BLOCKCHAIN FOR CERTIFICATION OF LOCAL FOOD PRODUCTS

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Abstract

Purpose:
In Europe, and particularly in France, there is growing interest in short food circuits, particularly local food systems (Augère-Granier, 2016). These systems involve the distribution of food products in a very restricted geographical area (Paciarotti and Torregiani, 2021). This interest is reinforced by new regulations aimed at promoting the consumption of local products to stimulate the local economy and reduce carbon emissions. Large-scale distribution sector is actively engaged in this movement by seeking ways to certify and promote products from these local systems. In this context, our study aims to propose a blockchain-based solution to ensure traceability, real-time monitoring and certification of products from these local food systems.

Methodology
Our study focuses on local food systems, where we recognize the retailer as the sole intermediary between producers and consumers. We impose a maximum distance threshold between these actors to qualify as a local food system (in our case, we assume that it must not exceed 80 km). To guarantee the origin of the product sold in supermarkets and allow traceability and tracking of orders in real time, we have developed a front-end application with two user interfaces: one for producers and retailers, and another for consumers.

On the one hand, our application allows producers and retailers to enter order details and track their progress in real time. When registering, they must provide their SIRET ("Directory Establishment Identification System") numbers and the addresses of their operational sites to calculate the distance between them. This information is crucial to verify if the product comes from a local food system. On the other hand, consumers can scan the QR code present on the product packaging to access its details.

Order data from producers and retailers is automatically stored in a database. To protect against data falsification, we propose securing them with blockchain technology. This technology, recognized for its transparency, traceability and security, has effectively responded to the traceability challenges in agri-food chains. Its integration into our solution improves security and transparency (Sunny *et al.*, 2020).
For this, we have opted for the Ethereum blockchain, a public platform widely adopted by researchers and industrials (Buterin, 2014). A smart contract was developed to automate the anchoring of orders in the blockchain, ensuring that all data from producers to consumers is recorded securely and immutably. After each transaction, the smart contract sends the transaction hash and TX data back to our front-end application, serving as proof of transaction completion in the blockchain for transparency and traceability.

Using a public blockchain platform allows consumers to verify transaction execution by accessing transaction hashes. Additionally, we provide the Application Binary Interface (ABI) generated during smart contract deployment, allowing consumers to verify the accuracy of the data retrieved by our front-end application against the data anchored in the blockchain.

Finding
We have developed a proof of concept (PoC) to certify products from local food systems. This PoC includes a common application for producers, retailers and consumers, with user-friendly interfaces accessible to all. The application is connected to the public Ethereum blockchain and we have implemented a smart contract to securely and immutably store product data. This improves transparency and visibility within our solution.

Originality
Our study stands out for its originality in the field of traceability and certification of products from local food systems through the use of blockchain technology. Although existing scientific literature explores

blockchain-based solutions for traceability in food supply chains (Wang *et al.*, 2019; Bumblauskas *et al.*, 2020; Ferdousi, Gruenbacher and Scoglio, 2020), to our knowledge none have specifically addressed the certification of local food systems using this technology. Additionally, our research reveals that there is limited exploration of traceability using smart contracts, often with insufficient technical details and IT implementation information (Burgess *et al.*, 2022).

Our contribution aims to fill this gap by providing a practical demonstration of how blockchain can certify food products from local food systems. In collaboration with Grandis, a subsidiary of Carrefour, we have developed a concrete application which presents the implementation of our blockchain-based solution in a real context.

Introduction

In recent times, short food supply chains and local markets, where farmers sell their products directly to consumers or with a minimum of intermediaries, have flourished in all European Union (EU) countries. Therefore, since 2014, the EU rural development policy have placed an increased importance to short food supply chains and tried to define them.

According to the research report of the European Parliamentary Research Service of September 2016, there was no common definition of short food supply chains (SFSC) at EU level (Augère-Granier, 2016). A first common European definition is given in (Reg.1305/13), where short supply chain is defined as: “a supply chain involving a limited number of economic operators, committed to cooperation, local economic development, and close geographical and social relations between producers, processors and consumers”. This definition is then complemented by (Reg.807/2014), which stipulates that “Support for the establishment and development of short supply chains ... shall cover only supply chains involving no more than one intermediary between farmer and consumer”. In France, SFSC have been officially defined by the French Ministry of Agriculture as a marketing mode involving either the direct sale of products from the producer to the consumer, or the indirect sale with no more than one intermediary (Augère-Granier, 2016).

Regarding the definition of local SFSC, known also as local food system, it seems to be more complex because the notion of “local” food is subjective and depends on the context (population, accessibility, etc.). However, the term “local” refers usually to the distance between the point of production and the point of sale. That is why, the Joint Research Centre (JRC) 2013 scientific and policy report on short food supply chains and local food systems defines local SFSC as: a food system in which foods are produced, processed and retailed within a defined geographical area' (depending on the sources, within a 20 to 100 km radius approximately).

Producers wishing to participate in local food systems can benefit from various measures jointly financed by the European Agricultural Fund for Rural Development. In France, this mode of distribution is now favored, to the point that a law has been introduced to promote short local supply chain: the EGALIM law (JORF n°0253, 2018). This law requires that meals served in collective restaurants contain at least 80% of products meeting the requirements of short circuits. This is why large-scale distribution sector is more interested in products from this type of channel and seeks to promote and label them on the supermarkets. To do this, it is necessary to have solutions allowing the certification of food products coming from a SFSC, in order to strengthen customer confidence and reassure them about the origin of their products.

This study falls within the project “Blockalchaine”, which represents a collaboration between the University of Le Havre Normandy, the company 2SN, and Grandis, which is a subsidiary of the famous Carrefour supermarket group. This multidisciplinary collaboration between the academy, industry and the distribution sector aims to respond to current challenges in the traceability of food products and to promote more responsible practices in the field of logistics. The aim of this partnership is to develop a solution based on blockchain to make the supply chain more transparent and sustainable by favoring local food system.

The remainder of this paper is structured as follows. Section 2 recalls related research on traceability with blockchain in food supply chains and explains the novelty of our study with respect to the existing literature. Section 3 is devoted to the presentation of the studied supply chain and the description of the proposed approach. The final section draws the conclusions and some suggestions for future research are pointed out.

Related Research

Blockchain technology is known as a Distributed Ledger Technology that provides a single, immutable ledger of transactions across the network, which are time-stamped and stored in “blocks” (Chandra *et al.*, 2019; Taherdoost, 2023). That is because tampering with a block makes it impossible to connect to other blocks. This ensures the integrity and security of the recorded data. Thanks to this immutability aspect, the blockchain is reliable, secure and resistant to hacking attempts.

This technology is increasingly used today in various domains (e.g. healthcare, supply chain and banking) and offers innovative solutions to improve business integration, specially within food supply chains. Its characteristics of transparency, traceability and resistance to falsification make it a valuable tool for solving a multitude of problems encountered in these chains (Li *et al.*, 2023).

The lack of traceability is one of the major problems encountered in food supply chains. According to Awan *et al.*, (2021), the biggest reason for foodborne disease is contamination which is hard to track in the conventional food supply chain. Furthermore, consumers are increasingly wondering about the nature of the food products they purchase and the sources of the product they buy (Hasan *et al.*, 2023). In order to address this issue, an emphasis is put on the blockchain, which could provide a relevant solution and offer significant advantages. Galvez *et al.*, (2018) and Feng *et al.*, (2020) have studied the potential of blockchain in order to ensure the traceability and authenticity of products. According to Dasaklis *et al.*, (2022), blockchain seems to be the most promising technology for offering traceability services in supply chain networks. Indeed, the data exchanged between the different actors in the agri-food chain are recorded in a common register, in an unmodifiable manner thanks to the block security mechanism, which helps to limit fraud (Laforet, 2023).

In (Awan *et al.*, 2021), the authors believe that the combination of IoT with a blockchain system could be interesting to handle the problem of traceability in food supply chain. However, the authors have only focused on issues related to sensor installation and routing rather than the questions about the data that should be registered in the blockchain and the anchoring mechanism. On the other hand, we find that several researchers have focused on the technical aspects of blockchain. They have mainly used smart contracts to address the traceability issues. For instance, the authors in (Ferdousi *et al.*, 2020) have proposed a smart contract based framework for beef traceability. Cocco *et al.*, (2021) have developed a smart contract to ensure the safety, quality and traceability of batches of bread. In addition to their smart contract enabling the traceability of products, the authors in (Wang *et al.*, 2019) have proposed an event response mechanism in order to verify the identities of both parties of a transaction in the blockchain.

It is worth to note that there exist other traceability approaches, which cover various food products such as eggs, fish, wheat, cereals and dairy products (Bumblauskas *et al.*, 2020; Sunny *et al.*, 2020; Cocco *et al.*, 2021). However, despite this large number of studies and based on the authors' findings in (Dasaklis *et al.*, 2022), it remains uncommon to find publications offering a detailed analysis of the technical aspects of their blockchain solutions.

Despite the significant number of studies on traceability with blockchain in food supply chains, it should be noted that we identified only one article using the blockchain technology for SFSC. In (Burgess *et al.*, 2022), the authors highlight the lack of research on this topic and propose a blockchain-based architecture for quality management in SFSC. However, their study remains theoretical and does not delve into the practical implementation of the proposed architecture. For example, the authors did not discuss which specific blockchain platform to use. Although they mentioned smart contracts, no details or specifications were provided on the structure of these contracts or the interaction between the different components of their proposed framework. Furthermore, the authors have focused on SFSC in general, without addressing the specific requirements of local food systems, mainly the proximity aspect, that requires verifying the distance between producers and consumers and certifying the origin of the product. In our study, we propose to solve this problem through a solution based on blockchain. While the scientific literature already proposes blockchain-based solutions for traceability in food supply chains, to our knowledge, none have specifically addressed the certification of local food system using this technology. In addition, our research reveals that work on traceability using smart contracts is infrequent and often lacks details on the technical aspects and IT implementation.

Blockchain Solution for Certifying Local Food Systems

In this section, we present a practical demonstration with a proof of concept (PoC) of the use of blockchain for the certification of food products from local food system. In collaboration with Grandis, a Carrefour subsidiary, we have developed a concrete application which illustrates the application of our blockchain-based-solution in a real context.

Presentation of the studied supply chain

As depicted in figure 1, we focus on local food systems with a single intermediary between the producer/supplier and consumer, which is the retailer, in our particular case, it is the supermarket. We consider that the distance between these stakeholders shouldn’t exceed 80km (Paciarotti and Torregiani, 2021).

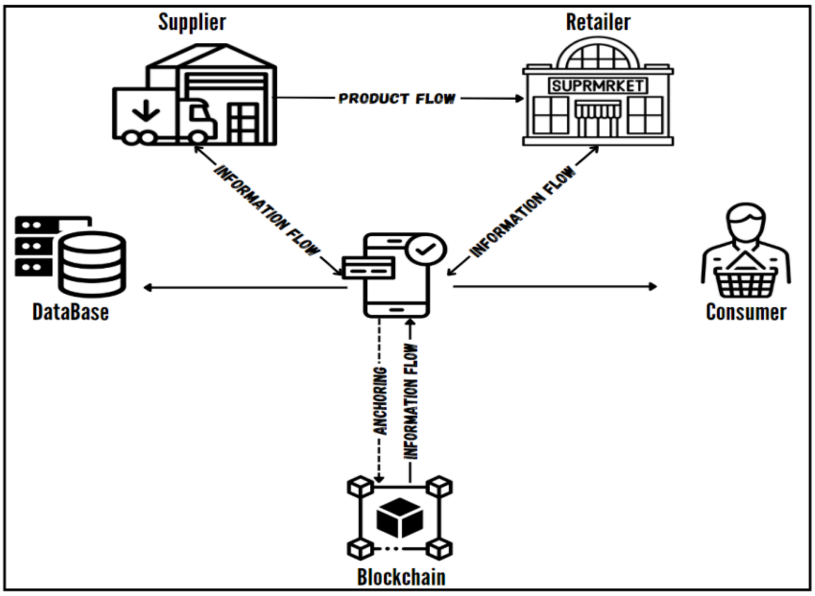

Figure 1: Overview on the Blockchain solution.

Product flow moves directly from suppliers to retailers. However, we have different types of information flow that passes through the mobile application implemented to track orders status in real time. It is to note that this application serves as a common tool between our stakeholders and helps to guarantee traceability and real-time visibility of orders. We have developed two user interfaces: the first one is dedicated to producers and retailers, while the second is intended for consumers.

On one side, our application allows suppliers and retailers to enter order related information and track its progress in real time. On the other side, it offers consumers the possibility to access details about the product they want to purchase by scanning the QR code found on the product's packaging. It is important to note that, during registration, suppliers and retailers must provide their SIRET numbers and the addresses of their operational sites to calculate the distance between them. The SIRET number is unique to each site, and any change in address requires a new SIRET number. This information is essential to accurately identify the company and, more importantly, to determine the distance between the supplier and the supermarket, ensuring the product originates from a local food system.

Blockchain-based solution

The data collected about orders from suppliers and retailers is automatically saved in an external database. However, in order to prevent any alteration or manipulation of this data, we propose to secure it using blockchain technology, which is recognized for its transparency, traceability and security (Wang *et al.*, 2019). In addition, blockchain has been widely used to resolve traceability problems in agri-food chains. That is why, we have opted for the Ethereum blockchain, a permissionless public platform widely adopted by researchers and industrials. This allows our stakeholders, namely suppliers and retailers, to create a node through our mobile app and join the network, as well as access the data stored within it. This is part of our transparency strategy towards consumers. Our platform enables suppliers and retailers to provide product information via the mobile app. This data can then be verified by consulting the public Ethereum blockchain to retrieve all relevant product details and the transaction hash that confirms its anchoring in the blockchain.

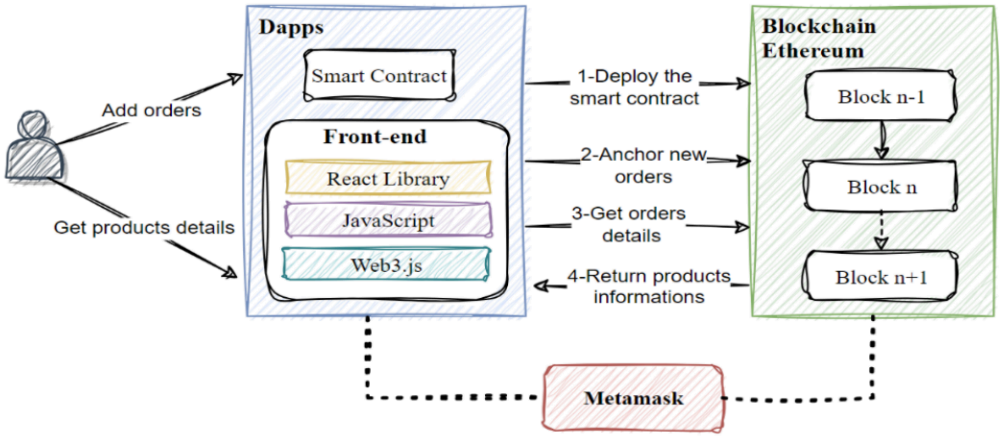

Figure 2: Architecture of the blockchain-based solution.

Figure 2 depicts the interactions among the different components of our PoC, as well as the steps involved in order registration and blockchain querying. A smart contract, written in Ethereum's Solidity language, was developed to automate the registration and anchoring of orders in the blockchain. It consists of a set of data structures designed to record the details of the orders submitted.

Thus, the data collected about the origin of the product and the addresses of the supplier and retailer is recorded securely and immutably in the blockchain (cf. Figure 3). After each order anchor transaction, the smart contract returns the hash and TX Data of the transaction/block to our mobile application. This data is then recorded in the database and serves as proof of the completion of transactions in the blockchain, ensuring transparency and traceability for consumers.

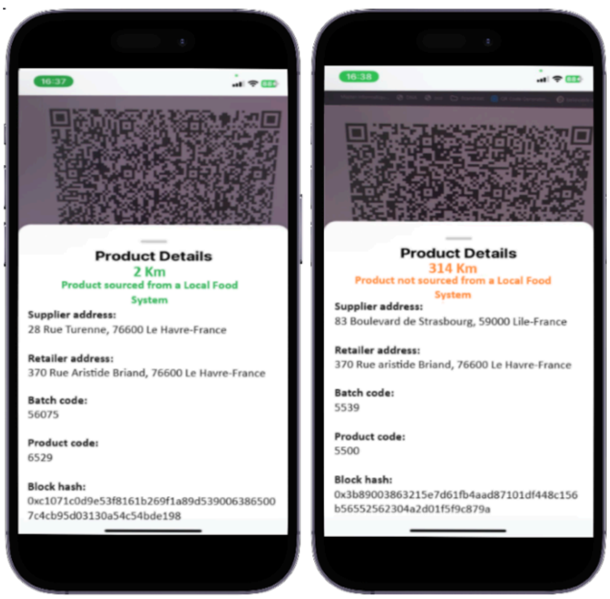

Figure 3: Examples of blockchain query results when consumers scan products' QR codes.

Since we use a public blockchain platform, the consumer has the possibility to copy the hash of the transaction to verify its execution directly on the Ethereum blockchain via Etherscan[1]. In addition, we provide the ABI generated during the deployment of the smart contract, thus allowing the consumer to verify the accuracy of the data retrieved by our mobile application by comparing with those anchored in the blockchain. This is can be done transparently thanks to decoder libraries[2], which are popular open-source libraries developed by the Ethereum developer community and that provide Ethereum input data decoder functionality.

Conclusions and Perspectives

We have addressed, in this study, the problem of certification of products coming from local food systems. For that, we have developed a PoC that includes a common application for suppliers, retailers and consumers, but with different friendly user interfaces This application, which enables real-time tracking of order processing, is also integrated with the public Ethereum blockchain. This is achieved through a smart contract that automates the process of recording order details in the blockchain. This process enables the secure and immutable storage of product data, thereby providing more transparency and visibility to our solution.

The blockchain-based solution proposed in this study is designed for certifying local food systems. However, it can be easily adapted to handle other certification needs, such as halal or organic/bio food products. The key adaptation lies in the type of information recorded on the blockchain. For instance, halal certification would require specific criteria related to religious guidelines, while organic certification would involve criteria related to agricultural practices.

However, it's crucial to optimize the amount of information recorded in the blockchain because it directly impacts transaction costs. Therefore, studying the costs associated with blockchain implementation is essential for understanding both the economic and environmental implications. A future research could explore how blockchain technology affects costs and sustainability, and propose optimization strategies to mitigate these impacts.

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