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Prototype traceability system for the dairy industry

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A R T I C L E I N F O

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A B S T R A C T

At the beginning of the milk manufacturing process, a refrigerated bulk tank lorry is in charge of collecting milk from dairy farms in the area within a few hours. In this process, a milk sample is also collected at every farm. At the end of the collection the milk contained in the tank is analyzed. The problems appear when the analysis reveals the presence of forbidden substances at levels above stated thresholds in the milk tank but not in any of the samples; this is mainly due to the extremely low levels that are being considered for some substances and the way in which they rapidly deteriorate at high temperatures. Therefore, all samples must be kept in optimum – temperature controlled – conditions during transportation to ensure reliable results in the laboratory. In this paper, a novelty solution for the tracking and tracing of milk samples is presented. This solution includes a customized and automated cooler for carrying samples, a smart sensor inside the cooler saving the data collected during the process, and an USB sticker to transfer the collected data to a computer for further analysis. Several technologies have been combined to register and trace milk samples on their trip from farm to laboratory: microcontrollers, sensors, Radio Frequency Identification (RFID), and Global Positioning System (GPS). Hardware and software prototypes have been successfully developed and tested in real vehicle case studies.

1. Introduction

Traceability, as defined by the International Organization of Standardization (ISO, 2000), is "The ability to trace the history, application or location of that which is under consideration". Product traceability is the guarantee for assuring the quality of products. The dairy industry is no exception, as milk quality is affected by several factors such as animals' health, raw milk handling, and external parameters like the addition of water, among others. Moreover, if the collection and transportation of raw milk are not appropriate, milk can suffer a large loss of quality.

In 2010, Lilcam (a local laboratory for the control of the quality of milk production) and Asaja (a local association of farmers) contacted the Autolog Group at the University of Castilla-La Mancha (Spain) looking for a system to ensure the quality of milk samples in the milk manufacturing process. As milk from all farms is mixed in the same tank lorry, Lilcam and Asaja requested a system to trace milk samples. When a problem is detected in the tank (typically antibiotics at extremely low concentration levels), the milk from all farms has to be discarded. Furthermore, as the total quality of the milk in the whole tank will be the average of that obtained at all farms and this is the only analysis usually being carried out, farmers are being paid only according to their production and not proportionally to the specific quality of the milk they are selling. To motivate farmers to produce better quality milk, it would be very important to improve the process of acquiring and transporting samples, so that all of them could systematically be reliably analyzed. Being able to identify the samples, collect the information about when, where, and by whom were them incorporated into the sample carrier, and trace the temperature of the samples is fundamental to improve the process, thus increasing the quality of the product.

This work focuses on reliably tracing the milk quality during transportation from the milking process to large-scale milk processors. A smart-sensor system is presented that includes a temperature sensor, an identification reader, and a geographical localization system (Global Positioning System, GPS) in order to track individual milk samples.

The structure of this paper is as follows: Section 2 presents the background of this work and discusses the related work. Section 3 describes the hardware of the proposed three elements in this implementation. Section 4 shows the communication between sensors and the way they are programmed (their firmware). Then, the results and analysis are discussed in Section 5. Finally, the last section presents the most relevant conclusions and future work.

2. State of the art

A Royal Decree has been published in Spain to ensure the hygienic–sanitary quality and safety of raw milk, enforcing European law. This Decree regulates the control of traceability and quality

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of raw cows' milk. It establishes a management computer system of traceability (named LeTRA Q) that declares the guidelines that should be followed in the sampling and in the dairy laboratories. In addition, the Royal Decree makes it obligatory to carry out several controls on the farm through the milk process. Sanitary conditions related to the smell, color, temperature, and other properties should be checked, verifying the non-existence of antibiotics with a test carried out at location, and collecting a sample to be taken to the laboratory for analysis following a sampling plan. The sampling plan is also regulated by Royal Decree, which states that samples must be stored above 0 °C and below 4 °C if no preservative is added and below 8 °C when a preservative is used. However, there is no reference to the maximum time that can elapse from sampling to analysis. Only when preservatives are not present it is permissible to transport samples at temperatures below 6 °C for transportation times under 24 h. At present, this Decree only refers to cows' milk, although there are plans to extend it to milk from other ruminants as well.

Bar codes are widely used for the identification of samples, associating codes with farms. Nevertheless, it would be desirable to extend the tracking with information related to when the sample was taken and by whom.

There are many studies about the importance of traceability systems in agricultural goods. Noteworthy is the application of Radio Frequency Identification (RFID) technology (Finkenzeller, 2010) to provide automatic wireless identification of products. "RFID – From Farm to Fork (F2F)" (F2F, 2012), is one of the most ambitious projects in this area. F2F is a European project led by the University of Wolverhampton working with eight other partners, representing five European Union states. The aim of the project is to showcase RFID technology in the food and drink industry and to identify and trace food information along the supply chain. In the aforementioned European project there is an interesting approach which combines Wireless Sensor Networks (WSNs) with RFID in wine traceability from vineyard to consumer (Catarinucci et al., 2011).

There are in literature several works regarding the traceability of the samples taken from raw cows' milk, but they are focused on the use of biotechnological methods. Thompson et al. (2009) proposed a bulk milk transportation security system that controls access to the milk during transportation. This system collects the information in a handheld device connected to an online database. Voulodimos et al. (2010) presented a platform for livestock management. It was based on tagging animals with RFID rewritable tags used as data repository to identify and track animals. Samad et al. (2010) proposed a system to certify the veterinary records of animals on dairy farms using RFID, mobile readers, and the Internet; in this way, details of the veterinarian performing the specified controls, the animal, and the examination results are stored in data servers for future queries. Dabbene and Gay (2011) introduced a methodology for measuring and optimizing the performance of a traceability system in case of recall actions in response to a food safety crisis. There are some studies related to the control and monitoring of the cold chain. Jedermann et al. (2009) studied the evolution of the temperature inside containers (pallets) using semi-passive RFID tags with temperature sensors for the transportation of perishable food. That work also presents a formulation to calculate the optimal number and location of the sensors. In this line, Amador et al. (2009) presented a solution for temperature mapping of the pineapple supply chain that also used RFID. Other authors proposed a three-level integral tracking system using passive RFID, semi-active sensor RFID, and GPS for use in the whole supply chain (Abarca et al., 2009; Gª-Escribano et al., 2012). A similar solution was proposed for terrestrial logistics using WSNs instead of sensor tags (Santa et al., 2012). Temperature monitoring of meat supply chains has also been reviewed (Raab et al., 2011). Wang et al. (2010) presented a mathematical model to predict the quality of goods supported by the information collected using RFID and WSN. As can be seen in the bibliography, the use of RFID in applications related to tracking of goods is common. Nevertheless, a specific stand-alone solution for the application of milk-samples tracing, which is the aim of this paper, has not been found in the bibliography. A deeper literature review of the use of RFID in agriculture is presented by Ruiz-Garcia and Lunadei (2011).

3. Proposal for the tracing of milk samples

The present work deals with the development of a system for ensuring milk quality starting at the collection process taking place at the farm. When collecting milk from a livestock area, a refrigerated tank lorry makes collections from dairy farms in the area through a process taking a few hours. Before collecting the milk from each farm, the driver collects a sample to be saved and transported in the cabin for further analysis in the laboratory. At the end of the collection from all the farms, the milk contained in the tank is analyzed. If the analysis reveals levels of substances above stated thresholds, the samples collected by the driver are analyzed separately to find out the origin of the problem.

Samples that travel in the lorry are the only credential by which milk processors can justify the quality of their products. Some studies evidence how, over time, heat adversely affects the conservation of milk (Bertrand, 1996; Borrás et al., 2008). As the small sample containers have little thermic inertia, they require to be kept in the proper preservation conditions to avoid fast degradation due to rapid temperature changes and other external agents.

This paper proposes a solution that starts by identifying samples through RFID tags on the sample tubes. These tubes/samples are stored in a grid inside a portable electric refrigerator (connected to the power supply of the collecting vehicle). The refrigerator is equipped with a small RFID reader and a GPS unit. It only opens when the RFID reader identifies a valid new sample. Once the new sample is introduced in the refrigerator, it is automatically locked again. The grid storing the samples also holds an electronic sample tube. The refrigerator sends the identification of the new sample and the geographical coordinates to this electronic tube (smart sensor), which stores all the information. The smart sensor also stores a timestamp for the opening and closing operation of the refrigerator. In addition, it incorporates a temperature sensor to periodically check and store the temperature inside the refrigerator with the corresponding timestamps. In this way, all of the information is stored in the electronic tube that travels with the samples.

Once the collection route has been completed, the rack carrying the samples and the electronic tube is taken to the laboratory while the refrigerator usually stays in the vehicle. The electronic tube keeps recording temperatures and timestamps even when outside the refrigerator. At the laboratory, the samples are taken into controlled storage and the information in the electronic tube is uploaded into a computer for further analysis.

The following subsections show the different elements of this tracking system. The proposed system is, therefore, divided into four basic components: sample tubes provided by RFID tags, the electronic tube that records all the information, the cooler hosting the GPS and RFID units and capable of writing the information to the electronic tube inside it through a radio-link, and the USB dongle for downloading the information stored in the electronic tube to the computer in the lab trough the radio-link. Fig. 1 shows the interaction between the three basic components of the proposed network and the analysis and control staff. The following sub-sections describe each component of the network in detail.