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Improvement of traceability processes in the farmed fish supply chain

Alfredo Parreño Marchante[1], Alejandro Alvarez Melcon[1], Mira Trebar[2], Andrej Grah[2], and Piero Filippin[3]

[1] Universidad Politecnica da Cartagena, Campus Muralla del Mar-Antigones, Cartagena, Spain

[2] University of Ljubljana, Faculty of Computer and Information Science, Tržaška cesta 25, Ljubljana, Slovenia

[3] University of Wolverhampton, School of Technology, Wulfruna Street, Wolverhampton, Great Britain

alfredo.parreno@gmail.com, alejandro.alvarez@upct.es

Abstract: In the project "RFID from Farm to Fork" an implementation of RFID technologies will be used along the food supply chain to be deployed in SMEs: from the farm to the consumer. As part of the project, we are undertaking two pilots in the farmed fish business. The intention of this paper is to show the business process of the farmed fish supply chain and novel system architecture is proposed to improve internal processes of fish traceability using Radiofrequency Identification (RFID) and Wireless Sensor Networks (WSN). In order to show the technological evaluation, a definition of each company ś business processes and how to upgrade them to the new technologies is presented. The new system will replace the current manual collection of data performed by the companies. Additionally, this paper identifies areas for improvement of business processes and highlights companies' return on investment from the use of the novel system.

Keywords: Traceability, farmed fish, supply chain, aquaculture, RFID, WSN

1. Introduction

The production and distribution of food is becoming one of the most important issues in many countries all over the world. The globalisation of this sector is creating concerns about the quality and the origin of the food products which is opening a place to collect as much information as possible from the whole supply chain.

In the food production chain, there are already many applications in Europe (Italy, UK, and Sweden), the USA and Canada where RFID technology was applied. Mainly large companies in the EU are dealing with distribution and retail (UK supermarket chain Tesco (Shanahana et al., 2009), an example of beef traceability from farm to slaughter RFID pilot (Ireland) (Watson, 2004)). These implementations are utilised on a national level which shows that the RFID technology implementation is mature and could be enlarged to an EU scale by linking a supply chain that involves companies in several countries, especially Small and Medium Enterprises (SMEs). With RFID technology used in their value chain, SMEs could benefit in (2010):

- Improved productivity and efficiency.
- Reduction in labour costs.
- Quality problems should be detected as quickly as possible with monitoring environmental variables using sensor networks.
- More efficient control of the supply chain due to increased information accuracy.
- Reduction of human errors from manual scanning operations.
- Better tracking and tracing of products.
- Enhanced profit margins.

The implementation of RFID pilots in different countries with hardware and software solutions including local and global database systems could impact on competitiveness and productivity gains nationwide and at the European Union level. Many SMEs would have opportunities to:

- Enlarge their market by increasing the productivity and selling their products in the EU.
- Employ more people or give the employees other work due to

automated processes with new technology.

- Assure and improve traceability in the EU.
- Intensify the competitiveness by the recognition of their quality and authenticity.
- Get help in the respective RFID application.

There have been several pilots of RFID in the food sector. Such projects are commonly centred on a major retailer which has control over its supply chains. Although they do show the potential of the technology, they are unsuitable as a model for SME's to gain value from RFID. This needs a business model which returns value to all stakeholders, and also needs to depend on an open standards regime, rather than one imposed by a large controlling stakeholder.

In the past, several European projects were launched to explore the feasibility of RFID in supply chain. Among them, the *eTrace* initiative is to focus on the use of RFID technology to gain visibility in a variety of food supply chains throughout Europe. One of the pilots tracked cod from the fishing boat to the processing plant, wholesaler and store, using Electronic Product Code Information Services (EPCIS) software (Swedberg, 2010). Benefits of using RFID in fish supply chain were already recognized in the fishery business in Scandinavian countries with the main objective to develop and evaluate traceability system (Thakur & Ringsberg, 2011).

Another European project called *TraSer* (2012) researched the linkage of the automatically retrievable identity of products (items in general) to identity-specific tracking and tracing, and related web services. The output was an open-source *TraSer* community which, through its web services, assists the targeted group of users (mainly SMEs) to improve their efficiency in changing environments, such as supply chains, service operations and project delivery networks. This concept of traceability of product through web services is obviously related to the project presented in this paper, and the project will build on the experience of *TraSer*.

Food is a specific case, which will require an additional element of traceability, in that it is perishable, hence the project presented in this paper proposes an extension to the webservices of *TraSer*, linking RFID traceability with sensor data (WSN) from the environments in which the products grow, are processed, stored and transported.

The paper presents two different pilot deployments of RFID and WSN technologies in farmed fish companies within the scope of the project RFID-F2F "RFID from Farm to Fork". The main objective is to define an applicable system which could perform the complete traceability by recording data at each stage. The pilots are deployed in two farmed fish companies in Slovenia and Spain and they are undertaken by University of Ljubljana and Universidad Politécnica de Cartagena with the technical support of the University of Wolverhampton.

At first, the paper presents the supply chain model of each pilot company and its business process. This is necessary to understand how the companies work and to be able to define the new traceability system. Afterwards, the RFID and WSN systems that are needed to automatism the collection of information along the supply chains are described. Finally, the novel system architecture proposed to integrate traceability information with WSN data through web-services is presented. The paper concludes with a discussion on the improvements achieved after the adoption of the new proposed system.

2. Business Processes in Farmed Fish Supply Chain

The basic objectives of each company are to capture data of a product moving upstream from a supplier to customer and to query data downstream to gain a shared view within the relevant business processes. The supply chain model in the farmed fish industry has special characteristics due to the type of a product being processed. The fish has high requirements on the traceability because its shelf life is very short and the cold chain must be maintained throughout the entire supply chain.

Another very important restriction of the product is that farmed fish supply chain must be as short as possible because of the short shelf life time. The lead time from when the fish is caught to when it is sent to the customer should be no more than 24 hours. All these requirements in the supply chain mean that any improvement in reducing the processing time of the fish is increasing product quality and, therefore, competitiveness of the company.

Therefore, it is necessary for the producers to monitor the information from their supply chain to ensure that their products arrive with the consumers in the

best condition. This information is collected along the entire supply chain and includes the following:

- Hatchery of young fish.
- Ongrowing farm.
- Processing.
- Warehousing.
- Transportation and Logistics.
- Retail.

In the continuation are described the business processes of the two companies in which the pilots are deployed.

2.1. Culmarex - Business Process

The Spanish pilot is undertaken in the company Culmarex. The company is an aquaculture enterprise that offers sea bream and sea bass of the highest quality in different sizes to satisfy a wide range of demand. Culmárex Group includes 7 companies, one breeding farm situated in Mallorca where juveniles are bred, 6 on-growing farms in several locations and a processing and packing plant in Águilas.

The basic business processes that are relevant to the project and that will be improved with the introduction of WSN and RFID technology are described. As already said, the business processes comprise three different locations, namely the breeding farm, the on-growing farms and the processing plant.

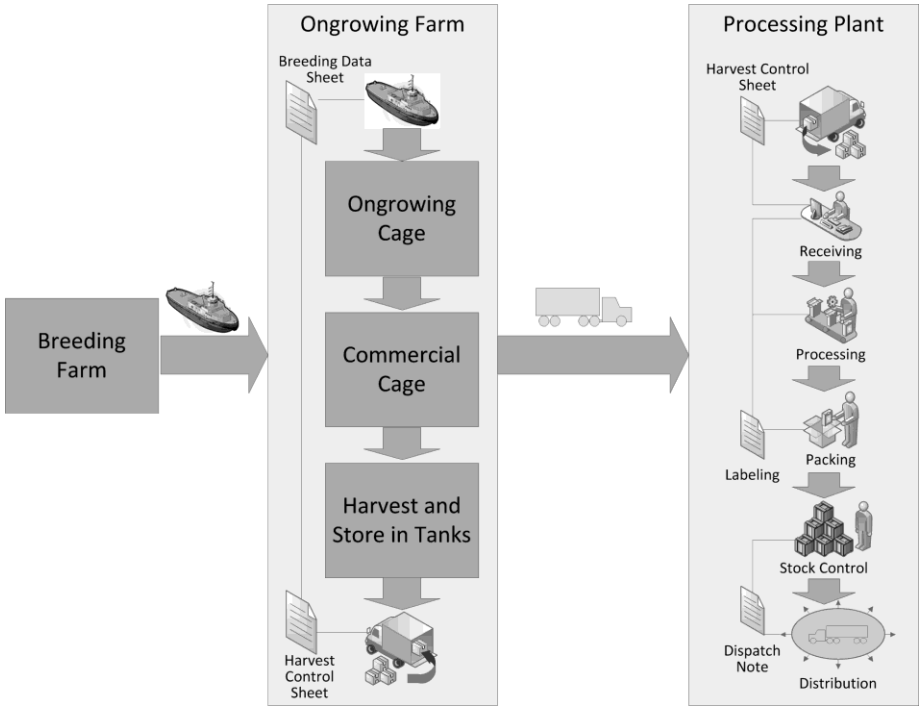

Fig. 1: Culmarex – business process.

The breeding farm is in charge of producing juveniles used in the 6 on-growing farms. The juveniles are transported from the breeding farm by prepared well boat. Juveniles are transferred directly to special cages moored in the sea. In the on-growing cages juveniles are reared to the company defined levels. When fish has reached proper size and weight, according to commercial needs, it gets transferred to commercial cages. In these cages, fish is maintained isolated until selling time. The harvest of the fish is done at night or at sunrise, collecting only the exact amount required, with no excess. The fish catch is done by estimation of the demand by clients. After harvest, fish is transferred in insulated tanks with sea water and ice until arrival at the packing plant. Then, tanks are loaded into refrigerated trucks and transported from the on-growing farms to the processing and packing plant. Paper sheets are used to collect traceability information during all this process (time of arrival, origin farm, etc.).

Finally, in the processing and packing plant the fish is weighted, sorted and packed. From there, orders from clients are collected, and fish is stored, packed and distributed to Culmarex clients by a fleet of trucks. In Fig. 1 we include a

more detailed graph of all the processes and tasks carried out at the three different locations. The aim of the pilot is to introduce WSN and RFID technology to improve and to automate these tasks, and to efficiently store and manage the data generated throughout all the processes.

2.2. Fonda.si - Business Process

In Slovenia, a small fish company Fonda.si was the focus of the second fish pilot within the project RFID F2F. They bread the sea bass in northern part of Adriatic Sea. As the previous company, the breading takes place for about three to four years in normal conditions that are similar to the fish living in an open sea, which ranks the quality of a grown fish as very high. Fig. 2 shows the supply chain of sea bass which comprises the Ongrowing Farm, the Processing Plant, the Logistics including warehousing of fish in Coldstore with distribution to Retail and also the sale at the Fish Market.

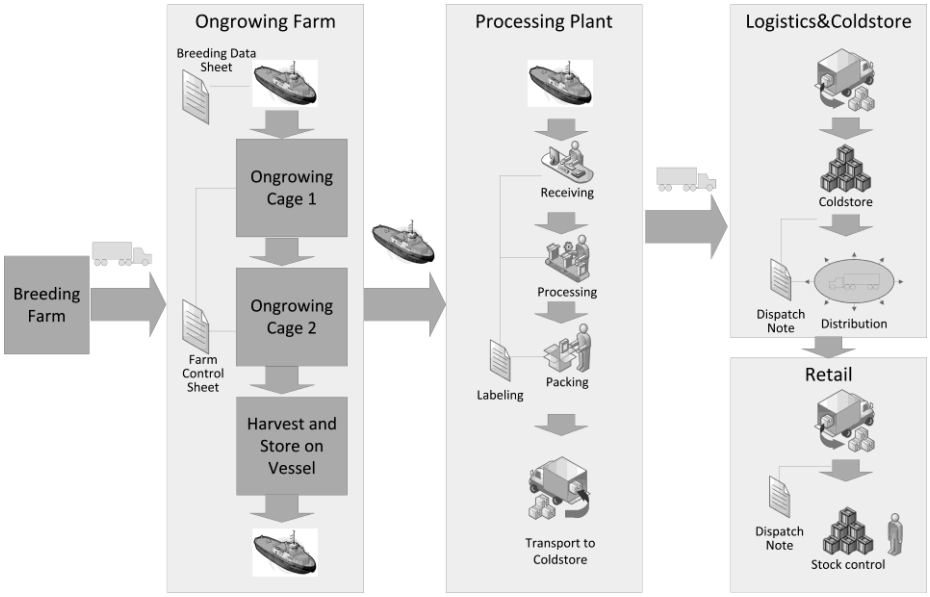

Fig. 2: Fonda.si – business process.

The Ongrowing farm processes include the arrival of juveniles in tanks by truck from the Breeding farm followed by moving them between cages during the growing period. The breeding conditions and quality of sea bass are monitored and the regulatory collected data is stored in Farm data sheets.

The supply chain processes are carried out in a reversed order as compared to the previous example. The whole process starts with assembling orders from customers on a catch day to define the quantity to be harvested. The sea bass is placed in tanks and brought from sea on a vessel to the processing room. At first, each fish is weighed sorted and packed to the boxes which define the category of sea bass. After that, customer orders are prepared based on the collected information. Two employees are needed to perform the weighing of boxes and writing the information on the box and to data sheets. Each fish is then tagged with paper tag to identify a producer-brand and the day of catch, covered with ice and transported to Coldstore. Data is written on paper forms and updated to a computer to prepare delivery orders for the transport to take place next day. The second day, fish is delivered to retails, restaurants, fish market and private customers. The company covers the whole supply chain for most of the companies selling sea bass in Slovenia, Italy and even Austria.

3. Traceability Solution

In the paper, the use of RFID technology in developing a fish pilot as part of the project "RFID from Farm to Fork" along the complete supply chain is shown. It will be used in all stages, starting from fish farms to the delivery to market, including all intermediate stages: transports, processing, packaging and storage. The main objective is to define an applicable system which could perform the complete traceability by recording data at each stage. Traceability data will be stored in a global database system accessible by each partner and will be useful to determine and control the perfect conditions of the cold chain of the product. Thus, the goal is to show that all parties, including consumers and producers would take advantage of such systems. Consumers, when buying a fish labelled with an RFID tag in the surroundings of a RFID reader, installed in the supermarket or even as an application at each personal smartphone could access the product information over the Internet. Producers could use RFID to control their production, perform inventory, control storage conditions, and other.

In the presented pilots, the deployment of RFID systems at specific locations, in order to improve the business processes is shown. This will be an integral RFID solution applied inside the companies taking part in pilot implementations to get the maximum benefit based on a new technology. The two pilot companies despite being in different countries and be of different sizes are

currently using a similar traceability system. Their traceability system is not automated and they don ́t use IT systems to monitor the data.

The system they are currently using is depicted in Fig. 3. The companies collect all traceability information manually. This means that to collect information, company workers fill in several paper sheets manually, these papers travel together with goods along the supply chain. At each point of supply chain new data are filled in paper sheets or new paper sheets are produced. At the end, a lot of information sheets are produced to control traceability and they are stored properly.

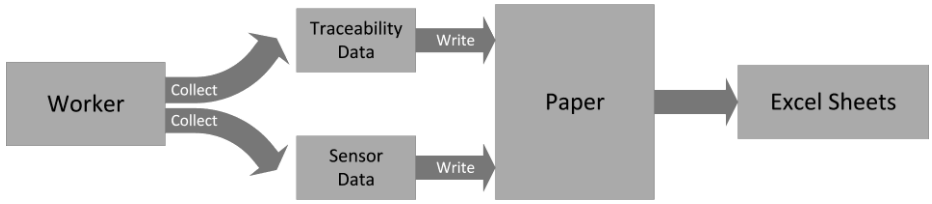

Fig. 3: Current traceability system based on manual collection of information.

After the process is finished, some data are entered from paper sheets into computer applications (Excel sheets) by workers to allow the Company to access to critical information easily. This work method produces a lot of wasted time collecting information and it is prone to errors during transcripts.

At present, both companies are not using any standardized labelling system. In the case of Culmarex, they are currently using a barcode system that is not compliant to any standard. They have built their own bar codes with internal meaning and not following any standard. In the case of Fonda.si, no barcode system is used to identify boxes in the supply chain. All boxes have paper labels with regulatory defined information, such as expiry date, LOT number, and other.

The traceability system architecture of pilots was defined at the project level. This system architecture will be implemented by all the pilots in the project, although the particular form for the implementation will and may vary depending on the actual pilot project. Globally, the system architecture for pilot implementation is shown in Fig 4.

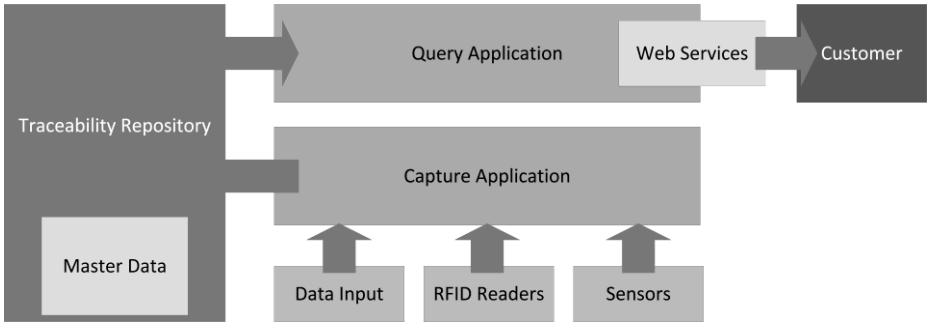

Fig. 4: RFID - Pilot implementation.

It can be observed that the overall architecture has four main components. On the first component we find:

- RFID hardware that can be used to implement traceability operations related to the specific business process of each pilot. In general, this node may contain barcode readers, handheld readers of many types, and RFID readers, among others. It is up to each pilot the definition on the actual hardware that will be needed at this node. This definition shall be made on several important basis, such as availability, compatibility with standards, and in general adequacy to the intended business processes implementation.
- Sensor hardware composed of specific sensor components that will collect relevant parameters of the environment, such as temperature, humidity, salinity, etc. The specific design of the wireless sensor network and of the hardware used will again depend on the particular pilot implementation. This design should be based on the best possible matching between the environment and the business process to be run by the company.

In the second component is included the software needed for the system, and it generally consists of capture applications and query applications. These applications serve to connect the physical data received from hardware to the traceability repository, and to allow external software to query the repository.

The third component is the traceability repository. It is used to store the relevant traceability data generated during the business process of the company. There are two kinds of data in the repository: event data and master data. Event data is created in the process of carrying out business processes, and is captured

through the Capture Application and made available for query through the Query Application. Master data is additional data that provides the necessary context for interpreting the event data (for instance different locations where the event data occurred).

The forth component corresponds to web-services provided to end users. The idea is to create a service that presents all the information collected during the business process of a particular company to the relevant end-users. This information can be accessed by simple web-browsers and shall be presented in a user-friendly way. For this purpose, we propose in this work to use a novel web-services architecture that is able to integrate information about traceability with the information gathered by the wireless sensor network.

3.1. Culmarex - Pilot Implementation

As already said, the hardware and the software to be developed will be dependent on the particular business process to be run in each pilot. Therefore, one of the key factors in the project was the definition of the information model and business processes relevant to each pilot.

It can be observed in Fig. 5 that the pilot implementation will comprise two different sites. The first one is the sea-platform where the on-growing and commercial cages are placed. The second one is a packing plant used to produce the final fish boxes ready for selling and to store them if necessary.

The scope of the RFID pilot will begin with the arrival of the well boat with the juveniles to the on-growing farm and will end with the shipping of fish boxes to clients.

At the on-growing farm handheld readers will be used. They allow storing information in a database at each step of the farm supply chain. Therefore, an application for the handheld device is written to perform this operation. This application consists of several application forms one per supply chain step.

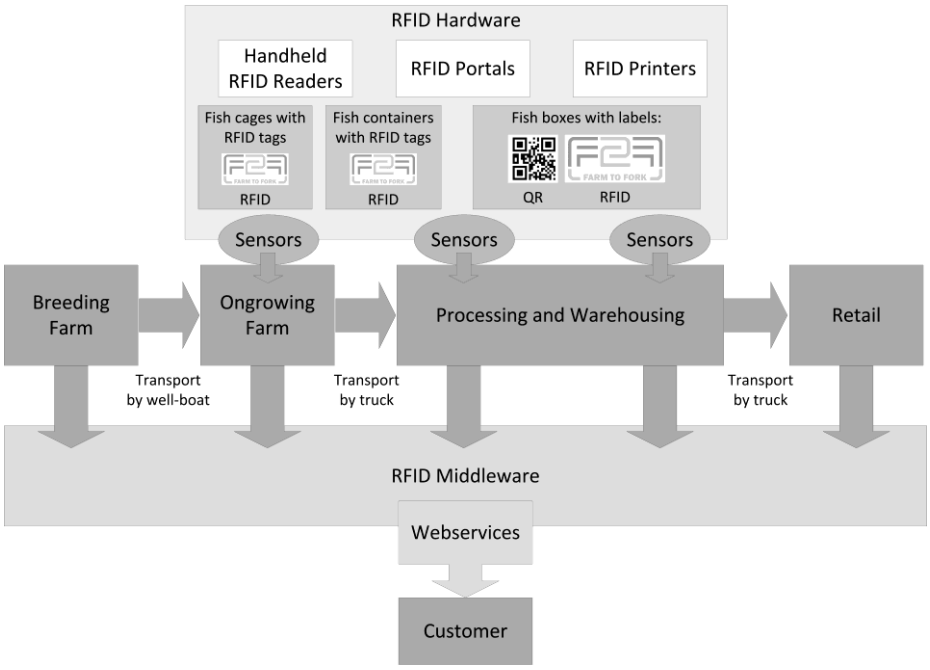

Fig. 5: Culmarex – pilot implementation.

Every cage is tagged with an RFID tag. The temperature of water is monitored with sensor loggers. These sensors are read with handheld readers at the sea platform. A sensor logger is also included in each tank to monitor the fish temperature in the transport from farm to processing plant. Additional research can be done by tracking other parameters during transportation, like temperature in real time, GPS position, and open door alert and so on.

At the Processing and Packing Plant, handheld reader and fixed readers are used. The implementation is as follows:

Fist business step is receiving the tanks with fish. The handheld reader uses an application form for storing receiving process data.

When the tanks are received, they are inserted in the sorting machine by a gate and then the fish is downloaded from the tanks to a pool. An RFID portal is installed at the entrance gate, with a fixed reader and several antennas that read the tank ́s EPC tag as they enter through the gate. Business events are stored in a database. At the same time, the tank ́s temperature sensor logger is read and data is stored in a repository.

The sorting machine has software that generates important data for business process, such as weight, number of pieces, size, etc. In order to include these data in the system, it is needed a new application to link data from the sorting machine to the system repository. This is done by reading the barcode that produces the sorting machine, process the data and store them (barcode reading is done only for pilot purposes; in a future it is expected to link sorting machine to our system and avoid this reading).

In order to identify each fish box, it is needed to tag them with an RFID tag. The sorting machine has printers that admit the installation of an RFID module over it which will allow them to print and write RFID tags. The memory of tags will be encoded with an EPC number, while the paper label will be printed with the same information and barcodes used so far. Operators will stick the tags on fish boxes, as they are currently doing now.

Then, boxes go to the conveyor belt where an RFID portal with a fixed reader and several antennas reads the tag and stores the box identification on the repository, changing the state of the box to ready for sale. In this way new prepared boxes enter automatically to stock and can be traded immediately with relevant clients.

The last process is shipping. RFID portal will be installed with a fixed reader, several antennas and a control PC. A system to insert orders and to check orders with loaded goods in trucks was developed in order to avoid shipping errors.

Regarding sensors, temperature and humidity sensors are installed to control processing, packing and cold store rooms environment. Wireless sensor loggers are used in key locations across the rooms for a complete coverage.

3.2. Fonda.si – Pilot Implementation

The proposed RFID pilot of sea bass which is shown in Fig. 6 collects tracking data from four steps in the supply chain: (i) Farm; (ii) Processing; (iii) Coldstore; and (iv) Retail.

At the farm, in a process of breading sea bass in cages the following actions are maintained: receiving juveniles at the farm, movement of sea bass between cages, food and medicament information, and other inspections of cages (number of dead fish, nets replacement, conditions of nets). On the harvesting days, the information of transporting sea bass in containers is included to the

database. All these operations are implemented as applications on the handheld RFID reader. Cages on the farm are identified with RFID tags and scanned during each action to insert the information connected to that cage.

The processing consists of two steps: (i) collecting orders, and (ii) processing, packaging orders for transport. The traceability data in the proposed RFID solution is collected during the process of preparing and packing boxes by customer order. To each expanded polystyrene box is attached RFID label with printed information as QR code where IDs will match. Each fish receives also a paper tag with pre-defined expiry date and boxes are prepared for the transportation. The implementation of processing orders comprises of an electronic scale, a personal computer, an RFID printer, RFID data loggers and RFID labels. The system generates traceability data and information needed for delivery documentation.

From the processing room are all packed boxes transported to cold store, stored there overnight and delivered to the customers (retail, restaurants, supermarkets and private customers) on the next day. An RFID portal (fixed RFID reader with two antennas) is used at the Cold store input/output door and connected to a computer with the running application to control the shipping and receiving logistics processes.

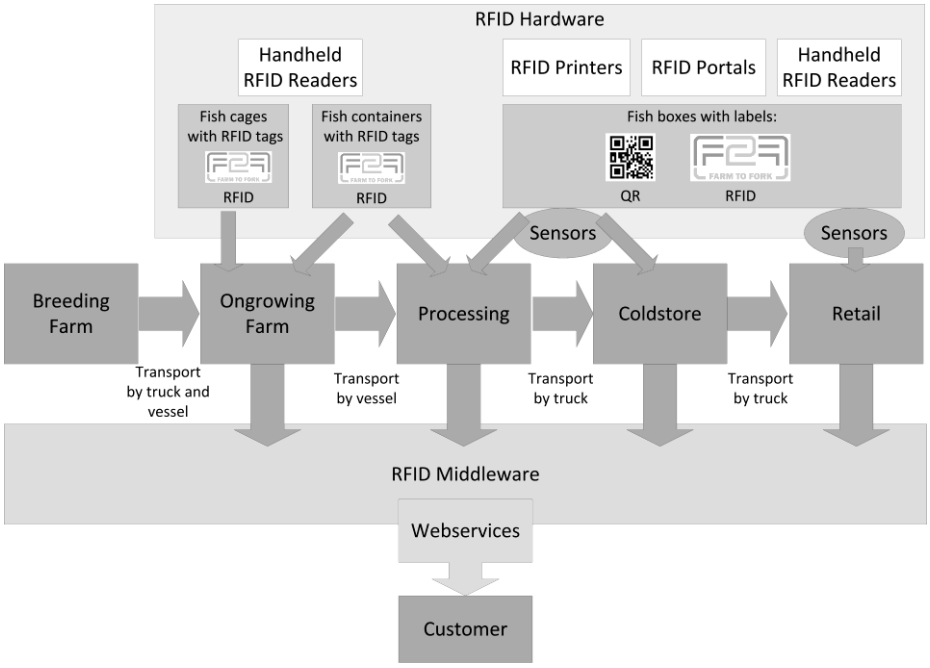

Fig. 6: Fonda.si – pilot implementation.

Tracking of sea bass in the pilot solution ends in retail with the delivery of boxes to the fish market where the application on a handheld RFID reader is used to read EPCs of boxes and temperatures measured with RFID data loggers during the logistics process. Boxes are stored in the refrigerated room and fish is available for sale.

3.3. Customer Information

As part of the system, it has been deemed meaningful and valuable to expose some of the collected information to the customer, with particular regard to product origin and conditioning. Doing so has been proven in other sectors to both raise the customer confidence on the companies involved and at the same time to increase the perceived value of the products (Ward, 2005).

To make it possible to link a particular product with the traceability backend, items have to carry, up to the retail point, a machine readable ID which identifies the smallest logistic/traceability unit the system can supply information about. This ID can in general be carried in the form of a barcode (linear or 2D-dimensional), an RFID tag (UHF or NFC) or a mixture of the above where and when convenient. For our pilots, the choice for the primary customer-facing identifier has fallen on QR Code, which allows the desired information to be conveyed to any QR Code-capable Smartphone, removing the need for the installation of specialist equipment at the point of sale (fish market/retail store/restaurant). This ID, which must be readily accessible by the customer, can be either physically attached on the item (e.g. label on the fish gills), on the item container (e.g. polystyrene box) or packaging (e.g. cellophane wrapping), on the shelf/market stall or directly printed on a restaurant menu.

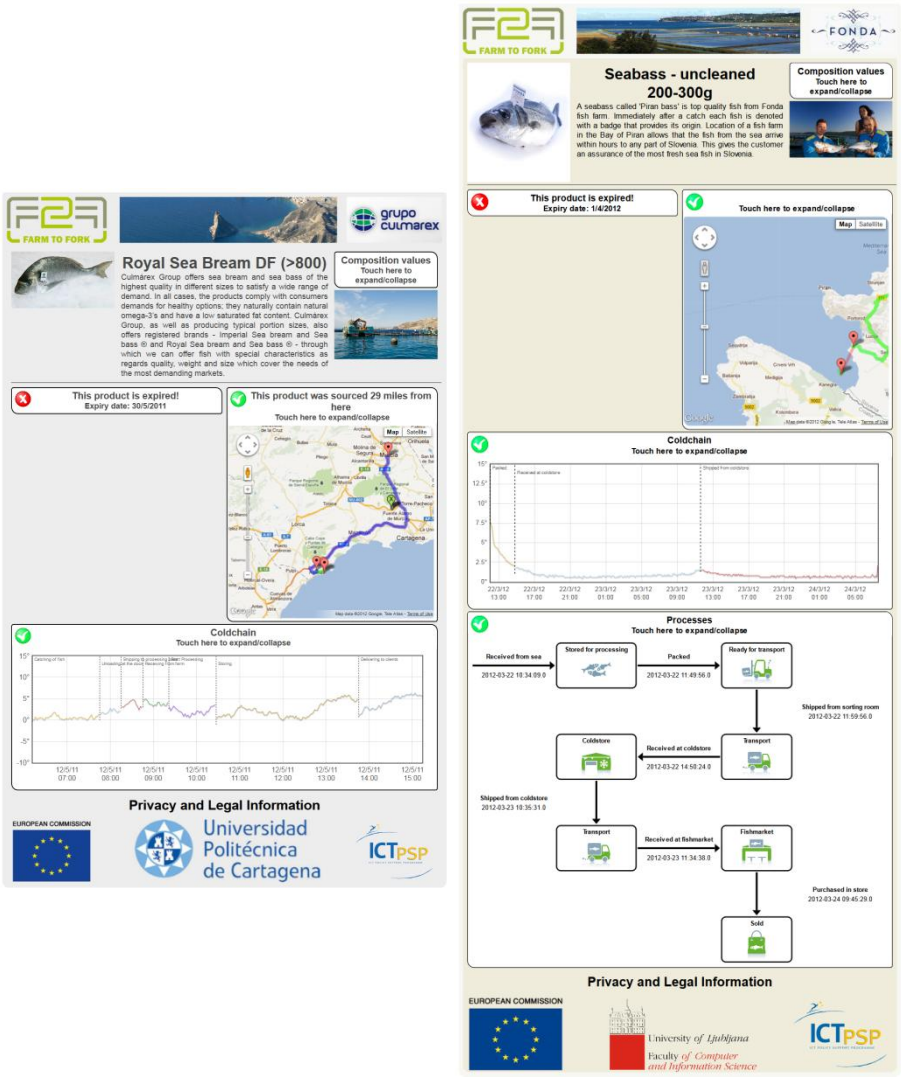

Fig. 7: Web page with traceability data: a) Culmarex b) Fonda.si.

Upon scanning, the ID is passed by the Smartphone to the online traceability system, which collates all the information from the entities that have been involved in handling the product (fishing boats, processing plant, logistics etc.). This information mostly comprises of times and dates, names of processing steps and states, locations and sensor data (temperatures). The information is then filtered in real time by the system, which makes it anonymous, collates and renormalizes it by translation from an event-based description into a set of higher-level summative views, which are more meaningful to the customer.

The information is then transformed into a visual representation in form of a web page – images, graphs, maps, diagrams and descriptions (see Fig. 7a and Fig. 7b) and presented to the customer along with a "traffic-light" coded signaling system which shows, at a glance, how close to the ideal range each piece of information is.

As an option, customer feedback can be collected, either manually - in form of a questionnaire - or automatically – for example by tracking the relationship between a particular item being scanned and the same item being subsequently purchased.

4. Discussion of Results

The food business is the one that provides huge potential for demonstration of return on investment for RFID. The technology has been proven to provide a return on investment by:

- Assuring the authentication of the origin of foodstuffs, thereby increasing consumer confidence and allowing access to premium markets.
- Reducing wastage and optimizing logistics costs.
- Increasing quality of goods to the consumer.

In the two presented farmed fish pilots, the paper shows how these technologies can be integrated into their supply chain model. The overall supply chain is covered from the breeding farm to retail (this last business step only in the case of Fonda.si) and there are a lot of advantages on adopting the technology.

The resulting pilot architecture deployment will allow to the companies to study the improvement of the processes involved and the return of investment they can get from it. It is important to highlight these benefits because they will be the reason for companies adopting the technology. There are some general benefits that have been identified, for instance: the automation of the processes will reduce the personnel work and the collection of information will make it possible to access traceability information in real time. But also, for each company depending on its own implementation additional benefits have been identified.

In the case of Culmarex, the improvements that will be reached with the introduction of the technology are the following:

- Automation of temperature readings inside farm cages. (Now reads are done manually).
- Computerize traceability information. (Now most traceability data are on paper).
- Reduce staff work by removing traceability handmade sheets.
- Reduce staff work by Customer access to traceability data by web (Now a person has to collect all handmade sheets to send them to the customer).
- Automation of shipping and receiving processes avoiding errors in these processes.
- Ensure the cold chain supply by the sensor network and keep recorded sensor data.
- Reduce personnel by automating box reads (Now 1 person is dedicated to this work).
- Increase accuracy and update time for stock by automating box reads.
- Increase customer confidence and improve company image.
- Ensure the proper Shipping process by using the RFID portal and RFID tags on each box or pallet to verify the delivery orders.

In the case of Fonda.si recognized as a small company, the improvements that can be identified with the introduction of RFID technology are following:

- Computerize traceability information. (Now order data and traceability data are on paper).
- Reduce time of the employee by removing handmade sheets which are later copied to a computer sheets.
- Reduce number of working persons in Processing .
- Automation of shipping and receiving processes avoiding errors in these processes.
- Ensure the cold chain supply by the sensor network.
- Increase accuracy.

Increase customer confidence and improve company image.

5. Conclusion

The project 'RFID from Farm to Fork' proposed the aforementioned pilot implementations in the farmed fish supply chain as a means to highlight the use of RFID and sensor technology in conjunction with a global EPC-compliant structure to collect, store and display the data from the farm up to the end customer. The proposed RFID solution, composed of hardware and software modules, is currently in the implementation phase after having been tested in a laboratory setup. In the next phase, the goal is to transfer the RFID system framework to a full integration with the enterprise information systems. The smaller pilot in Slovenia is already deployed in company where more tests are performed to measure the performance of the system, test and improve applications and to evaluate the implementation. The adopted solution offers an example of a flexible, scalable and interoperable system that can be easily transferred to any business processing of farmed fish.

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