An Information System to Track data and processes for food quality and bacterial pathologies prevention

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Abstract. Agricultural related products need to be tracked and treated to guarantee food quality as well as to minimize bacterial diffusion from production to human use. The main problem is related to the lack of tracking about provenance and detailed information about different aspects as, for example, environmental conditions and production sites, groundwater contamination, animal life quality and nutrition. For instance, tracking food process may help in identifying the contamination of lettuce production with escherichia coli bacteria. A controlled tracking mechanism in food supply chain ensures the wellness of citizens. Blockchain has been recently interested as technology to track production in each transaction of food process (e.g. in food origins and nutrition quality certification).

In this paper we present an information system able to model, monitor and track the entire food supply chain for farmland production which includes also milk production. The proposed framework is able to monitor agricultural areas where high quality land products (such as fruit and vegetables) and animal based foods (such as milk, cheese or meat) are produced, packed and then distributed. Moreover, the system provides different services, from land quality monitor to fruits check and milk control, by inserting and accessing useful information that allow the traceability of products. As future works, blockchain technology applied in the food supply chain could also be introduced to support the traceability process.

Keywords: Traceability · Information system · Food quality.

1 Introduction

The agricultural production has been integrated and improved to answer the always increasing requests from the market [1]. Globalization imposes that all simple rules related to natural time intervals have to be considered for agricultural production. Moreover, natural life cycle products in animal farms (e.g. excrements, dirty waters) need to be monitored due to the high pressure in land exploitation, and thus the arise of possible assimilation issues for the ground, which can lead to bacteria transmitted to agriculture products and thus to human. Geographical distribution, farm positions and logistics, i.e. distribution among animals (e.g., cows and pigs), with respect to plants land positioning have to be considered. The correlation among food productions and human potential diseases risk can be mapped by means of geographical information systems relating infections and disease cases obtained by clinical studies [2]. Moreover, rapid reconstruction of vegetables and fruits production, fresh milk nutrition characteristics as well as food provenance have been more and more required by consumers as well as by nutritionists.

Food traceability is the process of tracking any type of food through all phases of production, processing and distribution [3, 4]. Each step in the food chain needs to be tracked from raw materials (e.g., feed, livestock food, ingredients) to the final product up to the consumer. This is made by marking the documentation concerning the different processes in order to monitor the food safety of the citizen.

Modern foods need to be manipulated, processed and stored properly in order to guarantee low pathogens and security for a population-wide consumption. Nonetheless, the number of processing steps and their operational parameters have to be constantly checked and maintained to low threshold levels. In this way, the whole food process is a guarantee of safety and quality of produced food. In case of any issue, such as the recent USA case of Lettuce related Salmonella [5], it is mandatory to reconstruct the food generation process and distribution to gather the fail production issues. Recent salmonella events in USA were related to the production tainted lettuce that sickened more than 200 people in 36 states. In this case, one of the main relevant problem is the lack of limitation of zoonotic pressure (i.e., the impact of livestock on the environment pollution) on landfill. This can be avoided sampling lands, water sources and production by means of geographic database systems [6]. Data population during the farm production phases as well as the biological controls on farm production are related to managers as well as healthy related specialists that are in charge of monitoring production to control safe productions. Latter are generally demanded to government structures.

Different traceability tools are available [7, 9] to track products, but they do not support both food nutrition and control as well as do not guarantee or certificate safe and secure transactions. More recently, some initiatives and projects on the use of blockchain technology in food traceability have been proposed (see [8]). Nevertheless, they do not integrate functionalities for food traceability, nutrition, genetic analysis and production analytics. For instance, fresh milk requires safety procedures for quality maintaining (e.g., temperature and containment controls) as well as information enrichment by means of proteomics and genomics information.

To overcome these limitations and to support the farm production process, in this paper we propose a framework able to track information about: (i) agricultural production process tracking providing for biological controls on farmland related products, and (ii) data source tracking aiming to track milk, fruits and vegetables from their production processes in the supply chain, supporting storage and manipulation of their organoleptic and nutritional properties. The framework manages the recall of non-compliant products from the market, protecting consumers from flaws in the production process. The proposed framework represents a relevant mechanism able to support: (i) single farm (e.g. to reconstruct production phases in case of quality problems), (ii) food operators team (e.g., to prevent bacterial contamination), (iii) consumers (e.g. to track food provenience and gather nutritional as well as energy related characteristics).

The proposed framework has been used in a research project that involves the University of Catanzaro, with a heterogeneous research team composed by engineers, veterinarians, clinicians and nutritionists as well as an IT company and a farm operating in fresh milk and vegetables production, latter European-wide distributed. Preliminary results of this system have been presented in [10]. The paper presents the framework structure and samples of use case applications; finally, blockchain related solutions have been studying to be included in the framework to guarantee safe and reliable transactions in food productions.

2 The framework for farm production tracking

We report the design and implementation of the framework with particular reference to the farmland side.

2.1 Land control monitoring

We designed the proposed system, called SMAT (Sistema di Monitoraggio Ambientale e Territoriale, that means Environmental and Territorial Monitoring System), as a web-based one developed using the Grails framework and implemented to track the analysis and production phases. First results of this system have been previously published in [11].

In Figure 1 we report the data scheme supporting the analysis phases. Each farm, represented by the Company entity, is associated with a number of Assets (which can be of various types, e.g., vegetables, crops, waters, milk). Each Asset is in relationship with Samples, acquired during an analysis procedure. Figure 2 reports some screenshots about the SMAT subsystem which integrates functionalities for the asset analyses. Figure 2(a) reports the web client view of SMAT home page and Figure 2(b) shows an example of Asset creation. Moreover, Figure 2(c) and Figure 2(d) illustrate two types of analysis and biological tests for single sample viewing the bioanalytes dataset.

The analysis is useful to map and control, for instance, the use of water sources in production. Contaminated water sources affect crop production when

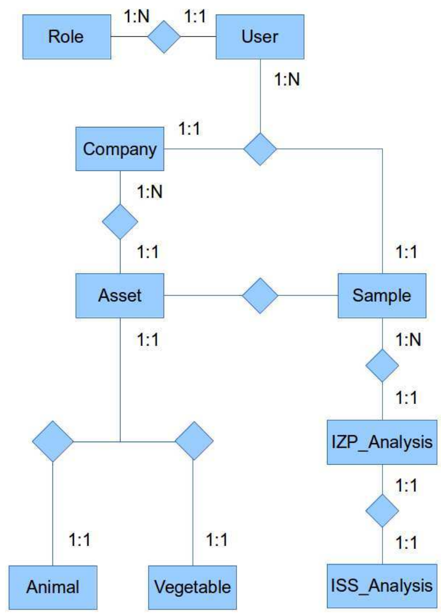


Fig. 1. Conceptual data scheme for the analysis phases.

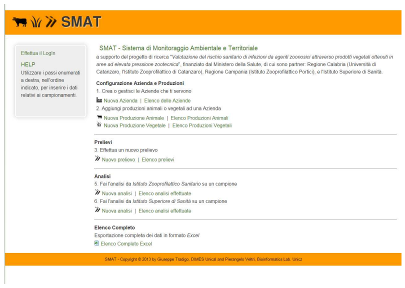
contaminated water is used with pesticides or herbicides, crop irrigation or washing in post-harvest operations. Similarly, animals may close the cycle need to drink water free from contamination because pathogenic agents can rapidly reach the animal nutritions and then food related productions.

The system is also able to provide geographical modules able to relate productions as well as environmental data associated with indexes reported for instance from different data sources. E.g., in Figure 3 we report analysis of mapping geographically related farm with water source potential pollutions. The land related with water source pollution event (e.g. river) are related to farm that use potentially water pumped from soil. The map shows a part of Calabria (an Italian region) and the green circles indicates the risk area with highest contamination risk related to rivers.

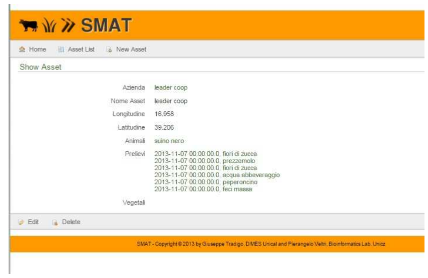
2.2 Production process tracking

We here report the infrastructure related to the production processes and its traceability. The general overview of the traceability processes management system for milk, fruit and vegetables is showed in Figure 4.

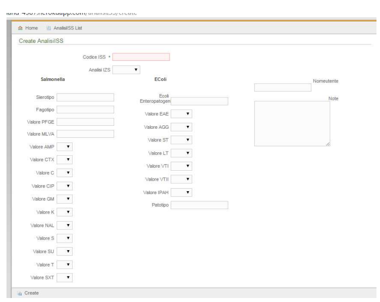
We report about two cases. One refers to fruits and vegetables and the other is related to fresh milk. Elements of the traceability process are related to identification of the logistic units (i.e. aggregation of products for delivery) and batches (i.e. aggregation of a certain amount of product) involved in the production pro-



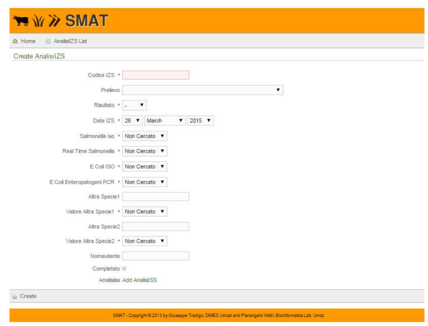
(a) SMAT home page.



(b) SMAT asset creation.



(c) SMAT ISS analysis.



(d) SMAT IZS analsysis.

Fig. 2. SMAT web interfaces.

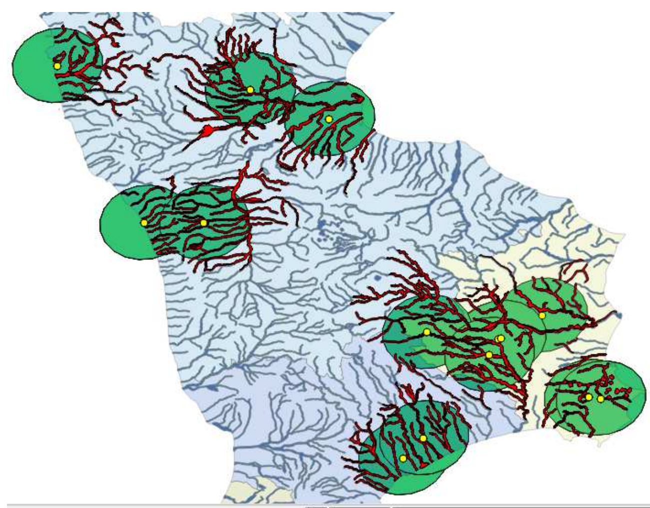


Fig. 3. Risky areas in green with the highest risk of contamination related to rivers.

cess in order to identify at any time the companies that have contributed to the

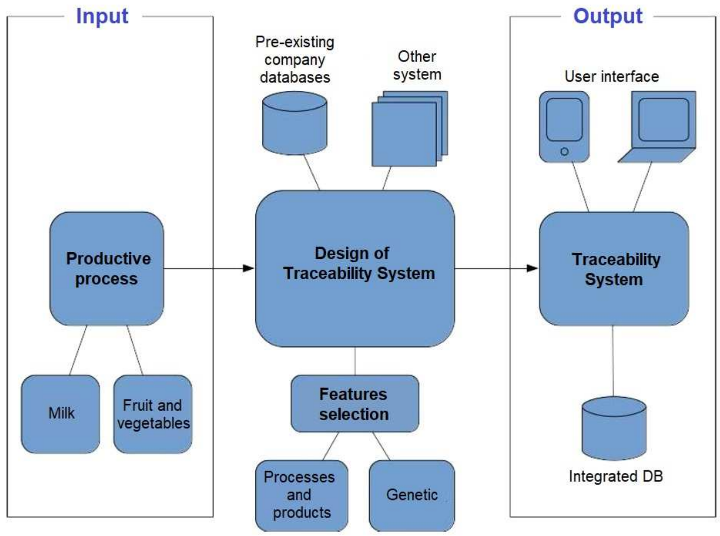


Fig. 4. Overview of the traceability process for milk, fruit and vegetable products with the interaction with external systems.

production of the raw materials. The tracking of the process consists essentially in the selection and registration of relevant information describing overall involved phases of the production process. A good production phase may contain data regarding administration, production, laboratory, packaging, logistics, cows feeding and phytosanitary treatments, functional foods and genetic.

The system aims to support the traceability process removing paper documentation and allowing only digital information. It is also able to track description and flows related to the production process, including check results and indications about the management and the verification of supply chain. The proposed traceability system allows the company to track all information about a specific batch (e.g., in the case of fruit and vegetables: the used fertilizers, harvest date and time, and phytosanitary treatments adopted). Moreover, QR-Code printed on the product label will be used to view all relevant information as the type of product and its variety, information of plants and land source. Indeed, the system is able to store, manage and retrieve these production steps, together with their specific properties. Thus, the possibility of knowing where, when and how a product has been manufactured, sent or stored, guarantees the wellness of consumers in that the process itself is rigorous, well known and also verifiable. Moreover, in case of an issue with any part of production, from a lot to a single product item, each party (e.g. user, company employee) is able to access the traceability system in order to verify all of the information about the product of interest, how and when it has been produced with specific process-related values.

This way, both the company's process awareness and the consumer confidence increase.

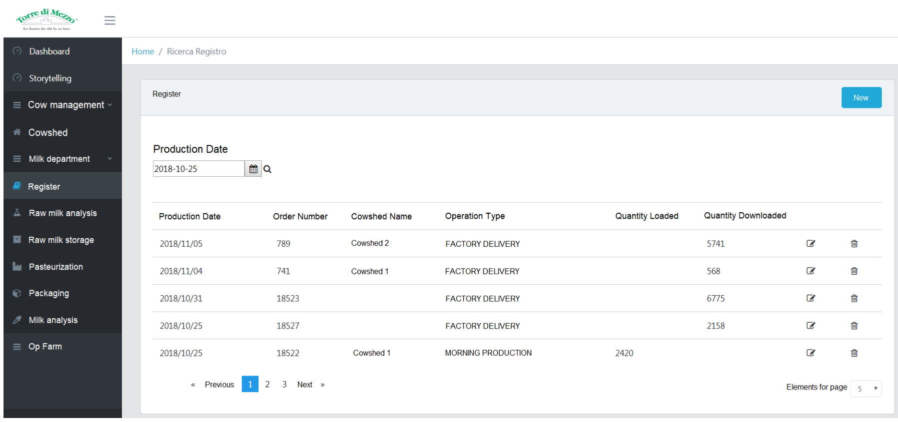


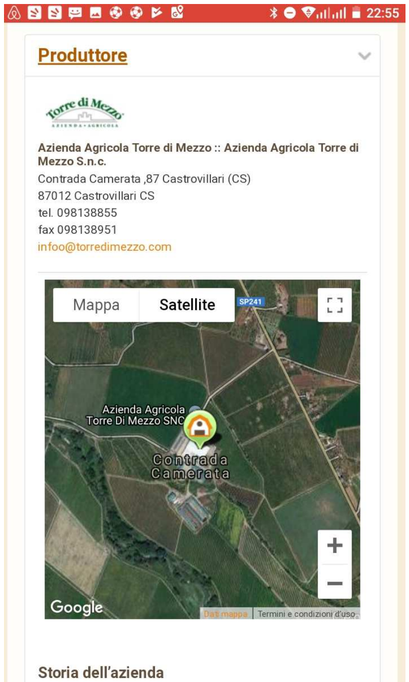
Fig. 5. Register about load/unload activity

An example of traceability system view is shown in Figure 5 reporting the register containing information about loading and unloading of products. It is also possible to shows the dashboard containing information about production trends and organoleptic tests as well as feedbacks that can be recovered from customers or users.

2.3 Customer applications

We now report some example and application of the customer view related to traceability for vegetables. We have information regarding nutraceutic (i.e., science of nutrition) as well as geographic data about production and provenience. Data are recovered from the databases that are loaded during the control and production phases reported above.

An App developed for customer about the track of nutraceutic characteristics and production of vegetables is shown in Figure 6. Figure 6(a) and 6(b) reports land production and nutraceutic information respectively that can be associated to fruits and vegetables. Finally, the customer is also able to track the information by starting reading by means of QR-Code an recovering information about the whole chain related to the fruits or lettuce. For example, Figure 7 reports about the possibility for customer to track information loaded from a QR-Code reported on the milk bottle. It is possible to track and recover information about cold process and cycle, as well as product conservation.



(a) Land production Information.

(b) Nutraceutic Information.

Fig. 6. App Tracking Nutraceutic and Production of Vegetables.

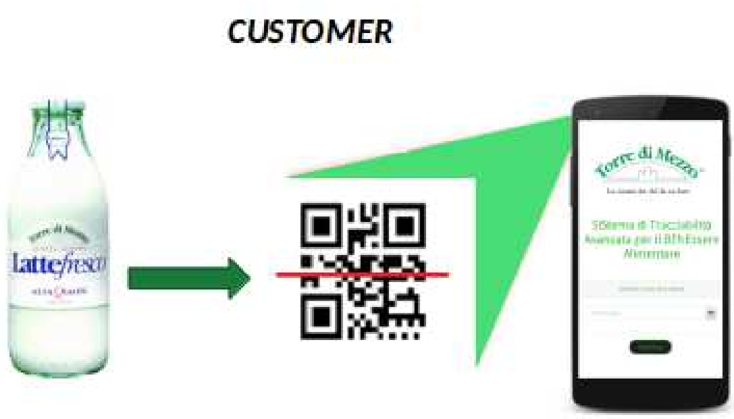


Fig. 7. Tracking nutraceutic information and production for fresh milk.

3 Security and Reliability of Tracking Phases: blockchain investigation

In this contribution, we investigated how blockchain technology can be used to provide greater asset traceability in food supply chains [12].

The food supply chain includes a lot of players (e.g. farmers, processors, distributors, packagers and grocers) often from different regions or countries and with own private record-keeping systems. Blockchain's capability of tracking ownership records and counteracting information tampering can be used to solve many issues in food supply chain as, for example, food fraud, safety recalls, supply chain inefficiency and food traceability [13, 14]. In this context, blockchain could make a positive impact on the food ecosystem.

Traceability is critical for the food supply chain and it can be ensured by the blockchain: each player along the supply chain generates and securely shares data points to create an accountable and traceable system. As a result, the record of a food process, from farm to table, is available to be monitored in real-time, ensuring moreover food safety.

For example, in fresh food supply chain, blockchain technology can provide the following potential use: (i) provenance, for a stronger warranty of origin and chain-of-custody; (ii) recalls, for a faster and more precise recalls; (iii) freshness, for fresher products reducing waste and spoilage; (iv) safety, for minor contamination problems.

We are currently investigating on the impact of this new technology and performing experiments for its integration in our traceability system architecture. This is particularly complex because of the involvement of both private (e.g., farmers, distributors) and public (e.g, Italian Health Agencies) actors in the process.

4 Conclusion

The presented traceability framework represents a valid solution to track and control the whole food process from raw materials up to distribution and marketing. The system is able to manage critical points for production, logistics and work organization, developing a safeness growth for consumer wellness. Moreover, the framework is also able to perform a land monitoring and it furnishes a simply app to be used by customer to obtain production details of the purchased product. Finally, blockchain technology has been introduced as an innovative solution in traceability process.

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