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IT System in the Food Supply Chain Safety: Application in SMEs Sector

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Abstract**—**Food supply chain is one of the most complex supply chain networks due to its perishable nature and customer oriented products, and food safety is the major concern for this industry. IT system could help to minimize the production and consumption of unsafe food by controlling and monitoring the entire system. However, there have been many issues in adoption of IT system in this industry specifically within SMEs sector. With this regard, this study presents a novel approach to use IT and tractability systems in the food supply chain, using application of RFID and central database.

Keywords**—**Food Supply Chain, IT System, Food Safety, SME.

I. INTRODUCTION

DURING the last decades there have been a trend for expanding the supply chains from regional and national to global and international context. Food Supply Chain (FSC), as a critical part of the supply chain framework, followed this trend as well. The network of raw material producers, food processors, warehouses and retailors are growing in a fast rate. On the other hand, the food division assumes a huge part in economy being one of the principle donors to the Gross National Product (GNP) of numerous countries, especially in developing countries. As indicated by the European Commission [1] the food and beverage industry is one of Europe's most critical segments comprising of more than 286 thousands organizations that give employments up to more than 4.2 million individuals, while SMEs in this sector plays an important role by 64.3% of employment, and 51.6% of turnover rate [1].

The main difference that separates food supply chain from other supply chains is that there must be a nonstop attention for the safety and quality of the products, from the time the raw materials enter the production to the time the product achieves the consumers [2].

Perishable foods, for example milk, fish, meat and more, can undergo safety impairment rapidly along the whole supply chain, even after they leave production step before coming to the purchaser. Therefore, keeping food safe and in great quality is a complex task, specifically when its travel through the different nodes along the supply network, and it demands for real time tracking and tracing.

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The traceability of food items and the capability of food producers to provide data about their sources, raw materials, production process and transporters are crucial to guarantee the safety of the food supply [3]. Traceability frameworks not only help firms to find the source and degree of safety issues, but also enable companies to have better control over entire supply chain and to facilitate the management practice. The more exact the framework, the faster a producer can distinguish and resolve food safety or quality issues [3]. Consequently, food-tracing frameworks are vital for the food safety and quality control.

II. TRACEABILITY IN FSC

Agricultural supply chains have opportunities for the usage of IT improvements to expand the effectiveness and viability of SCM. These supply chains have normally focused on the development of the food from creation to utilization. They incorporate all the input supply, preparing, processing, storage, transportation, administration and sale in the from 'farm to-fork' continuum. These capacities commonly compass other supply chains, geographic and regulatory limits, and variety of the authorities, private-division foundations and associations [4].

IT is a fast developing technology and the majority of the current concentration in research is on the innovation itself, as opposed to how it could be connected to agricultural supply chains. Likewise genetic innovation, information technology is one of the major movements driving the future change of supply chains around the world [5]. IT has been connected to the administration of the food supply chain network and more recently to the food quality and safety. In the field of agricultural supply chains, IT applications have potential advantages to agriculturists, the food business and consumers, through advancements in agri-food production, processing, transporting and selling [6].

The productivity of a traceability framework relies on the capacity to track and follow every individual item and logistics unit, in a way that proceed constant checking from critical nodes (e.g. farming, harvesting, and logistics) until last transfer by the customer. Traceability plans can be differentiated into two sorts: logistics traceability, which takes after just the production of the item and provide information on position of the item within the down stream supply chain (storage, transport, retailer) and subjective traceability that sharing extra data identifying with item characteristics and consumer safety. For example, pre-harvest and post-harvest process, stock, and transportation conditions, and so forth [7].

Transparency of a supply chain network is essential as all the partners of the system have access to item related data, accurately and on-time. Transparency empowers them to have better control over the supply chain network and have more efficient crisis management in case of the food safety outbreak [8]. Therefore, food-tracing frameworks are vital for food safety and quality control. Traceability frameworks help firms detach the source and degree of security or quality control issues. The more exact the framework, the faster a producer can distinguish and resolve food safety or quality issues [3]. In this way, traceability frameworks could provide data about whether control focuses in the production or supply chain are working accurately or not. So early discovery and quicker reaction to these issues could be achievable. However, the application of IT in Food Traceability System (FTS) needs more investigation and research. FTS is a challenging issue for food supply chain in terms of implementation costs, data processing, information lacking, and privacy in data sharing among firms involving in the supply network, without taking into account the, nature of products that could be difficult to trace (e.g. liquid products) [9]. The above-mentioned issues are more challenging for SMEs (that are significant part of food industry) due to their limitation of resources (i.e. budget, employees, etc.) and it causes more obstacles in controlling all the nodes of the chain. Therefore a new model is needed to support the SMEs and enable them to adopt IT in their management and control systems. The focus of this method will be on the food safety as the major concern for this industry, besides its many other management applications (e.g. capacity planning, warehouse management, and control of the supply chain).

III. Ethical Issues

Food production and consumption is crucial for every society and have many social, economic, and in many cases, environmental effects. The main ethical concerns in regard to food safety and traceability are discussed in more details as follow:

A. Social

Expanding the certainty of customers in their foods, the changing ways of life and expanding expectation of the consumers, the increasing attention of society about their health are some of social issues that inspire food organizations to execute traceability approach. The change in the food outbreak administration increased the concerned organizations to invest more in the food safety and security, which thus reinforces the social and political safety of a country. The contemporary Food Tractability System (FTS), organizations ought not only to meet the legislature rules, but to sufficiently give data that customers need to know, for example, the food characteristics, nation of origin, animal welfare, and processing related information [10]. The expanded occurrence of foodborne disease is the consequence of a multitude of variables, all connected with our quick evolving world [11].

B. Economical

The [11] expressed that foodborne outbreaks not only largely influence individuals' health and prosperity, but they also have financial outcomes for people, families, communities, organizations and nations. These outbreaks force a substantial load on health awareness frameworks and notably diminish financial profit. There is just limited information on the monetary consequences of food outbreaks and foodborne sickness. In 1995, studies in the US reported that the yearly cost of the 3.3 million foodborne disease caused by seven pathogens was about US $6.5 billions. As of late, previous U.S. Food and Drug Association (FDA) economist Robert L. Scharff assessed the aggregate financial effect of foodborne diseases across the country to be a joined $152 billion yearly [12].

In the European Union, yearly expenses leveled on the social insurance framework as an outcome of Salmonella contaminations (one of the major cause of foodborne diseases) are assessed to associate with 3 billion Euros [13].

C. Environmental

With development of the worldwide food market, the ecological effect of the food supply chain has turned into a developing concern. The separation that food goes from the farm where it is created to the kitchen in which it is consumed is longer than before. Hence, the utilization of energy, assets and the production of Green House Gasses (GHG) in the whole food cycle, including transportation is unavoidable. The initiatives to utilize carbon naming (i.e. carbon footprints of the items) and origination of food miles (the separation that sustenance is transported as it goes from maker to buyer) show that the food chain needs more efforts to decrease the ecological effects, for example, food decay and global warming [14].

In numerous countries, one of the issues concerning food safety and quality is food decay. The Food and Agricultural Organization, reports, one third of produced food for human feeding (i.e., about 1.3 billion tons) is wasted through the food supply chain [6], and each ton of food waste could result in 4.5 tons of CO_2 emission in environment [15]. Food decay is inefficient, expensive and can antagonistically influence consumers' trust. Commonly, all foods have a restricted lifetime and most foods are perishable. Temperature in the food chain can make microbial development and waste of sustenance and is one of the sources of foodborne diseases. Proper warehousing and refrigerating of food within the supply chain is a critical factor to avoid food decay and unsafe food. Therefore, tractability could facilitate the food decay reduction by providing more appropriate temperature control along the chain.

D. Regulations and Standards

Due to globalization of the food business, applying food control systems are vital to secure the safety and security of the consumers. The premier obligation of the food control is to authorize the food law(s) securing the customers against food hazardous and harmed [16]. In Europe, EU order 178/2002 went live on 1 January 2005 and obliges compulsory traceability for all sustenance and food items sold inside European Union nations. In the US, the Bioterrorism Act of 2002 specified that the companies who produce, process, pack, transport, stock, or imports food have the obligation to build and maintain records. It additionally permits the *Food and Drug Administration* (FDA) to investigate those records if there is a sensible conviction that an article of food exhibits a genuine wellbeing danger [17].

The necessity for food safety and traceability is included in the new ISO guidelines with more concentrate on traceability. ISO 22000 [18] predefined prerequisites for a food safety administration framework where an association in the food chain needs to show its capacity to control food safety risks so as to guarantee that food is safe at the time of human utilization. However, Absence of sufficient and institutionalized information and method for information exchange are lacking that need more examination attempts to enhance Food Traceability System (FTSs). FTS is normally entangled because of varieties in information gathering, irregularity in sorts of access to information, varieties in communicating information among FSC partners [9].

IV. Issues in the Food Traceability Adoption

Initially, the expenses connected with application of traceability frameworks have been seen as a barrier for supply chain network particularly for SMEs due to limited available resources. Nonetheless, the costs of unsafe and high-hazard food, disease outbreak and recall of the products, far exceed the expense of traceability. Therefore, many countries have established rules and regulation to mandatory the tractability system in the food production import and export. As it is defined by the European Commission Health and Consumers [19], Tracking and Tracing become mandatory by legislation in 2005 by EU as “the ability to trace and follow a food, feed, food-producing animal or substance through all stages of production and distribution”. However, one of the greatest difficulties with the traceability system is managing and controlling the huge amount of data in an institutionalized arrangement among different companies along the food chain [20].

Traceability frameworks are basically dependent on the recording of data. Sophisticated systems are needed to manage the gathering and verifying of any data, and spread it through the entire chain. Paper is still utilized as a less expensive choice for traceability, despite the fact that it constrains the capacity to record information precisely, store it, and inquiry it to recognize and follow items. Computerized databases for traceability are seen as more extravagant to execute, work, and keep up, needing investments in equipment and programming, talented human resources, preparing, and confirmation [2]. As it has been reported by [21] using the wireless network in agriculture business is new compare to other industries like automotive, however, it has great potential of usage in the near future. One of the greatest difficulties of food chain traceability is the utilization of the manual exchange of data between organizations. Reference [4] reported that just a couple of connections in a supply chain are utilizing programming for interior traceability as a part of existing traceability frameworks. The differences of the frameworks likewise make the coordination troublesome. However, the application of IT in Food Traceability System (FTS) needs more investigation and research. FTS is a challenging issue for food supply chain in terms of implementation costs, data processing, information lacking, and privacy in data sharing among firms involving in the supply network, without taking into account the, nature of products that could be difficult to trace (e.g. liquid products) [9]. The above-mentioned issues are more challenging for SMEs (that is the major part of the food industry) due to their limitation of resources (i.e. budget, employees, etc.) and it causes more obstacles in controlling all the nodes of the chain. Therefore a new model is needed to support the SMEs and enable them to adopt IT in their management and control systems.

V. Conceptual Model of IT and FTS in the Food Industry (using RFID in CCP)

Radio Frequency Identification (RFID) innovation is generally created and internationally recognized as a major technical improvement to the administration of tracking, data gathering and reporting inside a production network. Through experimentation and investigation of results utilizing different variables, [22] confirmed the enhanced readability of RFID labels in the longest distance comparing to other tractability system like barcodes. RFID labels are faster and more accurate in transferring multiple data at the time, and able to receive and transfer the information. Reference [23] came to the result that improvements to the utilization of RFID labels on agricultural items gave industry and government more efficient production network and product traceability in the occasion of a food outbreak.

In this study we introduce a new model to implement IT and FTS (using RFID) in the food companies, in order to monitor and control the critical points of the supply chain. Applying this method also enables the food stakeholders to have access to on time data about the critical points of the chain. The main objective of this method is food safety as the major concern for this industry, besides its many other management applications (e.g. capacity planning, warehouse management, and optimization of the supply chain). The developed model consists of two major phases.

In the first phase the Critical Control Points (CCPs) of the food supply chain will be identified, using risk management techniques or HACCP documents that already exist in many companies. Then these CCPs will be connected to a central control system (database) via IT system. The input of the database is all necessary data (control measures) of the CCPs and the output of the data will be available to the main stakeholders of the food chain to foster information sharing among them. This connection facilitates the control over the entire network in case of food outbreak and product recalls.

The second phase considers the use of active RFID tags with sensor (Read/Write) on the pallets of the end products after the production process (i.e. in warehouse, transportation, retailor) in order to control, initially, the time and temperature. Integration of RFID tags and RFID readers in downstream of supply chain could improve the food safety control in the point of sales and before the consumption.

The associated methodologies will improve both the product safety and the information sharing among the stakeholders along the supply chain. The method is characterized by limited cost and lower complexity of adoption, because it collects only the critical data in CCPs and use tractability system on the batch of the products (pallets), not every individual product. This model could be also adopted by the food SMEs due to its lower costs and complexity, allow controlling the most critical points along the food chain.

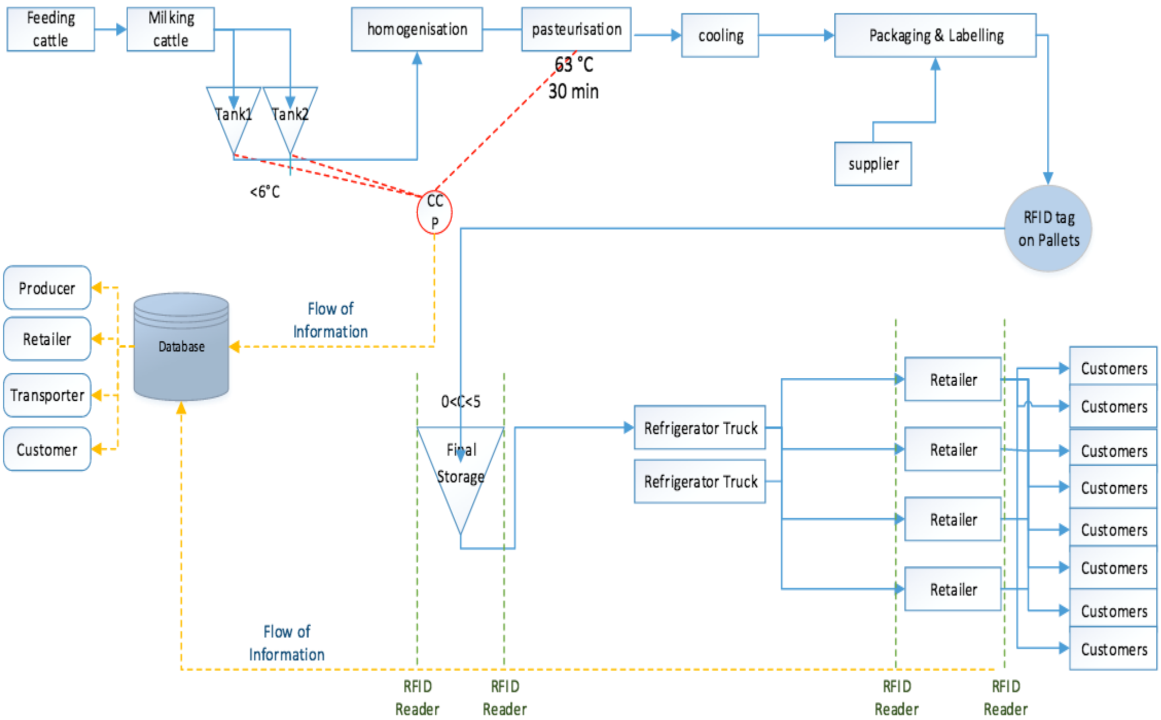

Fig. 1 Application of IT and FTS in the Food Industry

VI. Application of the Model in the Case Study

To show the application of the model we use a case study in dairy production supply chain and we delimit the study to milk product as a major product of the company.

A. Phase1

As it is shown in Fig. 1 the supply chain of dairy SME is mapped and the Critical Control Point (CCP) has been identified using the HACCP (Hazard Analysis Critical Control Point) standards and procedure that exists the case company. The CCP in the milk production are Fresh Milk Tanks, and Pasteurization, however, refrigerators in the storage, transport and retailers is critical to avoid growing pathogen in the products (Fig. 1).

B. Phase 2

In the next step, an active RFID tag (with sensor) will be devoted to the pallets of packed milk that have been produced in a specific timeframe. The sensor on the RFID will be set to measure and control the temperature and time of the storage. RFID readers will be placed in the gates of company’s storage and retailers. When the pallets of milk pass through the gates, the arrival/departure time and the temperature of the storage will be recorded. All these data transfers to the central-database, and if the control measures (time/temperature) deviate from the control limits, the alarm system will be activated.

The database connects the main stakeholders that in this case study identified to be producer, retailer, transporter and customers. The provided information on the product process and life cycle will be beneficial for the supply chain operators to control over the entire process and in case of any deviation or failure the system can alert automatically and problem can be resolve in lower risk and costs. In case of the food outbreak the supply chain partners have information on products position along the chain and could recall the products in lower time and risk for the end consumers. Customers also benefit from using this system and have more data about the production and process of their purchased products, and it could improve the trust of buyers.

VII. Conclusions

Foodborne disease caused by pathogens and toxins are particular issues in the food supply chain, which oblige concentrated control and monitoring the system. In order to control the system and procedure parameters efficiently, real time and accurate information on the process is necessary. In this study we introduced a new model to apply IT system for controlling the process. The model enables food operators to have better control on their critical control points along the entire supply chain with focusing on the major hazardous processes and critical control measures data. This model is beneficial for the SMEs in the food industry due to lower costs of implementation and lower complexity of the collecting and analyzing the data. However, the model in this study is still in conceptuality phase and needs to be applied in practice, in order to identify and analyze the potential issues for further improvements.

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Mohsen Shirani, works as a Marie Curie research fellow at Politecnico di Torino, Italy. This study is a part of InnHF – (Innovation through human factors in risk analysis and management) Marie Curie Actions Initial Training Networks. The INNHF main objective is to formalize an approach and make it possible to integrate the current and developing assessment methods recommended or required by recognized industrial standards and methodologies, with an easy to use but complete human factors and system health management approach.

The author PhD research focus is on the Food Safety Supply Chain; the main objective is introducing new model and approach in Risk Assessment of the entire food supply chain (farm to table) with integration of HOF (Human Organization Factor). The result would be in interest of Food Regulation and Standards authorities as well as Food Business Industries and Stakeholders.

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- Scientific Responsible for several projects and agreements; the active ones actually are:
- Marie Curie ITN: INNHF—Innovation through Human Factors in Risk Analysis and Management (2011-2015) – Coordinator.
- FP7 SME: TOSCA - Total Operation Management for Safety Critical Activities (2013-2016)
- CS&P: Study center on Safety and Prevention culture funded by INAIL – Direzione Regionale del Piemonte.