Harvest management and post-harvest technology

Scientific and technological research article

Design and implementation of a software for the traceability of coffee processing

Diseño e implementación de un *software* para la trazabilidad del proceso de beneficio del café

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Abstract

This article describes the implementation of a software which allows supporting coffee producers in the process of obtaining a certification of origin for their product according to the regulations established for trade in agricultural products, especially monitored in the European Union since January 2005. This regulation set down the requirements for a follow-up that guarantees the authenticity and traceability of the food, which satisfies the final consumer. The project was carried out using the Scrum framework and the eXtreme Programming (XP) software development methodology. The results showed that the integration of the framework and the method allowed organizing the work in phases and achieve incremental results. This application represents the first step to generate added value in a coffee farm through the traceability registration of their products.

Keywords: coffee industry, computer programming, food safety, food traceability, quality controls

Resumen

Este artículo describe la implementación de un *software* que busca apoyar a los productores cafeteros en el proceso de certificación de origen de su producto, de acuerdo con la normativa establecida para el comercio de productos agrícolas, especialmente vigilada por la Unión Europea desde enero de 2005, que estableció la necesidad de hacer un seguimiento que garantice la autenticidad y la trazabilidad de los alimentos, y la satisfacción de las demandas de calidad del consumidor final. El proyecto se realizó utilizando Scrum como marco de trabajo y *eXtreme Programming* (XP) como metodología de desarrollo de *software*. Los resultados mostraron que la integración de ambos instrumentos permitió organizar el trabajoen fases y obtener resultados incrementales. Esta aplicación representa el primer paso para generar valor agregado en una finca cafetera a través del registro de trazabilidad de sus productos.

Palabras clave: control de calidad, industria cafetera, inocuidad alimentaria, programación informática, trazabilidad de los alimentos

Introduction

In a global economy, food must travel long distances to get from the producer to the consumer (Zailani, Arrifin, Wahid, Othman, & Fernando, 2010). Therefore, it is increasingly necessary to closely monitor the quality and safety of these products through multiple mechanisms (Wang, Yue, & Zhou, 2017).

Tracking strategies are used for this purpose and are known as traceability tools. According to Costa et al. (2013), traceability includes all those techniques and technologies that allow locating an animal, specific merchandise or a food product and make a historical study of the origin and the processing to which it was submitted. This definition is in line with the one proposed by the European regulation 178/2002 (Zhang, Sun, & Liu, 2011).

According to Zhang et al. (2011), the first activity that is required for a traceability system to work is a good product labeling; this is achieved through barcodes (Colom, 2004) or radiofrequency identification devices (RFID) (Ha, Song, Chung, Lee, & Park, 2014). In the work of Badia-Melis, Mishra, and Ruiz-García (2015), a series of technological devices used to register food traceability are detailed.

In addition to the label, it is necessary to process a large amount of information such as the characteristics of the place of origin; the variables that were handled during the transformation, storage and transport processes; and the data of the people or organizations that intervened during the generation of the final product (Buhr, 2003), among others. A conceptual model of a framework for a food traceability system that integrates hardware technologies (global positioning system [GPS], identification labels, and devices to capture, store and visualize images) and software (information systems) is described by Aung and Chang (2014).

Currently, there are many examples of traceability in different areas: wines (Stranieri, Cavalieren, & Banterle, 2018, Vázquez et al., 2016), seafood (Costa et al., 2013), vegetables (Xinting et al., 2008), beef (Neto, Rodriques, Pinto, & Berger, 2003) and pork meat products (Wang et al., 2017), bacteria in food (Melo, Andrew, & Faleiro, 2015) and coffee (López & González, 2012), among others.

The society of today demands more information on everything related to its food products, which translates into the implementation of traceability systems available for the entire supply chain. In the specific case of coffee practices, it is important to identify soil characteristics, altitude, microclimate, crop location, coffee variety, cultivation and processing methods, as well as the people involved in the process (farmers, producers, processors, cooperatives, exporters, importers, roasters, shopkeepers, among others), since all these elements influence the quality of the final drink, and also allow establishing practices with fairer prices and the use of more environmentally friendly techniques (Puerta, 2013).

In Colombia, there are more than 563,000 coffee-based family businesses, and around 90,000 are located in the department of Cauca in Colombia (Federación Nacional de Cafeteros de Colombia, 2017). Most of them carry out artisanal processes concentrating their efforts on the production of raw material (coffee volumes), and many only transform the product into dried parchment coffee (even, many only reach the stage of wet pulped coffee), without generating added value to the marketing chain. Moreover, there is unawareness of the main features and specifications of the additional processes that allow obtaining a quality product. The lack of a traceability record by coffee producers causes a lack of control and monitoring of the product until it reaches the final customer. This generates a competitive disadvantage inherent in recognizing Colombian coffee as one of the best in the world, turning it into a generic article without identity.

In coffee traceability, several stages are identified, and different tasks are carried out in each of them (Evangelista et al., 2014). Each of these stages is explained as follows. The first phase is the harvest of the cherry coffee, in which the collectors collect the fruits of the coffee bush (cherry) and places them inside their baskets; the allocation of baskets and collection rows is done by the cutting pattern. With all the cherry harvested, the coffee is classified and pulped. The classification is done through an automated system that divides them into the following classes: decaffeinated coffee A+ (coffee to be exported as very high quality coffee), decaffeinated coffee A (coffee exported as high quality), decaffeinated coffee B (sent to standard export) and decaffeinated coffee C (sold for internal consumption). The criteria for classification are size, quality, and degree of maturity of the cherry (Federación Nacional de Cafeteros de Colombia, 2007).

The next treatment is to extract the cherry beans (pulped) in their respective hopper (one for each variety, except for the C class that is not pulped). Subsequently, the fermentation begins, in which the A+ and A classes pass to different tanks (depending on the class, the variety and the date of collection) where they are fermented; similarly, class B grains go into fermentation tanks, but before all the varieties come together in a single group. The coffee for internal consumption is not fermented, nor pulped, nor washed, and is left to dry directly. Once the coffee has been fermented, it goes to the washing stage, where the grain of each tank is washed using an automated system, in which a measurement of the weight of wet coffee and of the coffee that has been discarded must be made. Finally, it is passed to independent drying rooms where the water level is controlled according to international standards (Correa et al., 2016, Espinal, Martínez, & Acevedo, 2005). The coffee processing process is summarized in figure 1.

This work is the result of the initial construction phase of a software platform that makes a traceability record of coffee in its processing process and that, in the future, will allow certifying the origin of the product. The progress reported here was validated at the facilities of the company Supracafé Colombia S.A.

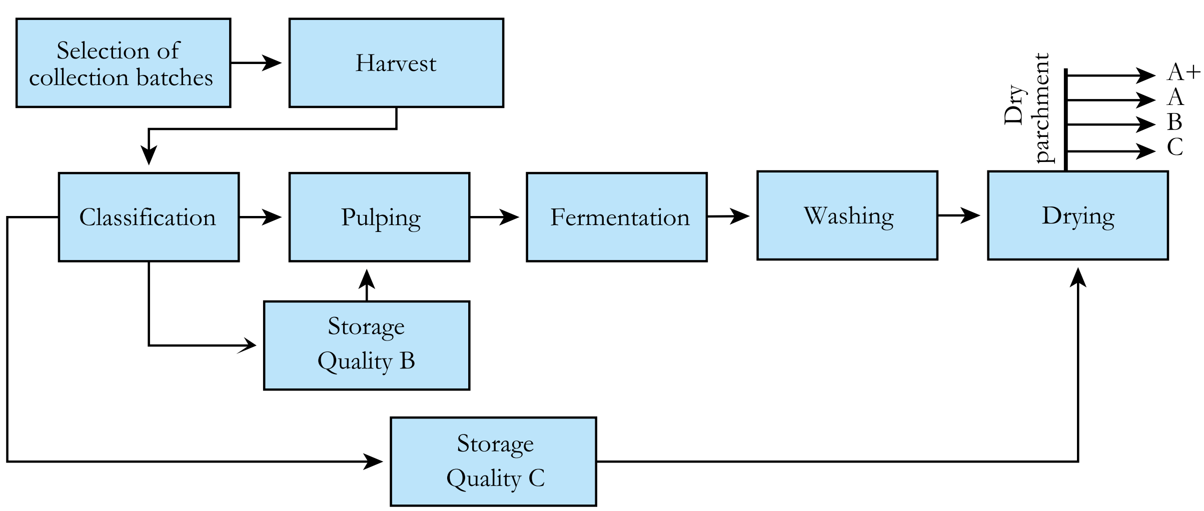

Figure 1. Flowchart of the coffee processing process.
Source: Elaborated by the authors

Materials and methods

One of the allies in the development of the software tool was Supracafé Colombia S.A., an organization dedicated to the production of high-quality coffee, whose farms are located in the plateau of Popayan (department of Cauca), at altitudes that vary between 1,700 and 1,900 m above the sea level. It has a department for R+D+i from which it supports the development of research and innovation projects. The company was established in 2008 aiming at generating value in the coffee chain, implementing innovations and development projects through strategic alliances with government institutions and the academia, based on the following premise: the specialty of a coffee begins in the farm where the coffee is produced. Currently, this organization has managed to differentiate itself by its remarkable improvements in coffee production and preparation. The development activities were carried out for the coffee processing process at the farm Los Naranjos located in the municipality of Cajibío (Cauca department, Colombia) (Supracafé, n.d.).

In Supracafé, the processing process has been standardized after several years of uninterrupted work; it consists of six sequential stages (figure 2), and its purpose is to convert the coffee fruit (cherry coffee) into parchment coffee ready for packaging and export (Federación Nacional de Cafeteros de Colombia, 2007, Ocampo-López et al., 2017).

After a process of analysis carried out jointly by the engineers in charge of development and the agronomists of Supracafé, the fundamental variables that are part of the traceability of the coffee processing process were identified:

- Recollection (harvest)
- Classification
- Pulping
- Fermentation
- Washing
- Drying

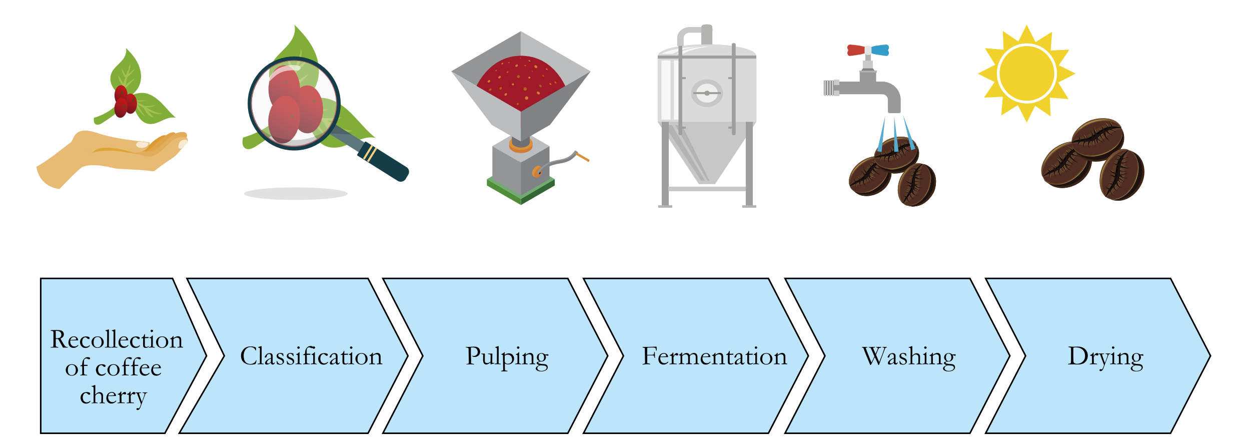

Figura 2. Stages of the coffee processing process.
Source: Elaborated by the authors

Subsequently, the six initial basic functionalities that the application should provide were established as follows:

1. Harvest record: it allows recording who made the harvest of the coffee cherry, as well as the approximate day and hour, assuming as a measure of collection a basket of 28 kg. This record will additionally store information about the start and end batch of the collection.
2. Estimated quality record: In this process, representative samples of baskets are taken at random, and an estimated percentage of green, ripe, overripe, bits (with damage caused by the coffee berry borer) and floating grains is recorded. This information has several purposes: to encourage collectors to harvest the best quality grains; estimate if the collection process is getting late (data on mature grains); observe and take corrective actions regarding pests (data on beans damaged by the coffee berry borer).
3. Hopper entry record: here the date and hour in which the entry process to the hopper is carried out is recorded to continue with the selection by quality and pulping; it is necessary to record the quantity by weight of the qualities known as inferior, B and C.
4. Fermentation record: in this record, the duration time of the fermentation is stored; the quality of the coffee; whether or not inoculum is applied and its quantity; Brix degrees of the inoculum applied; the minimum and maximum temperature of the environment during the fermentation process; and liters and Brix degrees of the inoculum produced.
5. Coffee washing record: this record keeps the date and hour when the washing process is carried out.
6. Coffee drying record: finally, this process records the date and hour when the coffee drying process begins, the type of drying process and the end date of the drying process.

The team chose Scrum as a framework for the multiple advantages it offers: application of good practices, collaborative work, the formation of flexible and adaptive work teams, and an iterative and incremental approach that accredits partial and regular deliveries of the product, according to the prioritization criteria established (Schwaber & Sutherland, 2017).

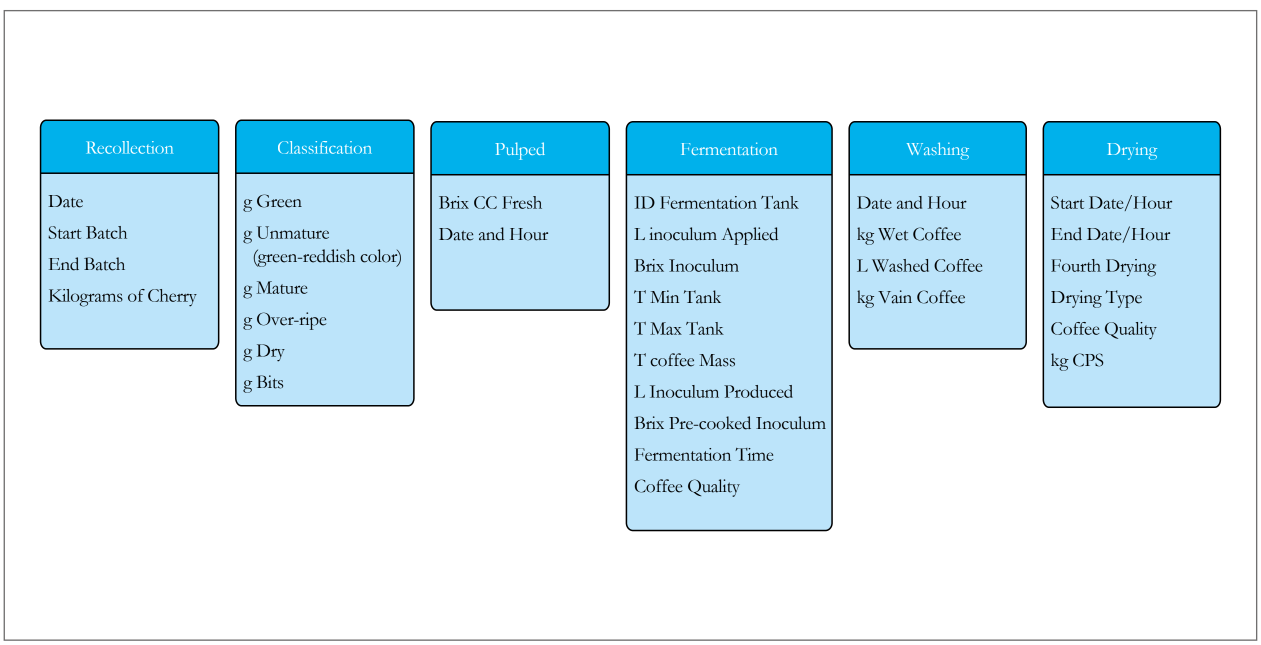

Figure 3. Variables resulting from the analysis of the traceability information in the coffee processing process.
Source: Elaborated by the authors

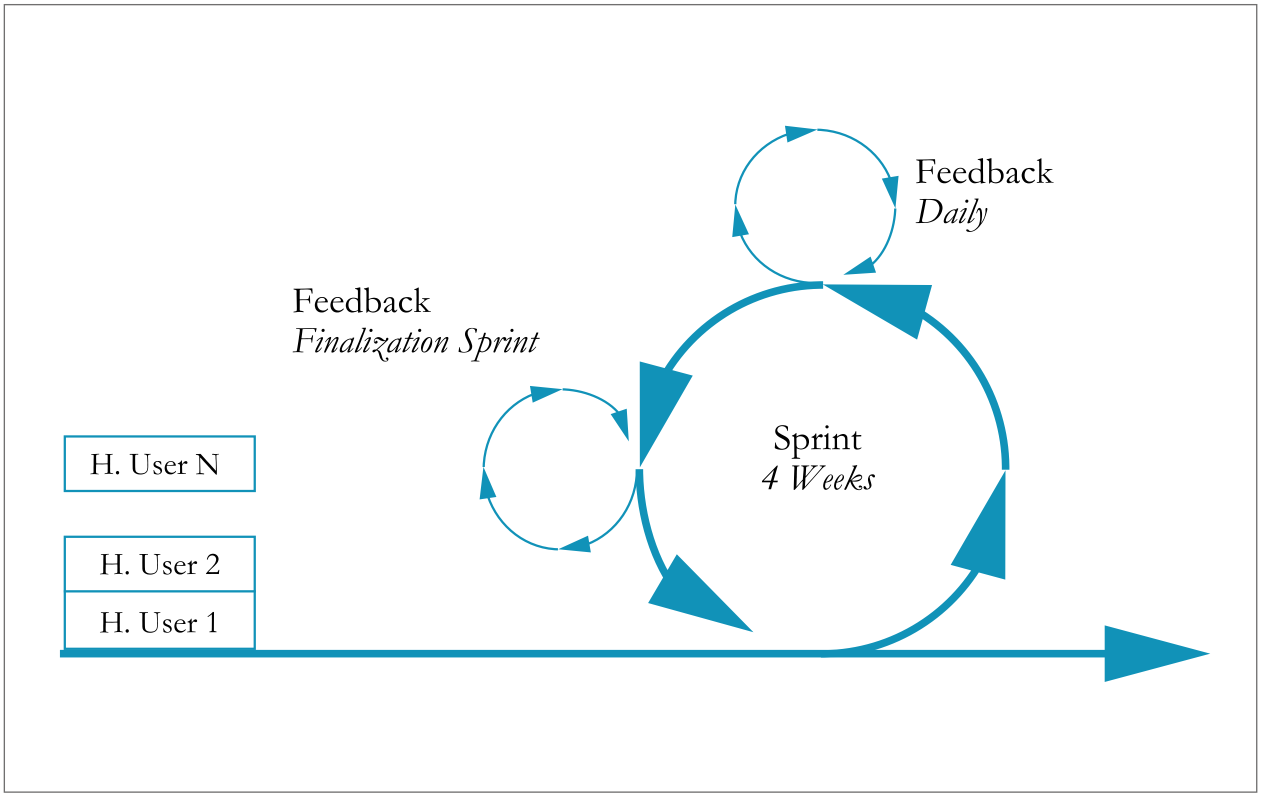

Figure 4. Scrum framework.
Source: Elaborated by the authors

The work team defined the functionalities of the system and, subsequently, these were divided into user stories, which were evaluated and prioritized according to the criteria of the end user. The user history with the highest priority enters the sprint, which means that it starts its implementation, and the maximum duration time is four weeks. Feedback was obtained, and daily work objectives were set to carry out error control quickly and guide the daily work.

If the user story ended before the end of the sprint, the next one was continued according to the order of duration and priority. When the sprint was finished, the priority of each user story was re-evaluated, and a new sprint was started. At the end of each sprint, there was a fully operational functionality. A diagram of the basic functioning of the Scrum framework is shown in figure 4.

For sprints that contained user stories that involved software development, the agile development methodology software, eXtreme Programming (XP), was used, which is comprised by the following six phases (Beck & Andres, 2004; Maurer & Wells, 2011):

1. Exploration phase: the general scope of the project was defined; the client established the user stories (cards in which the client describes in a summarized way the features that the system must have), and the development team became familiar with the tools and technologies that were used.
2. Delivery planning phase: the client assigned a priority to each user story, and the developers estimated the effort required for each of them; the parties agreed on the content of the first delivery and its corresponding schedule.
3. Iterations phase: the programming established in the previous phase was divided into a certain number of iterations; at the end of the last iteration, a complete system is expected to be established.

The following three phases, although explained below, are not the focus of this document, given that it is a slow and long-term process in which the real impact of the system will be established:

4. Production phase: The system is delivered to the user to perform tests and adjustments in a real environment.
5. Maintenance: during this phase, customer support tasks are performed parallel to the execution of new iterations.
6. Death of the project: the implementation of user stories concludes, and other customer needs are met such as performance, safety, and reliability of the system and, besides, the final project documentation is built.

Results and discussion

Exploration phase

The team defined the functionalities of the system (figure 5), which were described in previous sections. They were implemented from the analysis of the coffee processing process, the identified variables and the expert knowledge of professionals working in the company Supracafé and who supported the process.

Some examples of user stories (seven stories) can be observed in figure 6; the priority hierarchy is represented by colors: red, for high priority; yellow, for average priority. Each story involved the execution of two or three activities to be completed, given their nature. All have a software development component, which was made with the XP methodology, composed of the six phases shown above. Given the initial scope of the project, only the first two were executed: planning and iterations.

Planning phase

Based on the needs expressed by the user (user stories), a series of requirements were established that were divided into functional (describe how the system operates) and non-functional (derived from the inherent features of the system operation). Figure 7 shows the requirements that were implemented in the developed system.

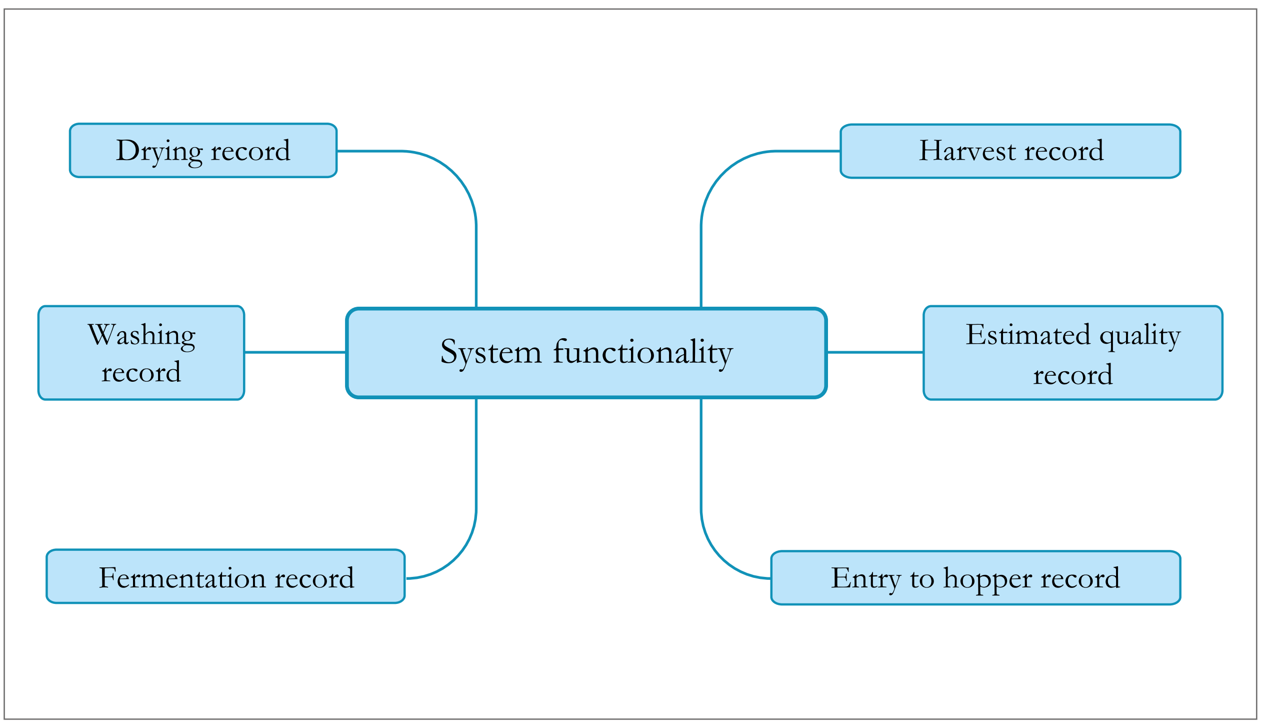

Figure 5. System functionalities.
Source: Elaborated by the authors

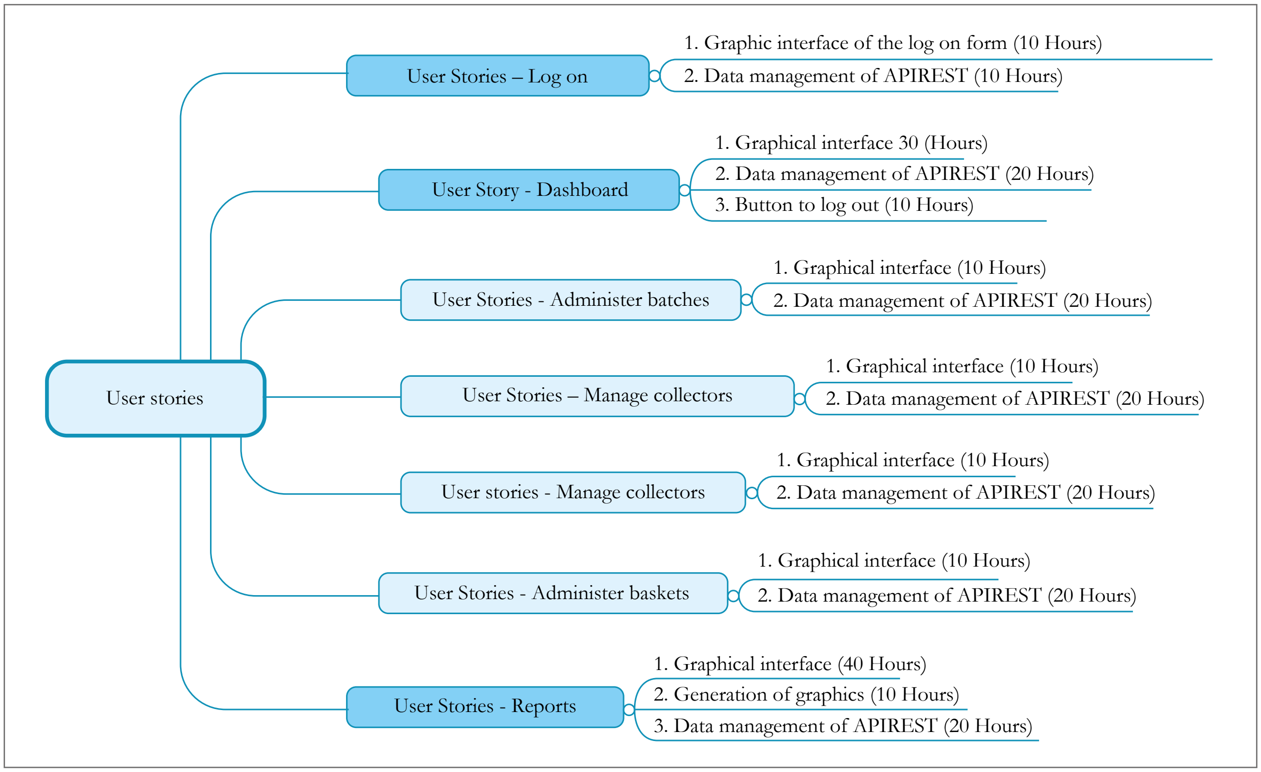

Figure 6. Examples of user stories for the development of the system.
Source: Elaborated by the authors

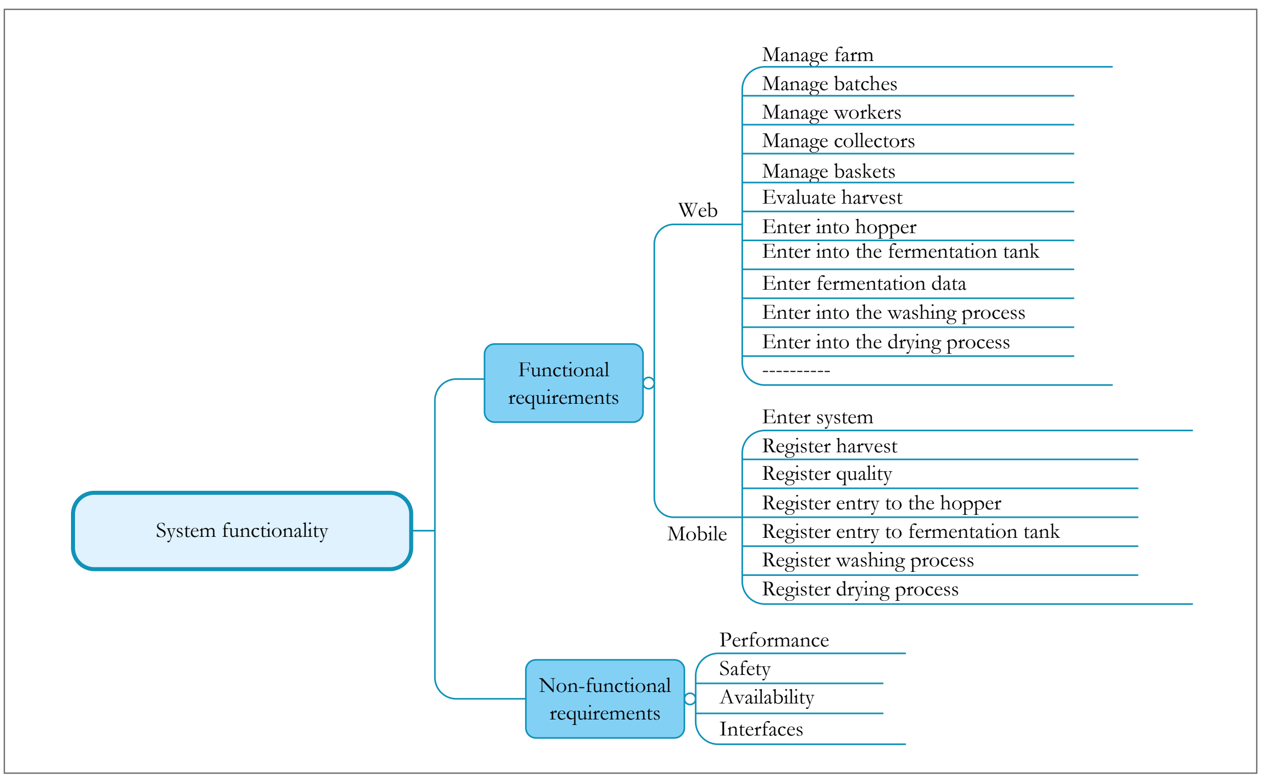

Figure 7. Functional and non-functional requirements of the system.
Source: Elaborated by the authors

Considering the described characteristics, the implementation of a client/server type architecture, in which the development of a Frontend (a website that the user can access directly, it is related to all the web design and development technologies that run in the browser, and is responsible for the interactivity with end users) and a Backend (application that connects to the database and the web server, whose function is to manage the information displayed in the Frontend) were suggested for use. A detailed view of the architecture of the system can be seen in figure 8.

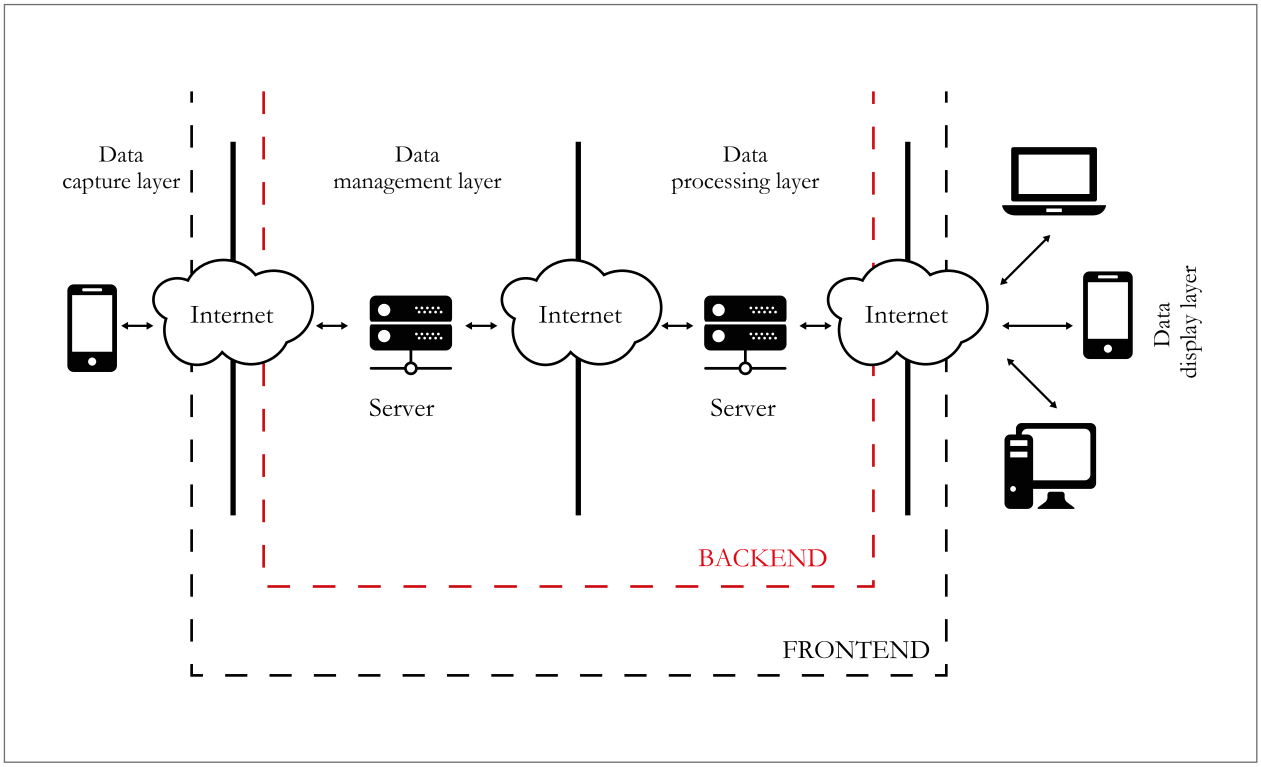

Figure 8. System architecture.
Source: Elaborated by the authors

The tools selected to carry out the programming of the system were Angular JS to program the web application, and Node JS, as a development environment; the libraries needed for the development are grouped in the NPM tool.

Iterations phase

During the different iterations, several applications were developed. Figure 9 shows the user interfaces of the mobile platform (Frontend) that allowed reaching the functional requirements.

The functional web requirements were covered by programming a Web application. Figure 10 shows the Frontend web user interfaces of the system.

It is worth mentioning that both the mobile as well as the web Frontends require the use of a support platform (Backend), which was designed as a cloud computing service, which allows the integration of all the information.

This integration is essential to record the traceability of the coffee processing process; however, to carry out its verification, the progress and possible improvements of this development is an arduous task that requires the active participation of the end users. This essential feedback and tests in the actual scope are under execution.

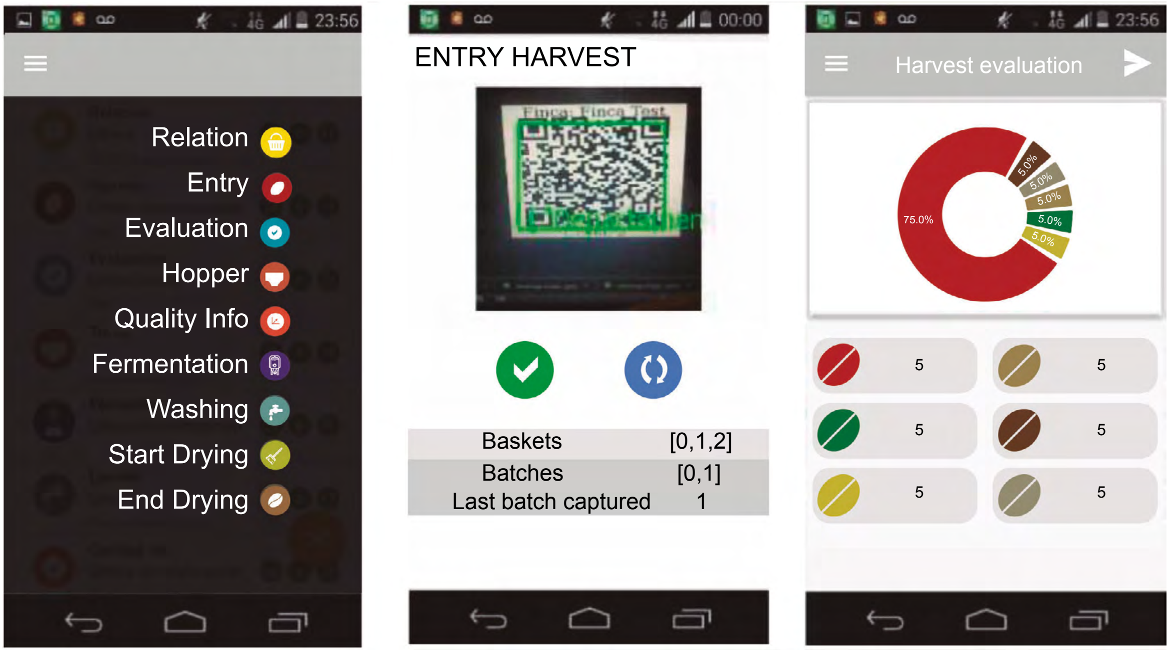

Figure 9. User interfaces for the mobile application.
Source: Elaborated by the authors

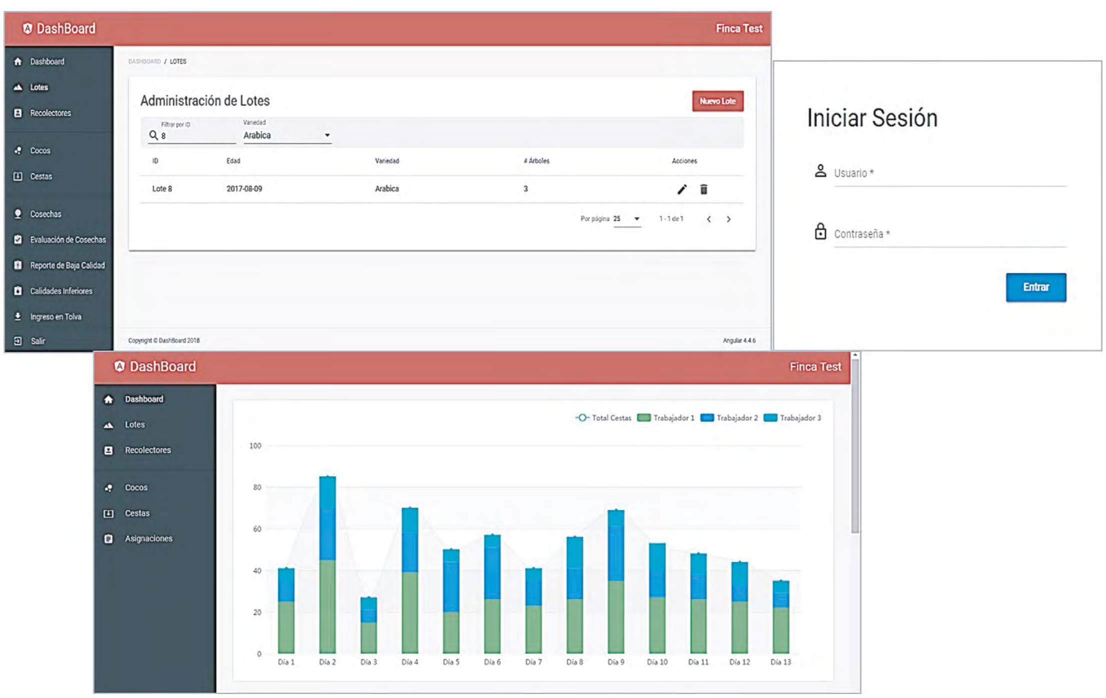

Figure 10. User interfaces of the web application.
Source: Elaborated by the authors

Conclusions

The use of Information and Communication Technologies (ICT) in different agricultural sectors allows the optimization of tasks: response times can be improved; information can be centralized and timely monitoring of processes can be carried out. All this goes hand in hand with a participatory process and training with the community.

At the farm Los Naranjos of the company Supracafé manual records were used and, in the best case, also Excel spreadsheets for the management of the traceability data in the coffee processing process. These practices usually generated waste of time during the data entry; additionally, the possibility of committing errors due to an involuntary alteration or omission existed, causing errors when performing their subsequent processing. The idea of automating these processes through the development of a software tool seeks to support the coffee industry.

Keeping the traceability record in the coffee processing process generates a competitive advantage over other coffee companies, which adds to the requirements of the final consumer who demands quality products. These arguments show the need to build devices that support the monitoring of the transformation and product distribution processes, especially regarding agricultural products.

The Scrum framework and the XP methodology were effective to fulfill the functionalities, since they facilitated the integration of several processes and techniques, to build complex products from iterative and incremental processes, in which each participant had a defined role. In the first stage of the implementation, the application allowed users to generate general reports of their coffee production as the quantity of cherry coffee collected in a given time and the percentage of conversion of coffee cherry to dry parchment coffee.

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Disclaimers

All the authors made significant contributions to the study and the document, and agree on its publication; moreover, all authors state that there are no conflicts of interest in this study.

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