

BinTraWine - Blockchain, Tracking and Tracing solutions for Wine

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Abstract

Blockchain is a shared, immutable distributed ledger that facilitates the process of recording transactions and tracking assets in a business network. The paper discusses the BinTraWine project, which aims to develop a blockchain-based platform that can offer simultaneous and shared management of information for the wine supply chain. While the blockchain technology has already been widely adopted in the wine sector, most applications have focused on short supply chains that involve a single company. In contrast, the BinTraWine project targets a longer and more complex supply chain that involves multiple operators and structures. The platform aims to ensure transparency, reliability, traceability, verifiability, privacy, and certification of data to all operators involved in the process thus representing a significant opportunity for the digital transformation of the highly competitive agri-food sector.

Keywords

Blockchain, Wine Supply Chain, Industry 4.0, Agri-food Sector

1. Introduction

The introduction of new solutions in the agri-food sector strongly relies on the digitalization and development of information technologies. In particular, the wine sector has shifted its focus towards higher product quality rather than its price. This trend introduced a series of renovations aimed at increasing controls throughout the entire supply chain. However, the systems used for these purposes, such as radio frequency identification, customs checks, and specialized databases, are fragmented and often operate as separate entities. The certification

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of both the product and production process ensures traceability, enabling compliance with current export market standards and meeting customer needs. Redesigning processes is a contemporary difficulty, which blockchain technology can help with, according to [1]. In this paper, we present the BinTraWine project which aims at leveraging blockchain technology to guarantee the *traceability* and *verifiability* of the wine supply chain phases and actors. The data is permanently and immutably recorded, enabling tracking of the wine's journey and monitoring every stage of the process, from grapes production to wine distribution and certification.

A blockchain implementation approach in the wine supply chain could represent a significant innovation in the future, thus progressively replacing the current traceability systems and ensuring data *transparency* at reduced costs [2]. The applications of this technology, born in the financial sector, still have to realize their full potential in the agri-food supply chain [3]. The growing interest in blockchain also stems from the possibility of applying this data control technology in combination with smart tags, i.e. QR codes and RFIDs, IoT sensors, and Big Data, to achieve an even more *reliable* system, ensuring correct circularity and transparency of information. Nevertheless, there have been examples of using blockchain in the wine supply chain [4, 5].

The need to mitigate counterfeiting with *certification* of data and rapidly detect fake products is another driving force behind the wine industry's adoption of digitalization and blockchain technology. These technologies offer effective protection against counterfeit products and are crucial for successful wine marketing. In addition, the wine sector is also characterized by complex supply chain relationships and strong competition of actors where data *privacy* is playing an important role.

Blockchain technology can also be used to enhance marketing and customer loyalty by enabling wineries to share information about their products. This allows consumers to access new product storytelling, with the ability to learn about the wine's history, from the vineyard of origin to the processing, refining bottling, and transport phases. By providing access to this detailed information, consumers can gain a greater understanding of the product and develop a deeper appreciation for the quality of the wine. In addition to the reasons outlined above, the decision to consider a long supply chain for the project has placed a particular focus on the trustless factor. This has led to the selection of Blockchain as the preferred option due to its unique advantage over other technologies, such as RFID or NFC, in terms of data permanence and immutability.

The rest of the paper is structured as follows. Section 2 summarizes the project. Section 3 outlines the objectives and presents the current status of the project. Finally, Section 4 concludes the paper.

2. Summary of the project

BinTraWine is a research project that started in March 2022 and is expected to conclude in September 2023. The project involves various partners, such as Aton and BSD, who serve as the industrial partners, Sapienza Università di Roma as the academic partner, and the association Cyber 4.0. Aton is the project leader, specializing in the development of information and communication technologies (ICT) solutions it is responsible for the proposed solution's

analysis, design, and development. BSD is a consulting firm specializing in Human Factors, Human-Computer Interaction, Interaction Design, and user-centered design solutions. Sapienza Università di Roma, particularly the Research Center of Cyber Intelligence and Information Security (CIS), provides technical and methodological support in devising the IT platform, while Cyber 4.0 uses its know-how to define the functional and architectural requirements and supports the final evaluation of the obtained results.

The project's objective is to leverage blockchain technology to establish a traceability system in the wine supply chain. Adopting such a solution provides companies highly positive opportunities. Indeed, the usage of a blockchain-based solution entails an important economic value for companies since making the entire production and certification chain fully controlled. Such value is fundamental for the satisfaction of end customers who strongly rely on certification warranties such as DOC and BIO. BinTraWine final solution would offer cross-cutting benefits to both agricultural companies that require certification, by guaranteeing bodies, and consumers who trust the validation of the product on the market as certified.

Additionally, the adoption of a distributed ledger in blockchain brings benefits to each individual operator in the complex (long) supply chain. For example, the trust relationship between wine producers and distributors is based on characteristics such as reputation and integrity, which are often difficult to evaluate, and where such an approach could be very useful in their assessment [6]. In addition, improved traceability can allow producers to demonstrate the origin and quality of their product, providing additional value to their brand.

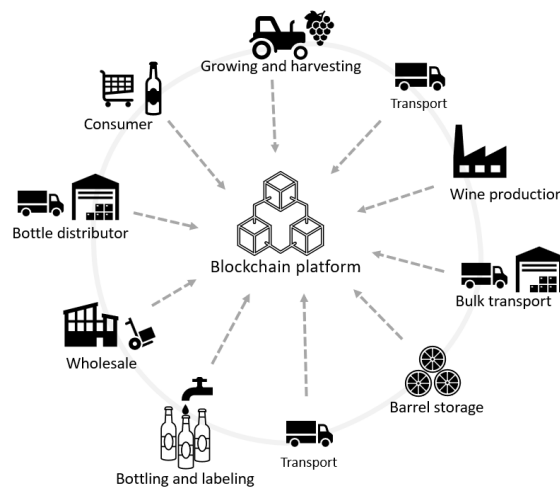


Figure 1: Blockchain-based wine supply chain.

Figure 1 depicts such a complex chain integrated into a blockchain-based environment. Specifically, it involves several main steps which could cover different organizations, i.e., grape growing and harvesting, transfer to the winemaking center for wine production, transportation to the conditioning center, and transfer of the packaged, labeled, and stored product to the distribution center for the sale to customers. The relative operators have a great interest in

adopting a verification system that ensures to avoid of contamination or problems along the entire production process and between the organizations. This is a crucial aspect of compliance with the necessary standards to obtain certification. Indeed, the certification process itself involves distinct phases that require chain control.

3. Objectives and current project results

The project is organized into 5 work packages (WPs). The first WP (WP1) has industrial research objectives, whereas the other four (WP2-WP5) represent prototype development activities. In particular, WP5, representing the validation of the developed prototype, temporally comes at the end of WP2-WP4. In the following, we show how these work packages contribute to the goal of the project.

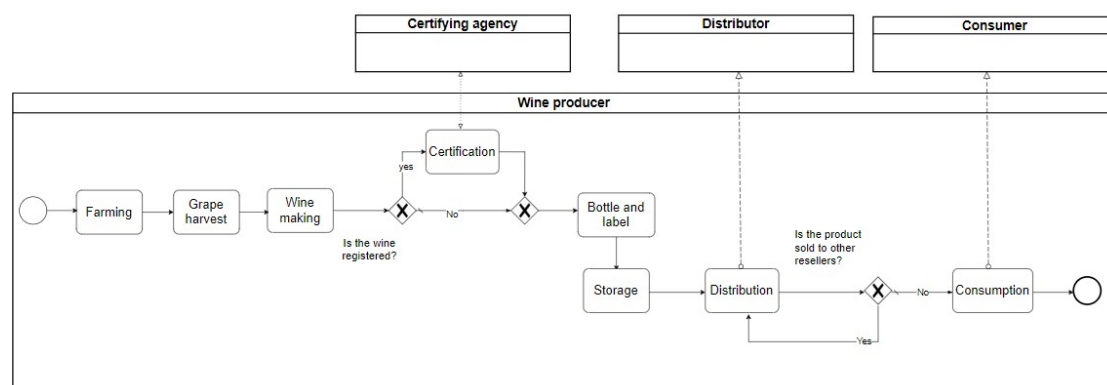


Figure 2: BPMN model of wine supply chain actors.

In the early stages of WP2, the AS-IS production process of the wine supply chain has been identified and analyzed from different perspectives. This analysis aims to define all the involved operators and understand their roles, responsibilities, and interaction.

The process defines the steps that a wine producer must fulfill, starting from planting the grapes, harvesting them, and then transforming them into wine (vinification). If the wine produced requires certification, the producer interacts with the certification agency, which emits the document attesting the certification. Otherwise, the producer proceeds directly to the bottling and labeling phases. Finally, the finished product undergoes a storage step and is distributed to one or more distributors before being consumed by the customer. The customer, certification agency, and distributors are not relevant to this process and are therefore represented by white boxes.

The BPMN [7] model depicted in Figure 2 has been defined following a series of interviews with Caprigliano¹, an Italian company cultivating and making wine from their own grapes. It helped to ensure that the platform meets the needs of all the involved operators and addresses any inefficiencies or bottlenecks in the current production process.

¹<https://www.caprigliano.com/>

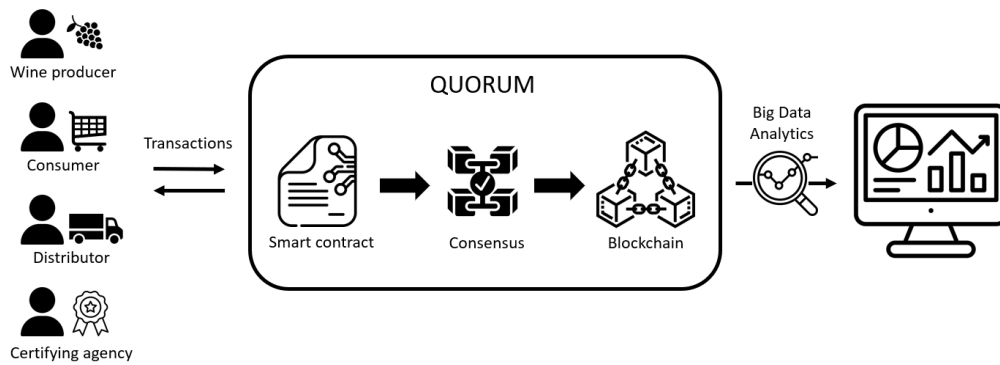


Figure 3: BinTraWine architecture.

Starting from the previous analysis, we derived the BinTraWine architecture that is shown in Figure 3. It illustrates the main technical components that are involved as any identified operator interacts with the entire ecosystem. The design and development of a new platform based on blockchain technology [8] is the goal of WP2. Smart contracts [9, 10] are defined and implemented, which on the one hand provide the guarantee of correctness of the information written on the blockchain, and on the other one implement the business rules relevant to the various stages of the wine supply chain (cf. Figure 2).

The employed blockchain technology has been chosen among three different existing types of blockchain: *permissionless* [11, 10], *permissioned* [12, 13, 14, 15] and *private* [16, 17]. In the context of the BinTraWine project, the aim is to ensure *transparency*, *reliability*, *traceability*, *verifiability*, *privacy*, and *certification* of data for all actors involved in the wine supply chain management process (e.g.: wine producers, distributors, certifying agencies and consumers). Consequently, a permissionless or private solution is not applicable for the purposes of the project for two reasons: (i) a permissionless blockchain does not guarantee *data privacy* between two different operators of the wine supply chain, e.g., obscuring the sale price to a third actor. In a competitive context, where a single wine producer sells his wine to multiple distributors, it may expect a different sale price among different distributors and thus need to obscure that information in the blockchain to a third distributor not involved in the act of sale; (ii) on the other hand, a completely private solution is not good as it would be allowed the supply chain actors participating in the network to change the state of the blockchain, which we do not want as it would compromise its integrity, violating the constraints of *reliability* and *verifiability*.

Conversely, a permissioned solution lends itself well to the purposes of the project since it not only satisfies the constraints of a permissionless solution but at the same time provides data privacy between actors involved with sensitive data management. Specifically, we have chosen Quorum² [15] as the reference permissioned technology, as it is based on Ethereum Virtual Machine (EVM) [10] with smart contracts in Solidity³. Additionally, Solidity is a Turing-complete programming language, which makes Quorum the best candidate for our purposes

²<https://consensys.net/quorum/>

³<https://soliditylang.org/>

among others (i.e., Hyperledger Fabric⁴, R3 Corda⁵, and MultiChain⁶).

WP3 contributes to the goal of the project with the implementation of a Big Data Analytics platform to process data stored within the blockchain. The Big Data Analytics platform integrated into the ecosystem enables the processing of large volumes of data in near real-time employing predictive modeling techniques, thus allowing operators to make informed decisions based on accurate and up-to-date information. Through the use of these advanced data processing technologies, the collected data can be effectively analyzed to generate useful insights, trends, and patterns. Furthermore, the analytics platform is designed to automatically generate reports based on the analyzed data. Its successful implementation will provide significant benefits to the wine supply chain, such as improved visibility, enhanced decision-making capabilities, and increased operational efficiency.

What is still missing is the provision of a unified solution on a cloud infrastructure that can be accessed through the SaaS (Software as a Service) format. This aspect will be tackled in WP4. Finally, the evaluation conducted in WP5 will help to determine the effectiveness of the developed solutions in WP2-WP4 and identify any areas that require further improvement, thus contributing to the continued growth and competitiveness of the overall agri-food sector.

4. Concluding remarks

In this paper, we have introduced the BinTraWine ecosystem, a blockchain-based platform that can offer simultaneous and shared management of information for the wine supply chain integrated with a Big Data Analytics platform for processing large volumes of data in near real-time. The project is in its last phase where important practical challenges have already been identified and tackled. There is still missing an evaluation of the developed solutions that we are going to address in the remaining months.

The first achievement of the project has been the analysis of the wine supply chain from different perspectives to understand the roles, responsibilities, and interactions of all the involved operators. By identifying all the actors involved, the BinTraWine project is able to offer a platform that meets the needs of all operators and addresses any inefficiencies or bottlenecks in the current production process of the wine supply chain.

To ensure *transparency, reliability, traceability, verifiability, privacy* and *certification* of data for all actors involved in the wine supply chain management process, our solution falls within the spectrum of permissioned blockchain technologies. Specifically, we employed Quorum as the candidate permissioned technology based on the EVM with smart contracts in Solidity.

Data stored within the blockchain are processed by the Big Data Analytics platform that employs predictive modeling techniques to extract valuable insights, thus allowing operators to make informed decisions based on accurate and up-to-date information. In conclusion, the design and development of the BinTraWine ecosystem will enable the digital transformation of the agri-food sector providing significant long-term benefits for the wine supply chain.

⁴<https://www.hyperledger.org/use/fabric>

⁵<https://r3.com/products/corda/>

⁶<https://www.multichain.com/>

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