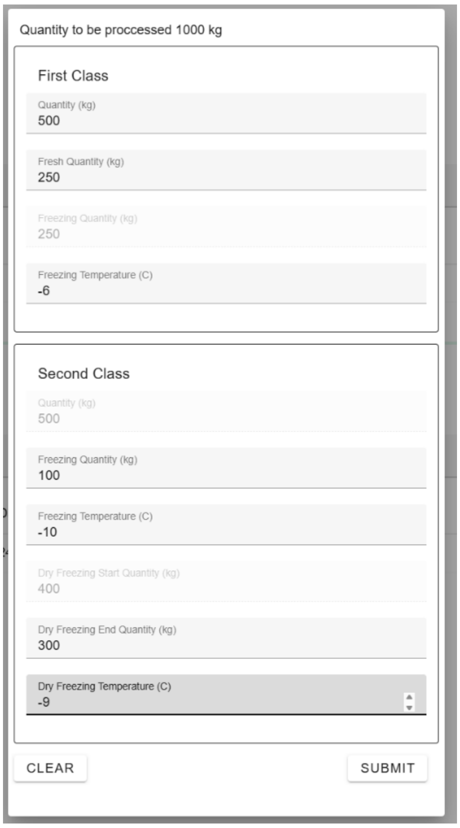


Figure 163: Form for raspberry processing.

3.8.4. Raspberry Process

On the Raspberry Process page, the user can view the processed products declared in the previous stage and proceed to packing by clicking on the corresponding button on each process record Figure 164. It is worth mentioning that if the class is any other than First Class extra fields referring to optional storage displayed but are not required as shown in Figure 165.

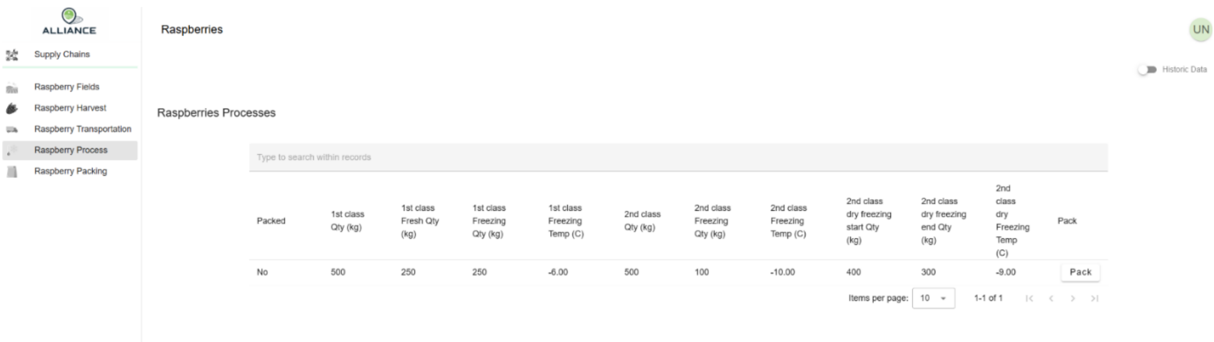


Figure 164: The 'Raspberry Process' view.

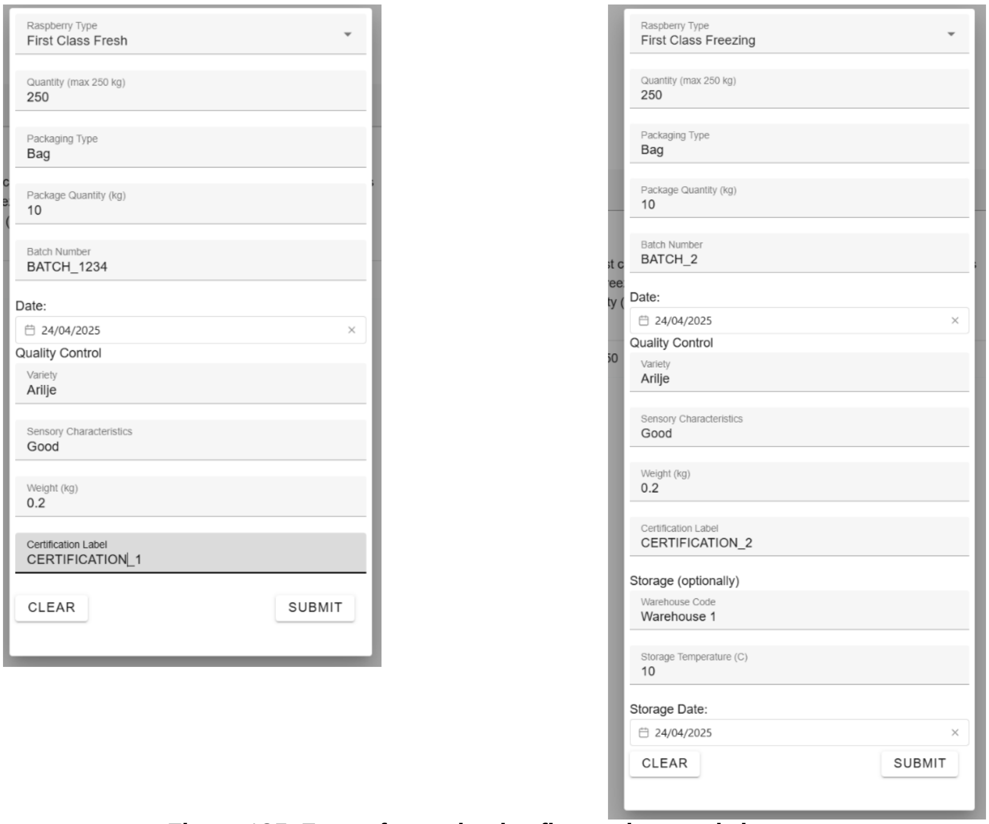


Figure 165: Forms for packaging first and second classes.

3.8.5. Raspberry Packing

On the last page of the Arilje Raspberries supply chain the user can view packing records, Figure 166, and edit the quality control results submitted in the previous step. Also, as already mentioned, if the class of the packaged product is other than First class the user can also edit the storage information as shown in Figure 167.

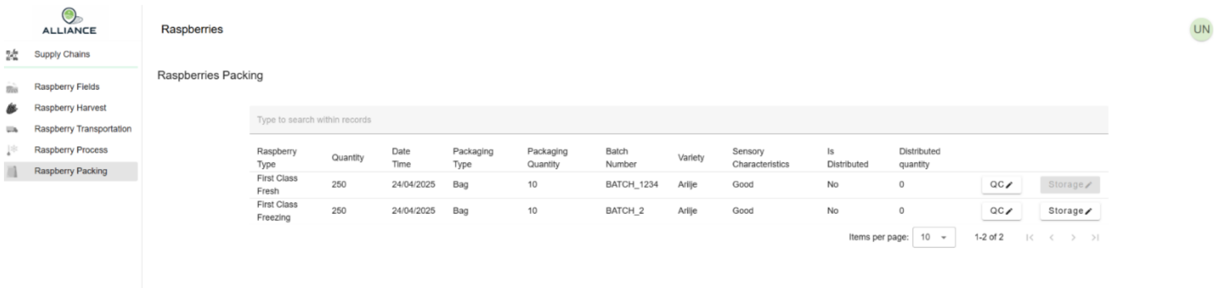


Figure 166: The 'Raspberry Packing' view.

Figure 167: Raspberry storage form.

4. Resilient Food Supply Chains

4.1. Overview

The resilience of FSCs against multiple unintentional threats or food frauds is one of the main goals of ALLIANCE. **Blockchain technology is the main pillar of building resilient FCSs**. Blockchain helps supply chain stakeholders share trusted data through permissioned Blockchain solutions. Businesses and consumers want brands to guarantee product authenticity, while supply chain participants demand responsible sourcing and better visibility to minimize disputes. Blockchain for FSCs help supply chain leaders use data to handle the disruptions and build resiliency. Through distributed ledger technology that provides a shared, single version of the truth, Blockchain applications give permissioned participants greater visibility across all FSC activities and increase its transparency.

4.2. Blockchain Technology

Blockchain is a technology that enables record-keeping in a way that transactions, authentications and interactions are recorded across and verified by a network rather than a single central authority. The Blockchain innovation is that storage does not rely on a central point to collect all data, rather, it enables decentralized operations, allowing all participants to have their own copy of the stored data. The data are primarily generated by the IoT devices and the human users of the developed apps. After the data storage in Blockchain, nobody can tamper with these data.

Blockchain is a technology that records transactions across a network of nodes rather than a single central authority. The consensus of the network validates the transactions, which either add, remove or modify the system data. Transactions marked as invalid by the consensus do not affect the system. The transactions are organized into 'blocks' that are linked to a chronological 'chain'. This chain is initiated with an empty block (genesis block), and as we generate transactions, they are always added to the last block. When the last block gets full of transactions (there is a maximum number of transactions that can be added at one block), the block is run through a hash function that generates its hash number, which then is entered into the new empty block that will be added at the end of the chain, creating a link from the new block to its previous one. In this way, a chain of blocks of transactions is created, hence the name Blockchain. If someone tries to alter a transaction or a block on one node, the corresponding hash will change, and the other nodes will prevent it from happening by comparing the block hashes and detecting the one that differs. This way no single node or minority can alter information within the chain, building data immutability. The following figure, Figure 168, depicts a Blockchain with multiple blocks, each containing more than three transactions. Below each block, apart from the first genesis block, is the hash value and the hash of the previous block.

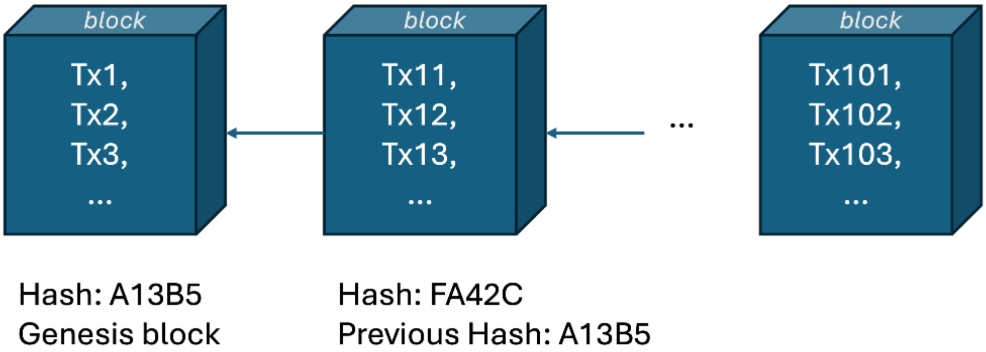


Figure 168: Illustrative representation of chain of blocks or Blockchain

There are two types of Blockchain networks: permissionless and permissioned ones. In ALLIANCE, *permissioned* Blockchain has been used, where multiple organizations come together as a consortium to form the network, and their permissions are determined by a set of policies that are agreed before the network initialization. The network policies can change over time subject to an agreement among the organizations of the consortium. Each organization brings its own components, which are either *clients*, *peers* or *orderers*. The orderers constitute the ordering service, which is the administration point for the network, since it contains the *channel* configuration. The channel is the means of communication used to connect all other components, including peers and clients. The peers are mainly responsible for keeping the Blockchain copies, while the clients are the ones generating transactions.

In ALLIANCE, each company is a different organization in the Blockchain consortium, bringing its own peers, two for each department in the company. Each involved member has a specific role in the FSC, depending on his/her company and department, and uses one of the two corresponding peers (there are two peers for resiliency to failures). The list of organizations is the following:

1. Ordering-Service
2. MASOUTIS
3. MIGROS
4. OLYMPOS
5. IGPFA
6. AGROVELEBIT (Founded in Lovinac-Croatia aiming at agricultural production of Lika potatoes.)
7. Honey Assoc. (Association of honey producers in Occitanie-France.)
8. ALCE NERO
9. CIAUM
10. Arilje raspberry Assoc. (Association of Arilje producers in Serbia, member of ORIGINAL.)

The first organization offers the common ordering service for all FSCs, consisting of three orderers: Orderer1, Orderer2 and Orderer3. The ordering service is configured to support seven channels, one channel for each FSC. Each single channel is used by a specific smart contract (distributed app especially designed for Blockchain networks), which is tailored to the corresponding use case.

The consensus is not implemented through the orderers, but through the peers, which also have the Blockchain copies. Thus, each organization must bring at least one peer that is connected to the channel and participates in the consensus. The ordering service of ALLIANCE is implemented using the Raft algorithm [13].

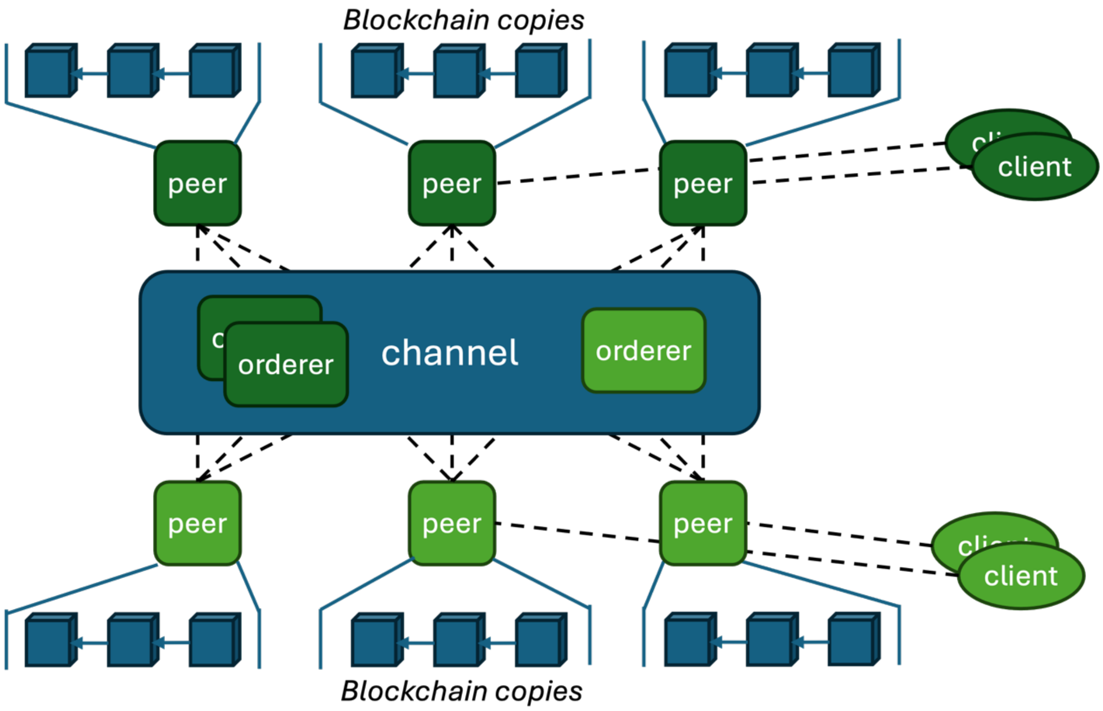


Figure 169: The Blockchain network of ALLIANCE.

The efficiency of the system depends on the transaction flow and its structure. In ALLIANCE, the transaction flow follows the Execution-Ordering-Validation model, since we use the open-source software of HyperLedger Fabric [14] to implement our platform. According to this model, each transaction is:

1. firstly, executed in a subset of peers that must endorse it in order to be later validated,
2. then it is inserted by the orderers in the last block of the chain, and
3. lastly, it is checked by all peers, and if it is validated (endorsed by a sufficient consortium subset), then consensus is achieved, and the transaction is allowed to affect their world state.

A graphical representation of this transaction flow is given in Figure 170. The world state of each peer is one of the multiple replicas of the system data, which is modified only under the effect of the valid transactions included in its Blockchain. It can be illustrated as a set of key-value pairs. In ALLIANCE, each transaction adds or modifies a subset of key-value pairs. The world state is partitioned into multiple 'assets', where each asset is one of the subsets that can be modified by a single transaction.

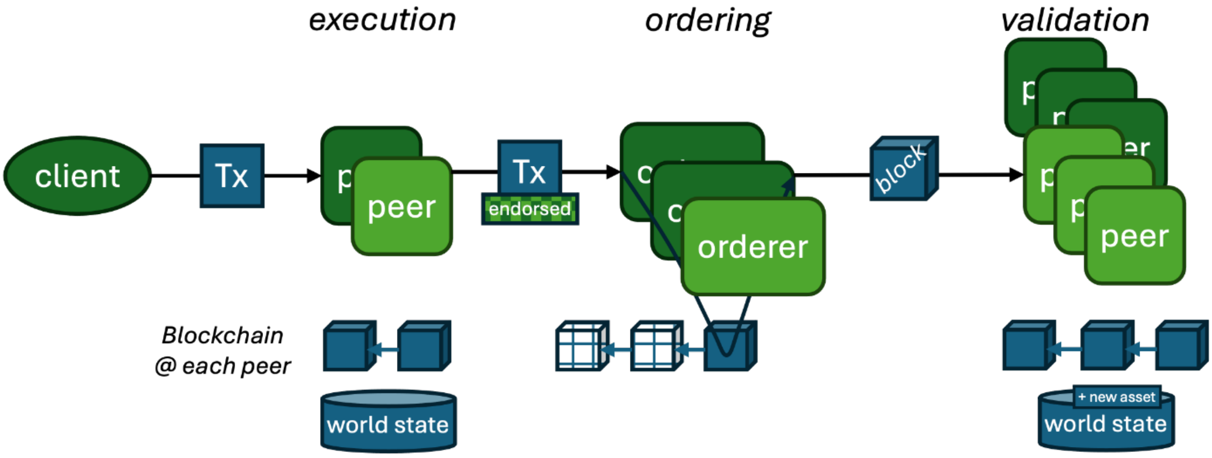


Figure 170: The transaction flow in ALLIANCE

The world state is the actual data storage provided by Blockchain, which is immutable and secure, while Blockchain is offered for versioning and backtracking. The problem is that the world state has some limitations and becomes inefficient for larger datasets. This is why the off-chain data storage design is required, offering solutions to store data efficiently while still leveraging the security benefits of Blockchain.

Blockchain serves as an excellent option for immutable data storage. However, its limits drive the research community to explore more efficient alternatives that integrate Blockchain with traditional data storage, referred to as *off-chain* storage. *On-chain* storage is when storing data directly on Blockchain, which unfortunately becomes inefficient for larger datasets. Off-chain storage involves keeping data outside Blockchain but still linked to it in a secure manner. This approach offers more flexibility, scalability, and efficiency, addressing the cost and speed limitations of on-chain storage. In ALLIANCE, Off-chain storage is facilitated by MongoDB [15].

A previous deliverable D2.3 presents the channels of the 7 FSCs, as well as the organizations involved in each FSC.

5. Conclusion

This deliverable *D2.2 - Final Distributed Ledger Technology for Improved Traceability* concludes the extensive efforts undertaken within WP2 from M06 up to M30. It describes the frontend and the backend system services that implement the Blockchain app for each of the quality-labelled FSC that the projects deal with. Specifically, it offers a comprehensive report and analyses the individual steps of each FSC. The ALLIANCE Blockchain platform successfully integrates distributed ledger technologies to ensure data integrity, enhance transparency across different stakeholders, and verifies the authenticity of certifications and quality labels throughout the supply process. Through secure data exchange protocols and smart contract mechanism, it offers services designed to establish end-to-end traceability from producers to consumers.

The blockchain system implementation exhibits operational maturity that will be demonstrated during the Pilots phase and shows the ALLIANCE Blockchain system's readiness for real-world deployment, offering a scalable and trustworthy digital infrastructure that supports regulatory compliance, strengthens consumer trust, and contributes to the digital transformation of agri-food supply chains The outcome of this deliverable establishes a foundation for the ALLIANCE platform implementation and integration with the other technological components. This will drive the final deployment of the technologies in the respective Pilot-Use Cases according to the demonstration scenarios and will be used for the assessment and evaluation of the pilot demonstrators by the end of ALLIANCE.

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