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Information technology applied to the process of traceability in the wheat supply chain

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The adoption of traceability systems in the food chain is a market differentiator for manufacturing firms. It is appreciated by consumers and is more and more common after the occurrence of certain problems related to food consumption. Legislation, quality standards and best practices now govern the traceability process. The aim of this paper is to address the main regulations that establish procedures for ensuring the safety of food in terms of traceability, and also to present the evolution of information technologies in this area. Although, the latter are still being developed, there are still many opportunities for growth and innovation. As a result, it is possible to see the commonalities between the models of traceability, and also to identify the points of the supply chain of wheat in which the processes are focused.

Key words: Traceability, quality management system, information technology, wheat.

INTRODUCTION

Brazilian market has increased its grain production, from 76 million tons to approximately 184 million tons from 1993 to 2013, respectively. About wheat production, this country is one of the greatest producers, nearly about 6 million tons in 2013 (MAPA, 2013). These statistics reinforce the importance of developments in the control and monitoring of the stages of the wheat production cycle.

Agricultural supply chains include products grown in different ways, regions, periods of the year; transported and stored by different means; all of these being important features that defines the traceability process. In this context, traceability makes it possible to recover the history of production process, from planting to the final product, regardless if the produced wheat for domestic consumption or for export, since in both cases, traceability is an important tool and contributes to the quality of the final product. The objective is to ensure food safety, guaranteeing the consumer's right to information regarding the origin of the product, and also the right to avoid the consumption of ingredients, for reasons of food intolerance, lifestyle or religion. An example, are the food codes of some religions that rule which animals can be eaten and how they must be slaughtered , prohibiting its consumption and mixing meat with dairy foods.

Traceability is established by rules/regulations that are related to quality and the certification of food products. The purpose of this article is to describe the standardization inherent in food safety, presenting the

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evolution of information technology systems that have been applied to the traceability of grain, and more specifically, wheat, in order to meet the requirements of the customer.

THE TRACEABILITY PROCESS

The importance of traceability in the food chain gained momentum in the 1990s, after the occurrence of incidents involving the consumption of beef from animals affected by bovine spongiform encephalopathy (BSE), commonly known as ‘mad cow’ disease.

Various occurrences of contamination of grain in the food industry are described in the literature. Karnal bunt fungus (Laux and Hurburgh, 2010) was found in wheat by the inspection service in the United States in 1996. This resulted in a reduction in exports, although the area of infection was limited to a small section of the State of Arizona. In this case, the process of traceability made it possible to determine the affected lots, thereby making it unnecessary to recall all wheat production.

According to Eckschmidt (2009), there is a degree of coverage within the production chain that makes it possible to classify traceability requirements. The greater the knowledge about a production chain, the greater the credibility of the information about the final product. Levels of traceability can be classified into 'basic', 'simple' or 'complete'. The first two are represented by information based on the credibility of the supplier, expressed in product labels; the difference between the two categories is that in the ‘simple’ category numerical codes are used to indicate the origin of the product at any point in the production chain. In ‘complete’ traceability, the product is followed along the entire chain, making it difficult to falsify information, but also requiring the complete participation of all agents involved at all stages.

The quality of information that is traced is equally as important as the level of information, which is directly related to the degree of confidence that the product will bring to consumers. The recorded data can be informative, validated or certified (Eckschmidt, 2009). When the information is validated or certified, it is confirmed by the authorities and physical evidence is collected, generating greater credibility for the supplier.

An important point, in terms of defining the level of traceability, is the knowledge of the risk points in the production process. The use of quality standards can meet this need because they are geared towards food safety.

The Hazard Analysis and Critical Control Points (HACCP) system (Furtini and Abreu, 2005) has been used by food production companies for the prevention and control of risks inherent to foods, particularly in relation to quality of health.

ISO 22005 (ISO 22005:2007) established standards for implementing a traceability system throughout the entire production process. In the ISO standards, traceability is the ability to recover the history, application and/or location of an activity or a process, or a product or organization, by registered identification.

Both the HACCP and the ISO standards establish best practices for developing traceability processes, with standards and procedures regarding environmental conditions, facilities, equipment, human resources, technology, control and quality assurance, storage, transportation, etc.

The technologies adopted for the implementation of traceability processes in the grain supply chain were developed following the cited norms, standards and regulations.

REGULATIONS

In 2002, after the occurrence of ‘mad cow’ disease, the European Union created Regulation 178/2002 (REGULATION, 2002), establishing principles and standards of traceability at all stages of the production, processing and distribution of foodstuffs. In this regulation, traceability is defined as the ability to trace and follow the trail of a foodstuff, animal feed, any animal that produces foodstuffs, or a substance intended to be incorporated into foodstuffs or in animal feed, or expected to be, throughout all the stages of production, processing and distribution.

The regulation cites the need to establish a comprehensive system of traceability within the food sector, to enable withdrawals from the market in an organized and precise manner, or to inform consumers or employees responsible for such control, thereby avoiding unnecessary disruption to the safety of foodstuffs (Regulation (EC) 178/2002).

This regulation became mandatory, stating that all exports to the European community would have to comply with the regulation to ensure the participation of producers on the local, regional and global scale.

In Brazil, Normative Instruction no. 20 of 9/27/2001 (MAPA, 2001) established Integrated Fruit Production. This program established a set of agricultural best practices, necessary for registration, so that producers can be certified. It targeted the monitoring of diseases, pests and environmental conditions in order to guarantee food safety.

In 2008, the program was expanded to the wheat production chain (Tibola and Fernandes, 2009), initiating the integrated production of wheat, which was intended to work towards the quality assurance of that grain. The monitoring of production, from the farming stage onwards, is designed to ensure a product that is distinctive, traceable and of certified quality. The wheat lots are segregated when they are received at the storage unit according to their characteristics of interest, such as variety, business class, or purpose of use (bread, pasta, cookies, etc.).

Normative Instruction no. 27 of 8/30/2010 (MAPA, 2010) established guidelines for systems that develop integrated programs. The principles are prioritized, based on the search for quality, safety of agricultural products, health, sustainability, certification, traceability and monitoring of the process, through the adoption of field and post-harvest notebooks to record relevant information regarding the stages of the productive chain.

The adoption of an integrated program by producers is not mandatory, but membership allows increased competitiveness in domestic and foreign markets through certifications held by private companies. This certification consists of the audit process in the farms that joined the system; once the requirements are met the farms receive a seal of compliance. The trend has been that there has been an increasing adoption of this system by producers because current demand indicates a prioritization on the part of consumers for products produced in standardized, production systems based on rationalization in the use of inputs, minimizing environmental impact, the optimization of operating costs, in addition to segregation, qualification and assurance of food safety (Tibola, 2007).

The regulations that govern and guide the implementation of a traceability process are not only applied in public policies related to food safety. Changes in government regulations have been accompanied by a rise in standards in the private sector, which may include rules on equipment, infrastructure, modes of production, quality management; the latter often stipulate stricter requirements than those described in public regulations and laws (Hammoudi et al., 2010). In this context, it is important to cite the GS1, Global Standard (GS1, 2009), which although not a regulation, is a global standard that is recognized worldwide for the identification and coding of products through barcodes, thereby contributing to the evolution of solutions related to traceability.

One of the tools for implementing traceability in the supply chain is the GTS, Global Traceability Standard (GS1, 2009), an independent technology that defines the minimum requirements for a traceability system, which also meet legal requirements. To perform tracking using the GTS standard, it is necessary that the traceable items, as well as the physical locations, have a GS1 identifier from the moment of registration until use. This standard does not compete with other international standards, such as ISO or other certifications of the food chain, but it helps companies and organizations meet these requirements by providing tools to achieve the desired level of traceability.

The technical manual of traceability for the wheat production chain (Fernandes and Tibola, 2009), establishes certain requirements for the implementation of a traceability system according to the GS1 standards. Parts of these requirements are as follows:

1. Registration of those participating in the traceability process, such as producers, transporters, storage companies, milling companies and the food industry;
2. Registration of lots, as a traceable unit, corresponding to the silo where the product was stored;
3 .Registration of the number of the silo where the grain was stored; information about the source and quality from the production phase, and the dates of the processes performed;
4. Use of computational tools to facilitate the register and transfer of records and also information regarding traceability.

The technical manual of traceability states that in relation to this last requirement of the process (the use of technologies to facilitate the recording of data) the records can be made by producers or technicians at the farm in spreadsheets that can be scanned in sequence or in electronic equipment with online systems for automatic data transfer. Therefore, some levels of traceability are legal requirements in certain sectors. However, as well as the mandatory requirements of traceability, companies are also developing voluntary processes in order to protect their brand and to ensure that their products are safe, making traceability a vital part of the supply chain.

This research will now address the information technology required to meet the demands of traceability processes.

THE EVOLUTION OF TECHNOLOGIES APPLIED TO GRAIN TRACEABILITY

Some applied technologies are described below, which have evolved and which have contributed so that traceability in the supply chain of grain is performed and recognized by consumers and the food industry.

The RIG model – The Integrated traceability of grain

In order to meet standards and protocols regarding the traceability of food and agricultural products, the RIG Model, the integrated traceability of grain, was developed in 2006 (Leonelli, 2006). This model consists of systematic management steps that allow for the promotion of integrated traceability in the grain supply chain. It was initially designed for the soy industry, but it can be used for other grain production chains.

The scope of the RIG model was defined for the activities of selecting inputs, planting, cultivation, harvesting, grain storage, processing and logistics. It is composed of three stages of information: (i) constraints against the adoption of mechanisms for identification and traceability, (ii) planning activities, and (iii) operations management.

The first stage covers regulatory aspects, both mandatory and voluntary, which influence the adoption of traceability mechanisms by the company. These aspects help to understand the needs of consumers in relation to what will be traced by setting the level of detail. The second stage concerns the planning of operational activities, such as the relevant attributes to be traced, characteristics of the product and its manufacturing process, specifics of where the product was produced, and information related to the labor used in production. Even at this stage, the critical control points regarding the most relevant information are defined. The critical nature of the traceability process can vary according to the size of the production chain, the number of agents involved, and the complexity of the relationship between the links of the production chain. This model allows these critical points to be defined and makes it clear which procedures can be audited.

The third stage systematizes the operations defined in the previous stages, that is, it guarantees the recording of information about inputs, planting and cultivation according to the standards of the product in question, such as harvest, storage and logistics. Of all the processes that are capable of being recorded, storage is one of the most complicated because the object in question is granular and farms do not always have an environment which can ensure the requirements for identification and traceability.

This model contains a proposal for a structured framework for managing the traceability of grain, which assists the implementation of traceability systems.

The RG system – Traceability of grain

The RG system, the traceability of grain (Ceruti, 2007) was developed to evaluate a program for traceability and preserved identity for wheat, documenting the entire process from receiving, drying, storage and processing, and focusing on insect management during storage.

The method traces samples of wheat in silos, during storage, after the use of various types of traps for insects and the application of insecticides. The RG system allows for the logging of data related to the production process, where both the product to be tracked and the entire production and storage process are customizable. Conceptually, the system was designed so that each product to be tracked is an 'entity' that has 'phases' that can be tracked through 'processes', for which required fields are created.

Using software, it is possible to quickly trace the processes in order to retrieve information requested by the industry, solving problems such as the quality of wheat flour. In addition to the modules that allow the registration of the whole process, a database was created with images of insects to aid in their identification. For the development of this system, data surveys were conducted with the help of cooperatives in Paraná State, linking the requirements of traceability with practical experience.

Technical manual of traceability for the wheat supply chain, and the digital field book

The technical manual for the traceability of the wheat supply chain (Fernandes et al., 2009) states that a traceability system includes the selection of varieties, production, transportation, storage, milling, the food industry and marketing (Figure 1).

The need for constant improvement of the traceability process, to supply real and updated information, is justified by the increased domestic production and export of foodstuffs, due to various factors such as demand, higher prices, weather conditions and technological innovations.

The digital field book (Tibola et al., 2009) corresponds to a system of internet traceability and certification of wheat, aligned to the standards of the integrated production system for wheat (PIT). The objective of this system is to maintain records of provenance and practices, from production to the process of post-harvest, such as physical and chemical properties of the soil, planned crop rotation, soil tillage and sowing, seed treatment, fertilizer, weed control and the application of growth regulators, the monitoring and control of diseases and pests, fungicide and insecticide applications, storage units, drying, and the thermometry and aeration of grains.

Using the digital field book, it is possible to integrate information between the agents involved in the production chain, making the certification of integrated production of wheat both agile and reliable. Data entries can be performed quickly via mobile devices, thus ensuring a higher quality traceability process.

Online traceability and qr-code

Some companies are focusing on developing systems for consumers who want quick access to information about the origin of the products they are buying. These are specialized applications to query the data that the company deems most important and of greatest value to the consumer. In the production of soya seeds, the system of online traceability (Gazolla, 2012) permits the storage and interrogation of information related to the seed production process, thereby forming a database with information that can be queried and evaluated whenever necessary.

The data from the 2010 to 2011 harvest were registered, and approximately 15,000 ha of area cultivated with soya were traced. At the UBS, the seed processing unit, seeds were uniquely identified by batches according to the date of receipt, variety, supplier and production area. Identification was performed by QR-Code (Quick Response Code) labels, which provide fast access via mobile devices. When querying the product code via the internet, the client can access the history of production, such as geographic location of the

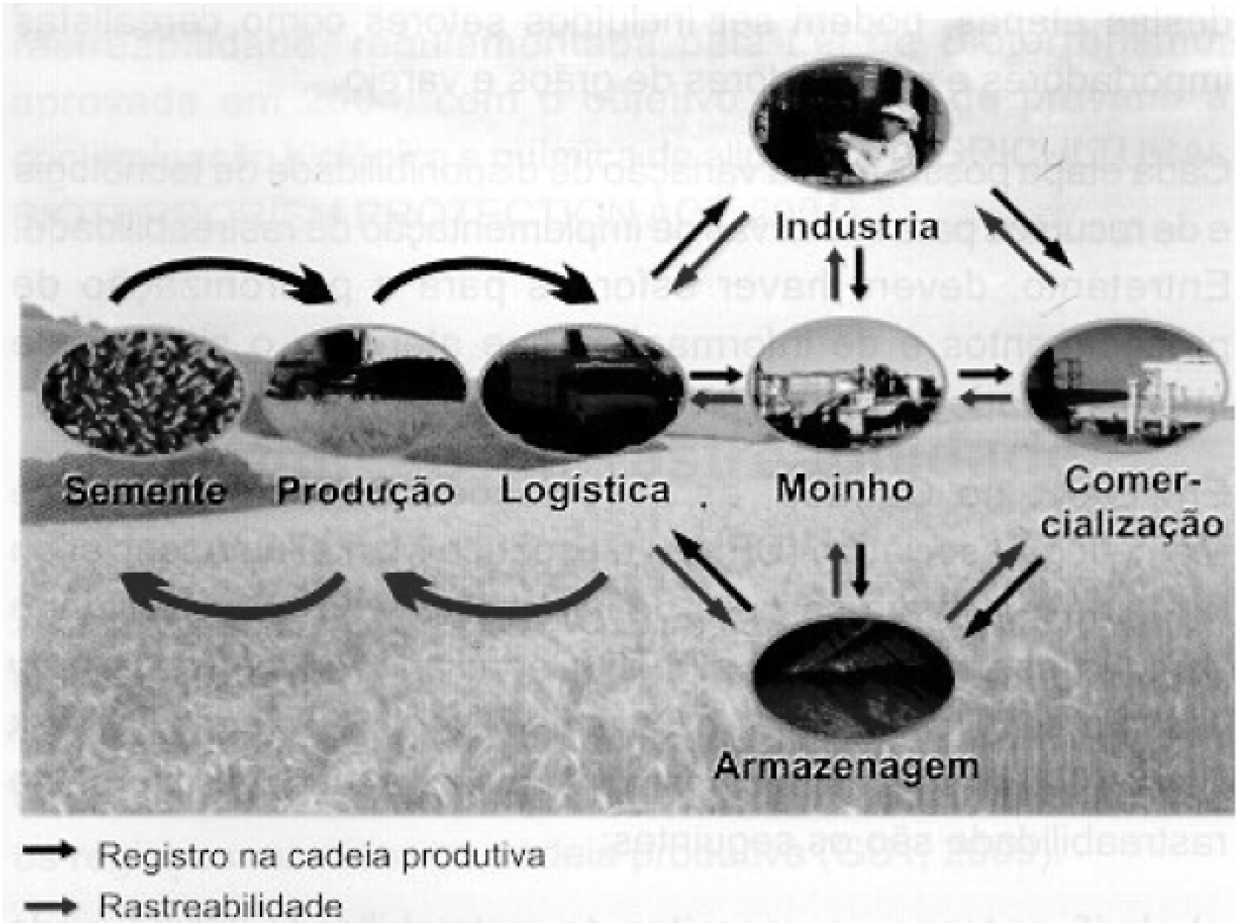

Figure 1. Stages of the traceability system for the wheat supply chain.

farm with photos, technical information on seed treatment, and the results of quality control reviews.

Another project that used the QR-Code Technology, was developed for flour mills in China (Qjan, 2012). The labels were placed on flour packages. Data which can be verified are: company name, product name, date and result of quality parameters. Therefore, the consumer has access to information through a website. Processes such as these add value to the product and bring greater security to the customer. Admittedly, the existence of a traceable process does not guarantee food security, but transparency for the consumer is what can make the difference in a moment of decision between one brand and other.

Traceability of grain and maize flow using radio frequency

In an attempt to reduce the risks of mixing within lots of grains, which can put a traceability system into disrepute, a project was introduced that incorporated the implementation of Radio Frequency Identification technology, RFID (Rodarte et al., 2011). This technology uses radio signals that access information stored on tags or labels through wireless devices called readers.

RFID technology has advantages over barcodes because the information recorded on the labels need not be in line with the reader in order to be accessed. Thus, it can be incorporated within the packaging or implements, depending on the purpose. The scope and speed of the readers are also attributes that being constantly improved, they can be hundreds of meters away, and thousands of tags can be processed per second (Garcia, and Lunardei, 2011).

In this project, the tags were encapsulated in material, imitating a grain of maize (Figure 2). They were loaded with information specific to the grain producer and the lot, and inserted along with the grains. Experiments have shown a low rate of faults associated with the allocation of tags in the middle of the lot, but the application of RFID in large quantities of grain can be enhanced in relation to range of the reader. Although this experiment was performed with grains of maize, it represents a major breakthrough for future studies and can be used in any grain production chain.

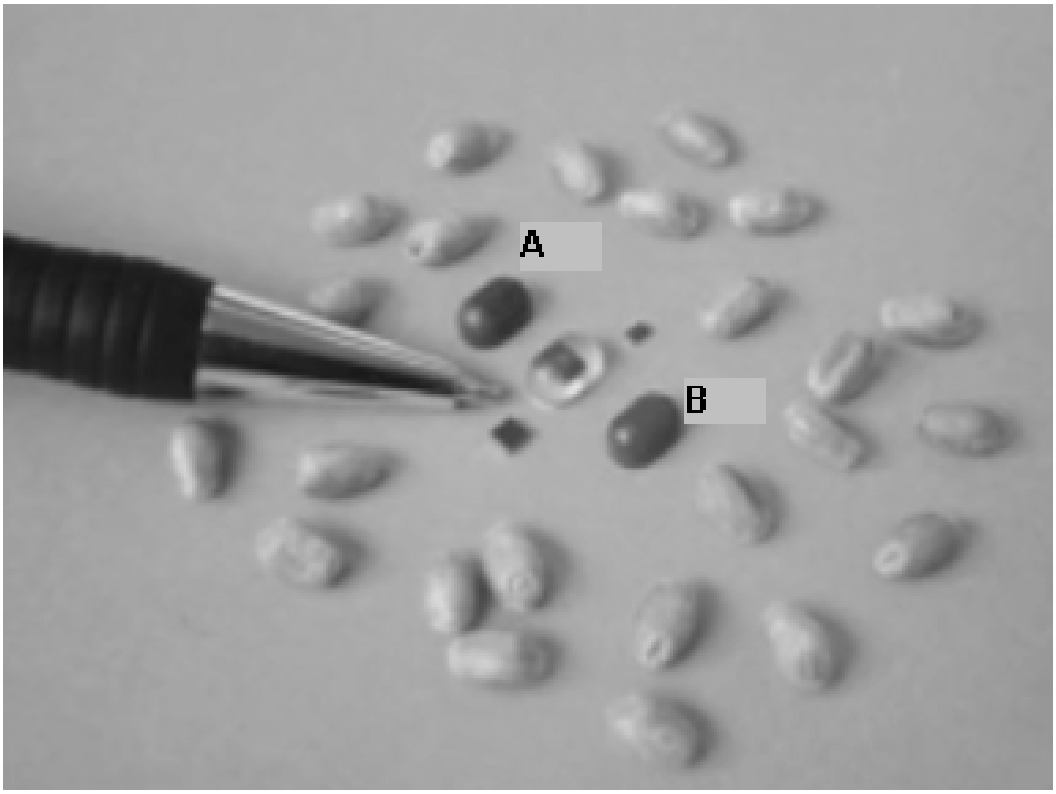

Figure 2. Encapsulated in the form of a grain of maize ('A' and 'B'); RFID Tag 1.6 × 1.0 × 0.5 mm (center). Surrounded by natural grains of maize.

The benefit of using RFID technology is that data collection can be performed automatically using sensors, thereby reducing errors and minimizing the need for manual data entry. Technology like this is currently seen as a market differentiator, but it can be considered to be a necessity for the future.

Use of 'frameworks' for traceability

'Frameworks' is a technology that can reduce the effort involved in developing systems by reusing knowledge that is already structured and which can be applied to similar problems. According to Larman (2004), a 'framework' is a cohesive set of interfaces and classes that collaborate to provide services for the basic and constant part of a logical subsystem. The concept described by Booch (2006) may be used in this context; it corresponds to a standard of architecture, providing an extensive template for applications within a domain.

A traceability system involves the exchange of information between different agents within the production chain. To ensure quality, and access to and interoperability of data, it is important to adopt standards. These standards describe how messages should be built, sent and received. A project called 'TraceFood' was recently developed to create a framework applied to traceability in the supply chain (Storoy, 2012). This framework contains recommendations for best practice in traceability, common principles for the unique identification of food items, and a standard for the exchange of electronic information related to traceability in the food industry, such as the identification number of the source, and how and when a product was processed, transported and received.

TraceCore eXtensible Markup Language' was developed for various food sectors, such as seafood, mineral water, honey and meat. The structure can be applied to the implementation of a traceability system for grain because it has standards and methods that are required in order to model the traceability relationships between the agents involved, in any supply chain. The first step in the construction of the framework is to define the requirements applied to the supply chain. In a systematic approach, 'use cases' can be utilized to represent the relationships between users and the system. TraceFood uses this approach to represent the main requirements of traceability. For example, in the case of registration the following are required: practices of seed development, agricultural practices, management practices and grain storage, practices used in processing, and the authentication of new applications for new system functionalities. This framework has been tested in food chains in pilot studies in Norway, Spain, France and China and the goal is to turn it into a methodology for the implementation of traceability in food chains. This has already happened with the standard for electronic information exchange in the fish industry, which has been incorporated into this framework, and is currently the ISO standard for the traceability of products from fish farming.

CONCLUSIONS

The traceability of a product is not a novel approach. Laws and registered quality control processes have been market requirements for quite some time. What is changing is the demand of consumers and non-governmental organizations for more detailed information on the origin of foods. The latter are now frequently demanding sustainable production from producers.

Solutions to address the demands of traceability in the food supply sector are of great importance for food quality and safety. When the product to be traced is grain, the degree of difficulty is greater due to the granularity of the product. This particular market requires more specific control and tracing.

Some companies are now structuring themselves to store grain in silos with smaller capacities, to ensure segregation and thus traceability. Thus, the use of standards for the exchange of information between the agents in the chain, and the definition of traceable requirements, contribute to the design and development of a relevant, applicable and quality system. Many laws, regulations, rules, standards and certifications have been created, which have contributed to guidelines on traceability. Technological solutions to implement systems for the different needs of producers and consumers are available and are in constant development.

This article has discussed projects like the model of integrated traceability, software specifically designed for the traceability of grain, digital field books, internet solutions with online information, and the use of more advanced technologies such as RFID and Frameworks. These tools are designed to simplify implementation, to reduce the effort of development, and to improve quality, thus reducing the costs of a project.

A comparative analysis was performed on existing systems and some important considerations can be highlighted. Some systems seek to control the productive tracts, from planting to harvest, but not all agents are part of the production chain, it does not store the information after harvest. In order to make the traceability process effective, particularly in case of any problem, it is necessary to have information on all production stages. Systems that use the QR-Code technology provide some information to the consumer that can be checked. This information is fixed, for instance, farm location, pictures and quality information. An interesting option for companies that implement a traceability process would be to customize the necessary information to become visible on the Internet.

Regarding prospects for future research, we suggest the development of a framework that can be used for the development of traceability systems in the production process of wheat, aligned to the ISO, HACCP and GS1 quality standards, and the regulations that guide companies in compliance with requirements relating to the tracking of the production process for quality and food safety. In this way, a set of pre-defined patterns can be obtained that can be applied to traceability systems, thus reducing development time and improving the quality of those systems. It is important to emphasize that technological advances should bring innovation because, as well as the legal requirements surrounding traceability, consumers are seeking access to information and this is a motivation for companies looking for solutions to meet consumer demand. The greatest obstacle to the successful implementation of traceability in the food chain may be organizational, not technical, because technological solutions are in constant development. Companies need to be motivated to implement new solutions, but there is often resistance, either to changes in operating practices or due to concerns over data security and reluctance to share information.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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