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EVO-NFC: Extra Virgin Olive Oil Traceability Using NFC Suitable for Small-Medium Farms

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ABSTRACT Food traceability is a fundamental requirement for the agriculture of the future. A food traceability system should ensure food safety and quality control, allow authentication, fraud prevention and control by the authority, improve consumers' safety and confidence. The agri-food supply chain is complex and difficult to handle due to the presence of various stakeholders and control authorities. Consequently, the complexity and the cost of traceability systems make it inapplicable for small and medium enterprises (SMEs). This work defines of a food traceability system using existing low cost digital technologies with the possibility to be integrated into a database for public authority controls. Smartphone applications allow consumer involvement and a bidirectional interaction between the company and the consumer. This work proposes the use of smartphone with NFC technology in every phase of the food chain bringing the information to the final consumer. An advantage of the proposed system is the low cost and easy to use, allowing its diffusion in small and micro farms, regional typical products, bio productions. The applications developed and the database architecture have been customized to the extra virgin olive oil process. Final considerations evidence the economic advantage of the traceability system.

INDEX TERMS Food traceability, smart farm, EVO, olive oil, NFC, android app.

I. INTRODUCTION

A. FOOD SUSTAINABILITY

Climate change and environmental degradation are an existential threat to the world. The governments of all countries must overcome these challenges. Some citizens and governments are more conscious of these challenges, some less. Europe is working on the "European Green Deal" to make economy sustainable. One of the aspects of the sustainable economy is the sustainable food system from Farm to Fork. Farm to Fork [1] is an approach taken by EU to face problems related to food sustainability with the aim of: reducing the use of pesticides and antimicrobials, reducing fertilisation excess, increasing organic farming, improving animal welfare, reversing biodiversity loss, preserving and restoring the land, ensuring neutral or positive environmental impact of the food chain (production, transport, distribution, marketing and consumption), ensuring food security, safety and quality, improve consumers' health and quality of life, reduce health-related costs for society.

Smart and precision agriculture can give a fundamental contribution in the reduction of the use of pesticides, but at the same time facing the increasing demand of food production due to the increase of human population. A review of sensor technology for precision agriculture is presented in [2]–[6]. In particular, Grimblatt [4] and Antony [5] evidence that the easiness of use and low cost of electronic technology allows the application in small-medium size farmers. Smartphone applications have developed for different aspects of farm management [6].

B. FOOD TRACEABILITY AS A SUPPORT TO FOOD SUSTAINABILITY

Food traceability does not only concern logistics, but above all traceability is essential for the insurance of quality and safety of the product to the consumer. It is also crucial for public health in the event of a food crisis, caused by fraud or the spread of pathogenic viruses [7].

The main requirements of a food traceability system can be summarized as follows:

- food safety control: back and forward tracing in case food crisis management.
- food quality control: monitoring, control and time/geo-reference the complete chain.
- security for authentication and fraud prevention.

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- control by the authority in charge to intervene throughout the supply chain to identify and eliminate food hazards.
- fast and accurate inventory.
- consumer involvement, improving consumers' safety and confidence.

The introduction of a traceability system makes the companies responsible of the entire supply chain in compliance with regulations to protect the characteristics of the product [8].

C. PROBLEMS OF FOOD TRACEABILITY

Many peculiarities of the food supply chain make difficult the implementation of traceability.

- food safety, quality and shelf life depend on time and transport and storage conditions.
- the agri-food supply chain is complex and difficult to handle, due to the presence of various stakeholders and control authorities.
- the data-flow connection is difficult, when several actors are working along the supply chain.
- the definition of data and specifications of the tracing system strongly depends on the specific type of food and type of supply chain.
- the complexity and cost of the traceability system make it inapplicable for small and medium enterprises (SMEs) or even individuals, who typically work in the food chain.
- the current food labeling system does not guarantee food quality and safety.

D. TECHNOLOGIES FOR FOOD TRACEABILITY

Technological and digital innovation can empower farmers and the complete food chain, providing consumers with safe and healthy food.

Blockchain is, actually, a widely studied technology as a possible solution to the request on food quality and safety [9]–[18]. Blockchain technology ensures data integrity through offering trust, transparency and full traceability of the stored transaction records to agri-food value chain partners. A review [15] of existing works outlines that the open challenges for applying blockchain in agri-food chain are storage capacity, high cost, throughput and latency issue. Additionally, the blockchain is a decentralized and distributed governance system. This aspect is in contrast with a central regulation authority and privacy leakage of the food producers. A possible solution is proposed in [16].

Recently, some big enterprises developed systems for food traceability using blockchain [19]–[22]. They provide traceability information on the supply chain (including dates, places, farm buildings, distributed channels, and potential treatments). Walmart studied the application to the traceability of pork meat and mango using Hyperledger Fabric [19], IBM is offering the traceability service "Food Trust" [20] and covid-19 vaccine management [21], from 2019 Carrefour is integrating the blockchain technology into some quality lines: chicken, tomato, farm-raised eggs, rocamadour cheese, fresh milk, salmon [22].

From 2000 RFId technology was applied in the food supply chain process, but the high costs and complexity of implementation allow for adoption only for large companies [23]. More recently, the QRcode has been used [24], [25], for example applied to wine bottles [25], to show information through the consumer's smartphone. The QRcode is not really a food traceability system, but essentially a quick link to the company website. The great novelty of the QRcode is the possibility for the consumer to get information about the product using his smartphone.

E. CONSUMER INVOLVEMENT

A food traceability system, that brings information in a simple and direct way to consumers, improves consumer confidence for the product and allows an informed food choice. The consumer is increasingly interested in quality, environmental impact and sustainability of food production. He is looking for certified quality, and ethical products with respect to the environment and law.

European Union implements a quality system of geographical indications, such as Protected Designation of Origin (PDO). Consumer interest in a reliable geographical declaration of food has increased over the last years. A traceability system that gives geographical and additional details on the food production chain is perceived by the consumer as an additional warranty of quality and authenticity [26].

F. AIM AND METHODOLOGY OF THE PROPOSED WORK

The aim of the presented work is the definition of a food traceability system using existing digital technologies with the following specifications:

- easiness to use and low cost, in order to be applicable for small and medium enterprises (SMEs).
- possibility to be integrated into a database for public authority control, reducing the time for administrative checks and controls.
- support to farmers' declaration and administrative documents, that could be instantaneously sent to the cloud database accessible by all control institutions.
- increase consumer involvement through app on his smartphone allowing a bidirectional interaction between company and consumer.
- integration of current food labeling system with web services and smartphone apps, in order to increase consumer confidence on the product quality.

The methodology used consists of:

- analysis of advantages and disadvantages of the existing digital technologies (summarized in Table 1 in Section III).
- analysis of advantages and disadvantages of some of the existing traceability systems (summarized in Table 2, in Section III).
- definition of the specification of the proposed traceability system (in Section III).
- study of the state of the art and application to the specific case of extra virgin olive oil chain. (in Section II and IV).

G. PROPOSED SOLUTION

The novelty of the proposed solution is the use of the same NFC technology for food traceability from production directly to the consumer. Furthermore, unlike conventional QRcode, the app installed in the consumer smartphone allows a bidirectional interaction between the company and the consumer. This allows market analysis and gives to the company feedback on consumer habits, taste and preferences, fundamental for market purposes. Block chain has not applied in the transcription of the data in the proposed solution, but it could be applied.

The traceability system has been developed in the specific chain of the extra virgin olive oil. A prototype of the system has been developed and customized to the two small Italian farms chosen as test examples.

Section II presents the state of the art on EVO traceability. Section III presents the proposed methodology. Section IV reports the application to the extra virgin olive oil supply chain. Section V evidences some economic considerations. The conclusions are reported in section VI.

II. STATE OF THE ART ON EVO TRACEABILITY

Virgin olive oil is obtained only from the fruit of the olive tree by mechanical or other physical means under conditions that do not lead to alteration of the oil.

The physical, chemical and organoleptic characteristics of olive oil are regulated by different standards depending on where they are traded: the most important standards are specified by the European Union (Reg. (EEC) 2568/91), the International Olive Council and the Codex Alimentarius. These standards define the methods for quality evaluation of olive oils, applied by the official controllers to some samples of the olive oil at the end of production [26]. Virgin olive oil is divided in four types: extra-virgin olive oil (EVO), virgin olive oil, ordinary virgin olive oil and lampante virgin olive oil [27].

The high price of high quality EVO makes it a target for frauds. The definition of a food fraud given by the CEN/CENELEC Workshop Agreement is "an action intentionally causing a mismatch between food product claims and actual food product characteristics, either by deliberately making claims known to be false or by deliberately omitting to make claims that should have been made" [8]. Public authorities can detect frauds applying specific controls in all the steps of the olive oil chain. Traceability is an essential part of the strategy to mitigate the risk of food fraud. It is a powerful tool that can be used by the public authorities, but if used in addition to controls in the field or by chromatographic or spectroscopic techniques applied to the EVO samples [27].

Some research works have been published on the specific application of traceability systems in EVO supply chain [28]–[35]. The work presented in [28] analyzes the economic sustainability and consumers' preference of technological systems supporting traceability applied to the EVO chain. In [29] a Hyperledger Fabric blockchain technology has been used to enforce the certification of the entire supply chain of extra virgin olive oil. The work presented in paper [29] focuses on the performance evaluation based on simulations in terms of transaction delay of the block chain.

In 2008, Giametta *et al.* [30] defined the fundamental data that the operator must record during the different phases of the EVO process and they translated the data into 14-digit barcode, in addition to paper documents.

In 2016, Abenavoli *et al.* [31] developed a WebApplication on Cloud Platform to store the same information defined in [30] in a QRcode format printable for each container. A great inconvenience is the necessity of carring a QRcode printer in the different steps of the olive oil chain. The tracing is not brought to the consumer.

In 2017, Papaefthimiou *et al.* [32] proposed an olive oil monitoring and quality assurance methodology. They store details on cultivation (using passive NFC tags placed on every tree of the farm, capable of record yearly fertilization, pesticide activities), on location and microclimate (maintained by the farmer using sensors, it is not clear if in automatic or manual way), and on the milling process (olive size, organoleptic classification). The data are analyzed using clustering algorithms, with the aim of maintaining uniform olive product characteristics.

In 2020, Guido et al [33] proposed a database management system, accessible to all the stakeholders involved in the EVO supply chain, using a PC or smartphone. The final consumer accesses to part of system information by a QRcode placed on the product label. The connection between the QRcode and the database is not clear.

In 2020 Violino et al [34] suggested to place an RFId in every olive tree and in the containers at the end of the harvesting, other information (yield after pressing, nutritional data) are manually inserted by the operators along the chain through a web interface. The final consumer accesses to part of system information by a QRcode placed on the product label. The storage phase before bottling is not considered in the work.

Recently, the industrial oil company Bertolli announced the use of Near Field Communication (NFC) in oil bottles for the American market [35]. The NFC is used as a link to a website without integration with a food traceability system. This Bertolli marketing choice shows that the consumer is ready to appreciate product details using his smartphone and NFC.

The database architectures reported in the research works on olive oil [30]–[34] is not able to correctly trace some typical cases of the EVO chain, for example when olives harvested in different days or from different fields are mixed together, or when the oil tank is filled many times during the harvesting period. These aspects are considered in the system proposed in this work.

The use of a single RFId placed in every tree [32], [34] does not give real information, the user can be interested in the location of the field and not on the single tree. Furthermore, the association of single the bottle of oil to a single tree is inapplicable.

In papers [32]–[34], the consumer accesses the traceability system through a QRcode applied to the bottle. On the contrary, in this work smartphone with NFC is preferred for all the food chain, due to the wide diffusion of smartphones with NFC, the easiness of use of smartphone apps for consumer and for small size farm, the availability of cloud storage, and the diffusion of platforms for Internet of Things.

III. PROPOSED METHODOLOGY

Different technologies can be used in the food chain for traceability purposes and to inform the user on the quality of the product. Each technology has some advantage and disadvantage, summarized in Table 1.

TABLE 1. Technologies for food traceability.

		Advantage	Disadvantage
Food chain	**Paper docs**	traditional, easy to use, low cost	slow and difficult to exchange information in the different phases of the production
	QRcode	low cost of the reader (smartphone), inexpensive tag, possible development of app for database management.	tag is not rewritable and reusable, possible tag damage, special lighting conditions and pointing to a figure.
	RFId	low cost of the tag (0.1€), reading distance 1-5m, simultaneous reading, possible development of app for database management.	high cost of the reader.
	NFC	the reader is a common smartphone, 0.15€ each tag, possible development of app for database management.	single reading.
Consumer	**Label**	traditional, well regulated, low cost.	reduced data brought to the user.
	QRcode	the consumer uses his smartphone to read data, low cost.	the QRcode is only a link to a company web site, there is no connection to the tracing database.
	RFId	indirect advantage for the consumer, due to the efficient traceability allowed for authorities.	the consumer has no direct access to data or he can eventually use the reader only in the supermarket.
	NFC	high user involvement, the consumer uses his smartphone, possible development of app for customer loyalty and simple connection with tracing database.	0.15€ each tag to be added to the product cost, not reusable.

The key aspect of the proposed methodology is to use the NFC technology in each phase of the food supply chain (production, processing, distribution and consumption) and cloud storage to share information among farmers, government institutions and final consumers. The methodology has been applied in pig [36] and the fruit and vegetable supply chain [37].

Table 2 reports the different solutions proposed for food traceability, with the main application on EVO. Focus of the works, advantage and disadvantage of the proposed solutions have been summarized and compared with the proposed work. In summary, the other traceability systems for EVO chain propose different technologies for tracing, few of them bring some information to the consumer using QR code, none of them connects directly the tracing system to the consumer and none uses smartphone apps and NFC to give information to the consumer. The novelty of the proposed solution is the use the same NFC technology for food traceability from production directly to the consumer.

The advantages of the proposed system are:

- it increases consumer confidence on the product quality allowing loyalty.
- it allows an easy management of data by the farmers, for internal use, and to fulfill the requirements of the regional, national and European authorities.
- the low cost and easiness to use, allows diffusion in small and micro farms, regional typical products, bio production.
- the use of cloud data storage allows to share information among farmers involved in the same production chain, farmer consortium (e.g. Bio-consortium, protected designation of origin), government institutions and authorities responsible for controls and final consumers.
- data and activities are automatically time and geo referenced. Consequently, it is straightforward to ensure geo-traceability of farm products ensuring quick and accurate trace-back or providing knowledge on agricultural products provenance. This geo-traceability is an 'added value' and it is required by food safety agencies, by certification bodies and by consumers too.

The work carried out in the development of the proposed system consists of:

- Identification of the stakeholders in the test application on extra virgin olive oil.
- Acquisition from small farms in EVO production the basic knowledge, the best practice and the European, national and regional regulations, in order define system specifications and database structure.
- Development of the app for smartphone with NFC.
- Creation and management of the cloud database.
- Customization of the applications and database for the specific farms and products. The test has been carried out on two small farms: Azienda "Fattoria San Donato": small farm for organic olive oil and wine production (San Gimignano, Toscany, Italy) and Azienda Agricola "Pecorara": small farm for organic olive oil production (Ancona, Marche, Italy).

Key elements of the traceability system are:

- Information is stored in NFC tags at each stage of the supply chain.
- The operator reads and writes the tag using a normal smartphone or tablet with NFC, which are currently available at a very low cost.
- The information is available online through a cloud database, accessible in a secure manner, allowing information exchange among other databases.
- All the details on the supply chain or part of them are available to the consumer through an application on his smartphone with NFC which reads the tag in the package.

TABLE 2. Advantages and disadvantages of the proposed traceability systems.

Ref	year	application	Chain tracing system	User involvement	Advantage / Focus	Disadvantage
[23]	2009	fruit	RFId	no	dB detailed description, RFId for fast tracing	No user involvement, high cost of reader
[24]	2020	vegetable	dB updated using web app	QRcode	dB detailed description, tracing used to give information on nutritional quality	No automatic tracing system (such as RFId)
[25]	2014	wine	not analyzed	QRcode	Explore the willingness of the consumers to accept QRcode on wine	Tracing system not proposed
[28]	2019	EVO	not analyzed	QRcode	Explore the willingness of the consumers to accept QRcode on EVO	Tracing system not proposed
[29]	2019	EVO	not described	no	Transaction delay evaluation of the block chain based on simulations.	Tracing system not proposed, No user involvement.
[30]	2008	EVO	barcode	no	Barcode for fast data collection and processing,	No details on the link between data. No user involvement. Few data on a barcode.
[31]	2016	EVO	QRcode. Web and mobile app	no	QRcode for fast data collection and processing	No details on the link between data. No user involvement. low cost of the reader, inexpensive tag, not easy readability and possible tag damage,
[32]	2017	EVO	NFC	no	RFId tag placed on every tree! Data recorded to keep uniform product characteristics.	No details on the link between data. No user involvement. NFC tags placed on every tree.
[33]	2020	EVO	dB updated using web or mobile app	QRcode.	QRcode for fast data collection and processing	No details on tracing and on the link between data. Low cost of the reader, inexpensive tag, not easy readability and possible tag damage. The connection between the QRcode and the database is not clear.
[34]	2020	EVO	RFId and QRcode	QRcode	RFId tag placed on every tree! Economic analysis of RFId in the harvesting phase (about 5%).	No details on tracing and on the link between data.
This work		EVO	NFC	NFC	Low cost, tag reader is a smartphone, easy to be used by the farmer, data shared among stakeholders of the chain, complete tracing from supply chain to the user, dB and tracing customized to the application, data automatically time and geo referenced, guarantees product quality to the customer, allows customer loyalty.	Lightly higher cost of tag with respect to QRcode, user acceptability to be verified.

- The methodology makes it easy the customization to each company in the supply chain, the system update and the customization to different supply chains.

The methodology involves the development of an application for each stage of the food chain, as shown in Figure 1. In the first phase of the chain, once all the data has been provided, the operator writes the tag. This operation consists in adding a new record in the product table stored in the remote database.

The smartphone receives from the database the identifier of the new added record, as confirmation of registration.

Finally, the smartphone writes in the tag the name of the table on which the information is written and the identifier of the record. In the subsequent stages of the chain, after entering the information relating to the company and operator, the operator reads the tag from the previous stage.

The smartphone, connected to the database, reads the data linked by the identifier written in the tag and displays it to the operator. Subsequently, the operator adds the information related to the current phase of the supply chain and finally he writes it in a new tag.

The tags do not really contain the data, but only the identifier, making the system independent of data and facilitate extension to different food chains.

Finally, a tag is added to the product. Before or after the purchase, once the application has been downloaded, the consumer reads the information on the tag with his smartphone and other information on the manufacturer's website. The application shows images, GPS coordinates of the various phases of the chain, links to company sites related to the specific product (e.g. tasting, recipes ...).

The code was developed in an eclipse environment and the applications were developed for android smartphones with NFC. The database was created on an altervista site, the site that holds the additional information to be shown to the final consumer.

IV. APPLICATION IN THE OLIVE OIL SUPPLY CHAIN

The proposed food traceability methodology has been used in the specific application of the EVO chain. The olive oil chain consists of four phases: harvesting, milling, storing and bottling. Therefore, four applications have been developed, and an additional application for the consumer. In the case of small farms, milling is usually performed by external companies. Bottling sometimes is performed inside the farm. The two cases are represented in Figure 2.

The architecture of the proposed system is reported in Figure 3. In each phase of the chain, the operator associates a tag to the objects of the olive oil chain:

1. Box containing the olives at the end of the harvesting.
2. Container of oil filled at the end of milling procedure.

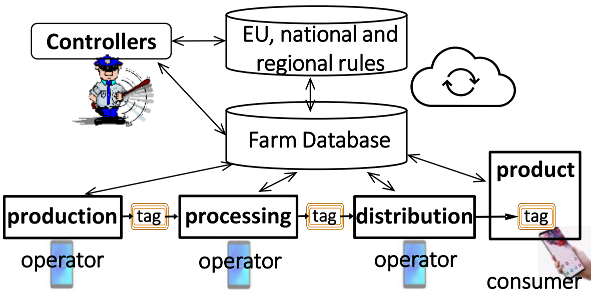

FIGURE 1. Smartphone and NFC used in all the phases of the supply chain.

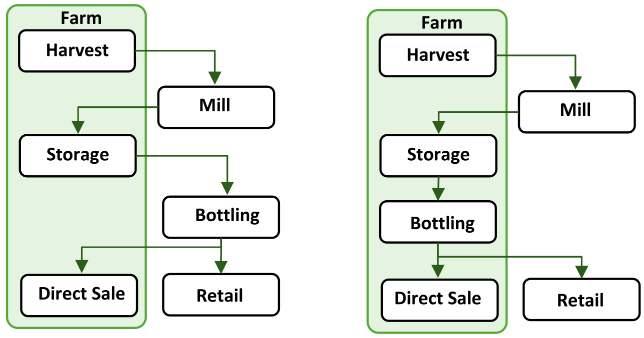

FIGURE 2. Olive oil supply chains for small-medium farms.

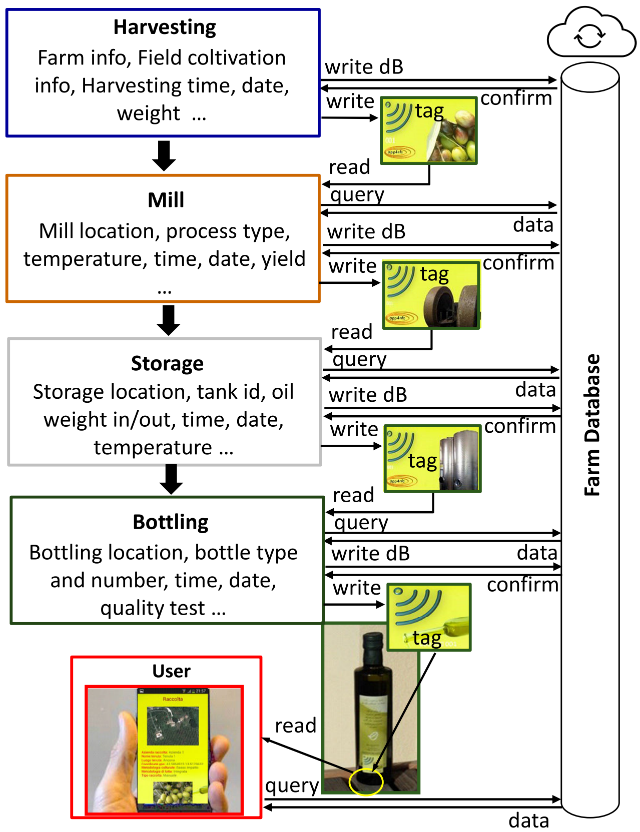

FIGURE 3. Architecture of the traceability system for the olive oil chain.

3. Storage tank used to store oil before bottling.
4. Bottle of oil with label and tag for the consumer.

The tag of the object can be reused and rewritten, once the object is used, for example the box for the olives after the olives are given to the milling company. Even the layout of the tags, shown in Figure 3, may be relevant to make easily understandable their use by the operator. The tag placed in the label of the bottle must easily show to the consumer the added value given to the product (product and chain brand). When an operation is applied to an object, the following steps are performed:

1. The operator reads the tag of the object with his smartphone.
2. The tag contains a link to a remote database of the company.
3. The history of the object is displayed to the operator.
4. The operator updates the information on the remote database.

The tag contains a link to the information in the cloud database. The data stored in the different phases and organized in tables are summarized in Tables 3-6.

Some of the information stored in the database are customized, once for all, to the specific enterprises involved in the supply chain. As an example, in Table "Field" related to the fields of the farms: farm name, fields of the farm, field location, field cultivation methodology. Similar fixed tables have been developed for the farms, olive varieties, mill companies, milling process, storage companies, tanks, bottling companies, bottling processes, tasting and cooking recipes. This customization facilitates the work to the operators, since the information is inserted in drop-down menus, whose fields the operator must select.

When an operation is performed, a new record with the data is added in the database, an identifier number is associated to the record.

Some information is automatically inserted by the app, such as date, time, gps location and android_id to identify the operator smartphone.

Some data are inserted by the operator, facilitated by a default value and by the drop-down menus.

When the operator writes the tag of the object that he is processing, the identifier of previous process is stored in new record creating a link to the previous record. In this way the tracing of the chain is obtained.

Finally, some fields are automatically evaluated by the system on the basis of previous information. For example, when more than one box of olives is brought to the mill, if all the varieties of the boxes are identical, that variety is associated to the resulting oil, otherwise the associated variety is "mixed".

The applications take into account the constraints of the specific olive oil supply chain, acquired from the knowledge of the two farms involved in this project. The system allows to trace some specific cases, for example:

TABLE 3. Harvesting.

Automatic	id_harv, timestamp_harv, date_harv, android_id_harv, gps_harv
Added by operator	date, operator, farm, field, field location, farm gps, variety, weight

TABLE 4. Mill.

Automatic	id_mill, timestamp_mill, date_mill, android_id_mill, gps_mill
Added by operator	date, operator, mill, process, category, oil weight, yield
Id link	id_harv_1, id_harv_2, id_harv_3, …
Evaluated	farm, field, variety, time harv-mill, start harv, end harv, origin, expiration date

TABLE 5. Storage.

Automatic	id_stor, timestamp_stor, date_stor, android_id_store, gps_stor
Added by operator	date, operator, company, tank id, oil weight in/out
Id link	id_mill_1, id_mill_2, id_mill_3, …
Evaluated	farm, field, variety, time harv-mill, start harv, end harv, origin, expiration date, yield, category, oil weight

TABLE 6. Bottling.

Automatic	id_bott, timestamp_bott, date_bott, android_id_bott, gps_bott
Added by operator	date, operator, company, bottle type, bottle number
Id link	id_stor
Evaluated	farm, field, variety, time harv-mill, start harv, end harv, origin, expiration date, yield, category, quality test

- not always the olives are brought to the mill in the same day of the harvesting. It is important to know the dates of start and end of harvesting and time between harvesting and milling. The quality of the oil strongly depends on this time.
- harvestings from different fields and/or collected in different days can be joined together to the same milling process.
- a tank can be filled with oils coming from different milling procedures.

As an example, let us consider the case reported in Figure 4. To the 50 bottles associated to the id_bott n.378, the id_stor operation n.18 is associated. The bottles have been taken from the tank n.2, that has been filled with oil coming from the mill associated to the operation id_mill n.178. The milling process n.178 is associated to the harvesting with id_harv n. 60 and 61. From the tracing we know, for example, that the start of harvesting is November 5, 2020 and the end is November 6, with a maximum time between harvesting to milling of 2 days, they come from the same field and the variety is "leccino".

The applications are described in detail in the following sections.

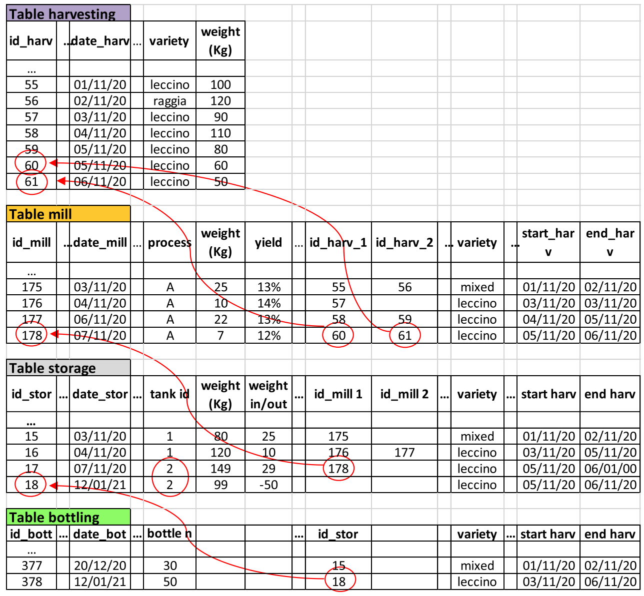

Table harvesting

id_harv	…	date_harv	…	variety	weight (Kg)
…					
55		01/11/20		leccino	100
56		02/11/20		raggia	120
57		03/11/20		leccino	90
58		04/11/20		leccino	110
59		05/11/20		leccino	80
60		05/11/20		leccino	60
61		06/11/20		leccino	50

Table mill

id_mill	…	date_mill	…	process	weight (Kg)	yield	…	id_harv_1	id_harv_2	…	variety	…	start_harv	end_harv
…														
175		03/11/20		A	25	13%		55	56		mixed		01/11/20	02/11/20
176		04/11/20		A	10	14%		57			leccino		03/11/20	03/11/20
177		06/11/20		A	22	13%		58	59		leccino		04/11/20	05/11/20
178		07/11/20		A	7	12%		60	61		leccino		05/11/20	06/11/20

Table storage

id_stor	…	date_stor	…	tank id	weight (Kg)	weight in/out	…	id_mill 1	id_mill 2	…	variety	…	start harv	end harv
…														
15		03/11/20		1	80	25		175			mixed		01/11/20	02/11/20
16		04/11/20		1	120	10		176	177		leccino		03/11/20	05/11/20
17		07/11/20		2	149	29		178			leccino		05/11/20	06/01/00
18		12/01/21		2	99	-50					leccino		05/11/20	06/11/20

Table bottling

id_bott	…	date_bot	…	bottle n			…	id_stor			variety	…	start harv	end harv
…														
377		20/12/20		30				15			mixed		01/11/20	02/11/20
378		12/01/21		50				18			leccino		03/11/20	06/11/20

FIGURE 4. Example of data in the tables and tracing methodology.

FIGURE 5. Harvesting application.

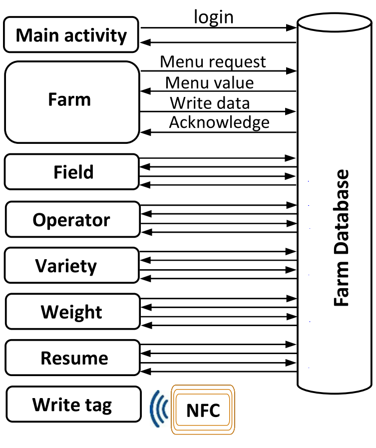

FIGURE 6. Activities of the harvesting application.

A. HARVESTING APP

The Harvest application takes care of tracking the olive harvesting. The tag can be applied to the olive containers at the end of harvesting, as shown in Figure 5. During the collection phase, the application uses the android id of the phone and the GPS coordinates at the time of collection. The steps the

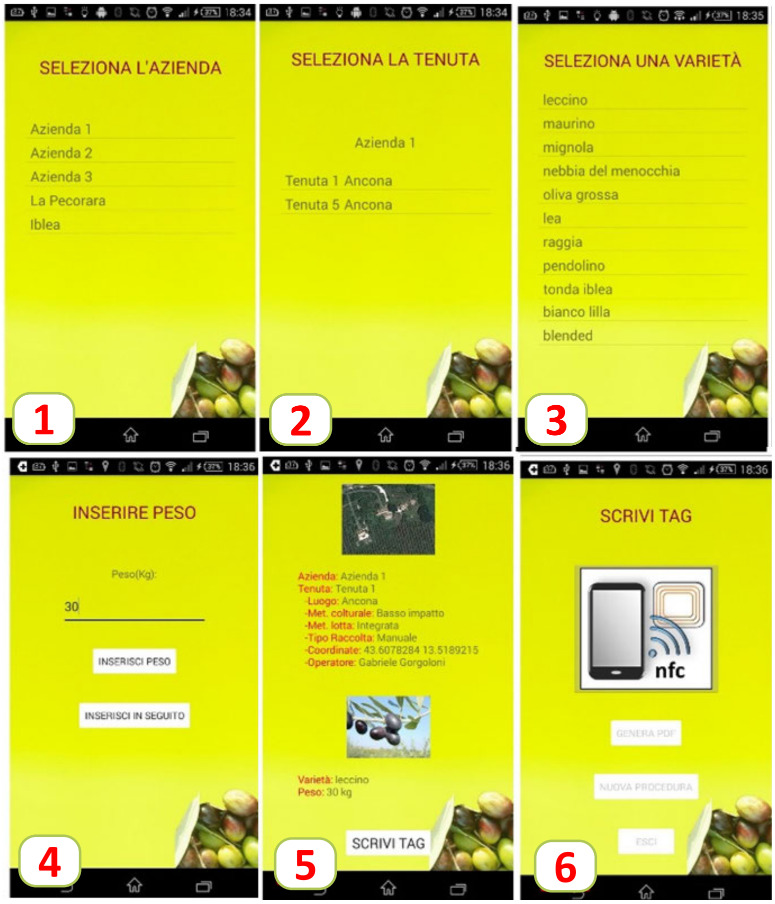

FIGURE 7. Main screenshots of the harvesting application.

operator performs are shown in Figure 6. The operator inserts from a list of drop-out menu the name of the farm, the name of the field, his name, the type of olive variety. The drop-out menu is previously filled by the information:

- Farm: identifier, farm name, web link
- Field: identifier, farm identifier, field name, place, cultural methodology, parasitic control methodology, harvesting methodology, photo, gps, web link.
- Operator: identifier, farm identifier, operator name.
- Variety: identifier, farm identifier, variety name, image.

The advantage of the prefilled drop-out menu is that the data are inserted in the customization phase.

For example, all the data are automatically inserted, if the farm is owner of just one field with just one olive variety.

Then the operator writes the weight of the harvesting. All the data inserted are resumed to the operator, as shown in screenshot 5 of Figure 7: date, hour and minute of data entering, the name of the operator, the android id of the phone and the GPS coordinates at the time of collection, the name of the farm, name and place of the field, the cultural methodology, the variety of olives and the weight of the harvest.

Then the operator presses on the "write tag" button, approaching the smartphone to the tag, as shown in Figure 5, the id_harv received from the database is written on the tag and at the same time the data are written in the database.

It is not necessary to use one tag for each box of olives, one is enough for each collection, the tag acts as an accompanying document at the end of daily harvesting.

The activities of the android application is shown in Figure 6, while the screenshots of the application are shown in Figure 7.

B. MILL, BOTTLING AND STORAGE APPS

The mill application reorganizes the information of the different harvestings, analyzing the differences in the different harvesting processes. The tag written by the mill application is applied to each container of oil produced by the pressing process. Images representing this phase is reported in Figure 8.

As previously described, the system is able to manage and trace the fact that the milling process can mix olives coming from different farm, fields, varieties and dates of harvesting. Usually, but not always, for high quality products farm, field and variety is the same. The oil containers with their tags arrive at the entrance to the storage process. The drop-out menu is previously filled by the data:

- Mill: identifier, mill name, place, gps, web link.
- Milling process: identifier, mill identifier, process name, defoliation, washing (water liters), crushing grammage (minutes), extraction temperature (T), milling (continuous or not).
- Operator: identifier, farm identifier, operator name.

Then the operator writes the olive category (e.g. superior), weight of the oil and yield (oil weight/olive weight).

Other fields are automatically evaluated and stored from the harvesting identifiers of all the harvestings that are mixed in the mill: variety, farm, field, time between harvesting to milling, start date of harvesting, end date of harvesting, origin (e.g. ITA), expiration date (e.g. 2 year from milling). For example, if the same variety "leccino" is the same for all harvestings this "leccino" is stored, otherwise "mixed". All the data inserted are resumed to the operator, then he writes the tag and the data are written in the database. Table Mill in Table 3 summarizes all the data stored.

In the storage phase, the oil coming from milling phase is deposited in the tank used to store oil before bottling. The images representing this phase is reported in Figure 9. Every time the tank is filled or emptied a new record is inserted in the storage table, updating the information on the current quantity in the tank and the history of the oil that is inserted. The process is complex since the tank can be filled many times during the olive harvesting period.

The drop-out menu is previously filled by the following information:

- Storage: identifier, storage name, place, gps, web link.
- Tank: identifier, storage identifier, tank name.
- Operator: identifier, storage identifier, operator name.

Then operator writes the tank_id and the weight of oil he is inserting or taking from the tank. The system automatically updates the weight of the oil currently in the tank.

Similarly to the other phases, Table Storage reported in Table 4 summarizes all the data stored.

When the oil is bottled, the storage table is updated and all the data collected by the tracing system is available in the bottling table record linked by the tag applied to the bottle. The operator inserts the number of bottles he is filling and the type of bottles.

Before the bottling procedure starts the farm performed the quality test that is associated to the bottles: organoleptic characters, color, acidity, ...

Images representing this phase are reported in Figure 10.

C. USER APP

The tag in the bottle is available to the consumer. The consumer downloads the user application on his smartphone, this step is useful for the loyalty to the product. Before or after the purchase, he can read all the information that the farmer and the law want to show about the supply chain, simply approaching his smartphone with NFC to the tag placed on bottle of olive oil.

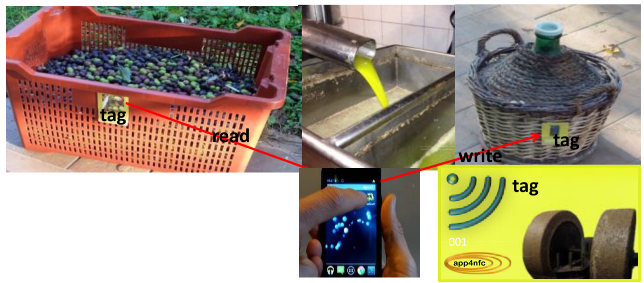

FIGURE 8. Mill application.

FIGURE 9. Storage application.

FIGURE 10. Bottling application.

FIGURE 11. Consumer application.

Figure 11 shows the data that will then be displayed to the consumer. The application will read the data from the web site, in which they were loaded in the different stages of the chain.

When the consumer approaches the smartphone to the tag applied on the label of the bottle, the application reads the tag and shows the information on the supply chain copied in the "Consumer Table": harvesting date, variety type and image, farm name, web site and photo, field location, farming methodology, milling date and process type, milling process, expiration deadline, bottling date, tasting (color, smell, taste), cookbook, cooking recipes.

The data are copied in a new "Consumer Table" instead of collecting the data in recursive way from the single tables of the chain. This strategy allows with a single query and therefore a single connection to retrieve all the requested information, avoiding overloading the database with many queries. The complexity of the user app code is reduced. Furthermore, the tracing database is not accessible by the external users, improving the security of the system.

By means of buttons, the user has the possibility to view secondary information as well. In this way he is not disoriented in front of an excessive amount of data, but at the same time has the possibility to go down to a very high detail. The main information is grouped into three different categories: harvesting, pressing and bottling, each of them has a button that, when pressed, shows more details about that specific category.

V. ECONOMIC IMPACT

As a performance indicator, a preliminary analysis of the economic impact of the proposed tracing system is reported. Big are the differences in the quality of the different types of olive oil: Lampante, EVO, EVO DOP (Protected Designation of Origin), EVO IGP (Protected Geographical Indication), EVO BIO. Big are the differences on the production costs and price to the consumer. The consumer is not always completely informed on the quality of the oil he is buying. The NFC tracing system, applied to the high quality EVO, is a way to guarantee this quality and justify the difference of price.

Figure 12 reports the production price in €/liter in the last 5 years, vat excluded, for Lampante, EVO (Italian and average among oil from Spain, Greece and Tunisia), average Italian EVO DOP and of 22 of the 43 Italian EVO DOP and IGP, obtained from the data available in [38].

The cost and the consequent market price of EVO DOP is about two times the EVO oil. The consumer attention and sensitivity to high quality productions (DOP / BIO) is rapidly increasing, so the consumer accepts to pay a double price if ensured of the product quality.

The study of the production costs of high quality EVO has been carried out, in order to analyse the economic impact of the proposed NFC solution.

Figure 13 reports the average total cost of the Italian EVO DOP, the data are derived from [38] and confirmed by the two farms involved in this research. The average production cost, is about 8.2€, as shown in Figure 12. The cost consists mainly in manpower, then machine depreciation and maintenance, field treatments, administrative personal and certifications. To this production costs, the costs of marketing, bottling, bottle and label must be added for an estimated amount of 10.85 €/l. The additional cost of about 0.15€of the NFC tag corresponds only to 1% of the total cost.

On the other hand, the use of the NFC traceability system could allow a more efficient administrative management of the production data, thus reducing the administrative cost. Furthermore, the proposed traceability ensures to the consumer the quality of the product giving added the value of the product itself, that is actually obtained by the marketing, whose cost is 1.65€/l.

Up to now, about 400 Italian EVO product chains have a tracing system with 8000 farms involved [38], but usually the tracing system is paper based and the information is not brought directly to the consumer.

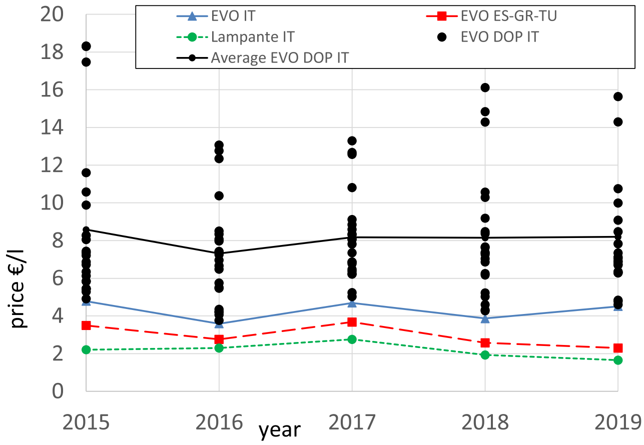

FIGURE 12. Production price in €/liter in the last 5 years, vat excluded, for Lampante, EVO (Italian and average among oil from Spain, Greece and Tunisia), average italian EVO DOP and of 22 italian EVO DOP.

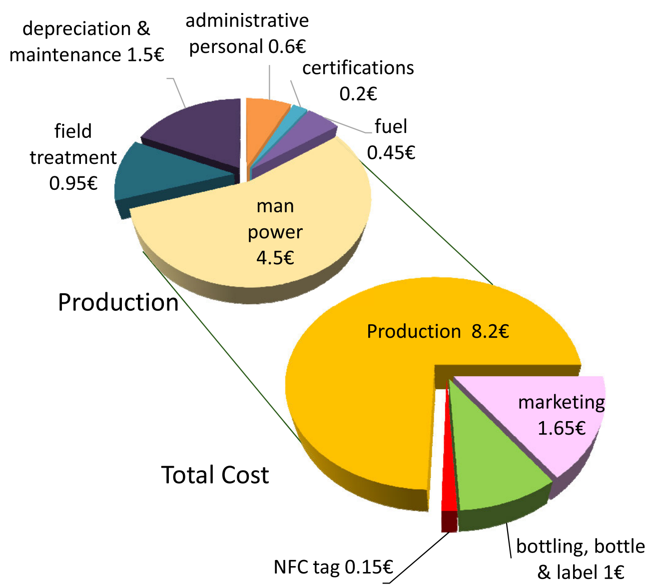

FIGURE 13. Average total cost of EVO DOP and production price in €/liter.

VI. CONCLUSION

This paper proposes a complex traceability system that allows to bring easily the product information to the consumer using his smartphone with NFC. The prototype has been developed in the specific chain of the extra virgin olive oil.

A great work has been carried out carried out on the acquisition the knowledge and best practice of the extra virgin olive oil from small farms, that are the main target of this research. The knowledge allowed the definitions of the specification of the traceability system. A prototype of the system has been developed and customized to the two small Italian farms: Azienda ''Fattoria San Donato'' and Azienda Agricola ''Pecorara''.

Future research will be devoted to the verification of user acceptability and cost-benefit analysis for the farmer, but the example of the Bertolli company suggest that the extra virgin olive oil user is ready.

We think that the research presented in this work is in line with the goal of sustainable food system from Farm to Fork carried out worldwide and specifically by the EU government.

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