VILNIUS UNIVERSITY
FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

QUALITY MANAGEMENT MASTER PROGRAMME

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MASTER THESIS

SKAITMENINIMO ĮTAKA MAISTO SAUGOS VADYBOS SISTEMŲ EFEKTYVUMUI	**THE IMPACT OF DIGITALIZATION ON THE EFFICIENCY OF FOOD SAFETY MANAGEMENT SYSTEMS**

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Vilnius, 2023

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INTRODUCTION

Relevance of the topic. Food safety is an important concern for all stakeholders in the food industry and consumer health is getting more attention and awareness.(Alfiana et al., 2019) Food-safety threats come from different types of spontaneous hazards: physical, chemical, and biological; moreover the food frauds and risks caused intentionally by humans. It is estimated annually that 600 million cases of foodborne illnesses and 420000 deaths are detected in the world. Along with health issues, economic consequences are generated by food recalls, which after each food contamination announcement, make a big loss for food businesses that can reach $578 billion annually.(Yu et al., 2020)

Usually, the determination of food products' safety is based on the periodic inspection through quality control procedures and laboratory analysis to search for possible signs of adulteration or contamination. Although it provides reliable and accurate results, lab analysis requires sophisticated instruments, large time consumption, and a big labor force. Thus, this conventional approach is high-costing, inconvenient for on-site food analysis and not bringing immediate results.(Yu et al., 2020) Therefore, food quality assurance, and associated transparency should be guaranteed across the food supply chain as a prevention method against food hazards, and to ensure that food-borne illness' risks are eliminated or reduced to a minimum level. Traceability is the core part of food safety management systems, it is defined as "the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing, and distribution" (Yu et al., 2020). An effective food traceability system allows recording product's location, the ingredients it contains, or any related information from producers to consumers. In case of food-related incidents, the recall of product is mandatory and thanks to the traceability system, the identification of the source of contamination will be quickly. Thus, managers take effective actions and protect consumers from the contaminated food.

The data generated from the food supply chain is heterogeneous. A food product can contain multiple ingredients coming from different suppliers, and different geographical origins. Taking in consideration this diversity, a huge amount of data will be generated and it will be difficult to analyze with the paper-based method. That's why the food industry is urging a demand for

digitalization to make the traceability system more practical which allows better data management, real-time tracking and quick response to the incidents (Yu et al., 2020).

Level of exploration. Previous studies have shown that digitalization enables more robust testing, monitoring and managing of food safety. Different authors like Jiang X., 2015; Chen J., 2021; Jung D. ,2020 and Danyluk M.D., 2021 highlighted some digital solutions in their scientific papers, like the Big Data concept, Block chain technology, Wireless-based detection and freshness sensors based on the Internet of Things (IoT). They demonstrated how much those tools are enhancing the effectiveness of the food safety management system by allowing a better tracking of food products across the supply chain and better communication between actors.

Problem. Though previous studies discussed the benefits of implementing those digital tools for the traceability in the food chain, they lack a complete explanation on the impact of those tools on the efficiency of food safety management systems.

Novelty. The present study proposes a complete picture of the different digital tools used in the food safety traceability systems, moreover the different aspects of efficiency related to the food safety management systems' implementation. Then, we merge these two parts to understand the impact of digitalization on the efficiency of food safety management systems.

Aim. To define the impact of digitalization on the different efficiency aspects of the food safety management system.

Objectives. First of all, to identify the different tools used for the food safety management systems (FSMS). Secondly, to identify the impact of digitalization on the different efficiency aspects of FSMS. Thirdly, to present a conceptual model showing the interaction between the digitalization and the efficiency of the food safety management systems.

Methods. The literature analysis started with the identification of all keywords related to the "digitalization" and "food safety management systems". Then, to combine them in the search engines of different platforms that collect many scientific journals and books. After the selection of all interesting papers, a deep research is conducted to analyze each paper, the digital tool mentioned, the research method used and its final findings. Based on the literature analysis, the problem is defined, the aim of this paper and a research model is formulated. A qualitative research method is chosen to support this research to find answers for research questions directly from different experts related somehow to the topic. A live discussion with them can reveal better understanding of their point of view and will provide richer outputs from the interview

than quantitative research through surveys and standard questions. The results are collected from interviews' transcriptions then, they are explained and summarized in a conceptual model.

Structure of the Master thesis. Four major sections in this paper, the first section is an introduction that shows briefly the relevance of the topic, its level of exploration by scientific literatures, then defines the problem, novelty, aim and objectives of this research. Also, description of the methods used and its general structure. The second section is matching with the first objective, to identify the different tools used for the food safety management systems, where it explains the different variables and terms related to the topic through a deep literature analysis: Food safety management system' structure, Efficiency of food safety management systems, Traceability system, Digitalization in the food safety management system, Food Information System, Big Data, Internet of Things, BlockChain, Impact of digitalization on the cost of the food safety management system, and Elements moderating the impact of digital tools on the efficiency of food safety management system. The third section is explaining the research methodology adopted by the author to reach the second objective "to identify the impact of digitalization on the different efficiency aspects of FSMS". The fourth section is presenting the results of this research and analyzing them according to the third objective "to present a conceptual model showing the interaction between the digitalization and the efficiency of the food safety management systems". The last section of the master thesis consists of the limitations of this research, the final conclusion, list of references and appendix.

1. FOOD SAFETY MANAGEMENT SYSTEMS

1.1 Integral elements of the food safety management system

Food Safety Management System (FSMS) is a set of activities that are planned, operated and updated following the framework of some standards or regulations in order to assure food safety throughout the food chain and provides benefit to the organization and their interested parties.(Panghal et al., 2018).

The concept of food safety assurance is based on preventive measures, the control of food processing conditions, and not only the final product's quality. Management of food safety has been progressing over decades, from the application of basic good hygienic practices, to the establishment of risk assessment system called Hazard Analysis and Critical Control Point (HACCP), to involving more interested parties related somehow to product's safety like supplier auditing; management of people by training and performance's evaluation; consumer and customer's relationship management; distribution management by auditing transporters and retailers, leadership and top-management review; incident and crisis management, etc…Gaps or failures in the food safety management system are threat, that if not managed and corrected could lead to food-born incidents. (Motarjemi, 2016)

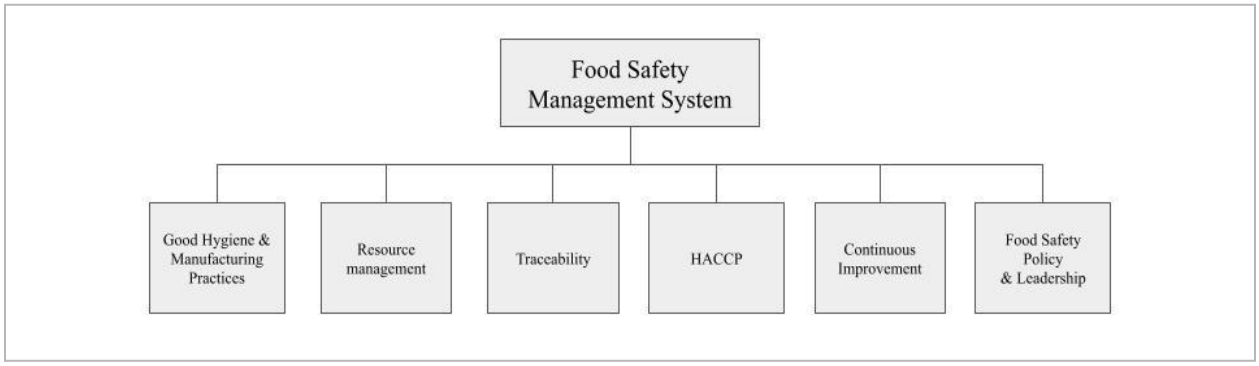

Figure n°1: The general structure of a food safety management system. (Motarjemi, 2016)

The HACCP is based on identifying the different dangers (biological, physical and chemical) related to a specific food product through a Risk assessment method consisting of hazard identification, classification based on its type, evaluation of its severity and its likelihood of occurrence. This analysis is the foundation for deciding about the further actions needed to control this risk. (Unnevehr L., 2003)

The implementation of a food safety management system contributes to the compliance with food safety requirements defined by regulations, customers and all interested parties. It assures the continuous improvement by regular internal and external audits to detect non-conformities in all parts of the system and guarantee their disappearance through corrective actions and preventive actions plans. Most food businesses are implementing FSMS to get a recognized certification according to one of the international schemes that allows them to build confidence with their stakeholders and customers. (Panghal et al., 2018)

Table n°1: The recognized food safety management system schemes (Abebe et al., 2020)

FSMS	**Ownership**	**Area of application**
HACCP	Public (Codex Alimentarius Commission)	Across the food supply chain
ISO 22000	Public (International Organization for Standardization)	Across the food supply chain
Global GAP	Industry; collective (Consortium of retailers run by FoodPLUS GmbH	Primary producers
BRC	Industry; collective (Consortium of retailers)	Food manufactures/ suppliers
SQF	Industry; collective (Food Marketing Institute)	Across the food supply chain
FSSC 22000	Industry; Collective (European Food and Drink Association and the American Groceries Manufacturing Association)	Across the food supply chain
IFS	Industry; collective (German, French, and Italian food business operators)	Food processing/ packaging companies

1.2 Efficiency of food safety management systems

The main objective of implementing a quality management system is to increase the company's performance based on the predefined goals. Each organization defines its specific key performance indicators called "KPIs" which will help in assessing and quantifying the achievements of the quality management system, and show the progress objectively. The final aim of any type of business is the economic efficiency measured by the financial performance indicators or other indirect indicators that will lead to this same general goal. Those KPIs should be directly connected to performance, measurable and ensure compatibility with various references: Output rate (sales), Cycle time of the process, Quality rate/Non-conformity rate, Turnover of employees (Involvement and motivation of employees), Rate of clients' claims and returns, Number of injuries or incidents related to the safety of people or environment, Rate of costs and variable expenses, Waste management, Return on investment from quality management system methods or new technologies, etc…(Kazaryan et al., 2020)

The quality management system itself needs to be efficient in addition to being effective, for a better business performance. Efficiency means achieving the desired goal and compliance results with the ability to avoid wasting resources like materials, energy, money, time, and humans. (Manz, 2019)

Focusing on the principles of the quality management system, the efficiency indicators can be divided on three levels: The first one is the level of product's quality which depends on the index of defective products and the rate of internal defects. The second level is the assessment of the quality management system which combine several indicators such as the level of compliance with the customer needs and with legal requirements, the level of leadership involvement inside the organization, the availability of resources, the level of standardization and the implementation of plans, the handling of nonconformance according to the requirements, the effectiveness of solving problems by implementing corrective measures or preventive measures, the continuous internal assessment and following of KPIs. (Antipov et al., 2020)

The last level focus on the expenditure within the system and the product which combines the share of costs from the methods and technologies used for the implementation of the quality management, the share of costs due to internal failures, the share of costs due to external failures, the share of costs from preventive measures and the share of costs for quality inspection and periodic analysis. (Antipov et al., 2020)

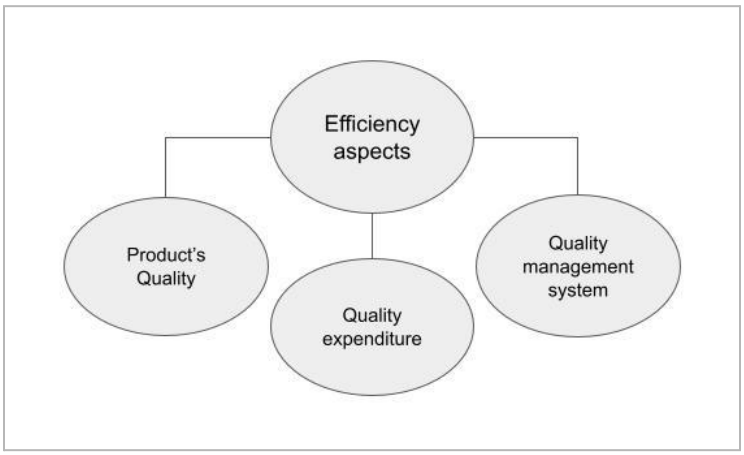

Figure n°2: The fundamental levels of the efficiency according to Antipov et al.

Achieving a good level of quality service has a cost, however failing to provide it can be more costly since corrective actions might sometimes be more costly than prevention. Meanwhile, in an industrial environment, it is challenging to prevent all the failures and to eliminate pertinent costs. Several studies in industrial enterprises showed the impact of quality initiatives on the improvement of companies' financial performance. The cost of the quality management system's implementation helps in the decrease of non-conformities, rework and corrective actions; it helps in reducing the number of customer complaints and scraps. Thus, failure costs decrease and sales volume increases. (Uyar & Neyis, 2015)

The KPIs are different from organization to another depending on their policy, goals and objectives related to the implementation of a particular quality management system. Moreover, it depends on the type of industry or sector, to where the organization's activity belongs: automotive supply chain, medical devices, information security or food safety.

The costs of implementing Food safety management systems (FSMS) represent a third of overall costs related to personnel's time and effort. Maintaining the food safety system is challenging for some businesses since they have complex processes involving many products or materials with different specifications. Food manufacturers need to keep costs in proportion to sales. Obviously there are labor costs included in the cost from the time spent by personnel in implementing and maintaining activities related to the FSMS. The cost varies from one food business to another as those having daily routines related to the FSMS will spend more than those having few activities per week. The size of the food business is a factor in the overall cost of the implementation and the maintenance of FSMS. Larger businesses have more output on which to spread the overall costs bringing to them a competitive advantage compared to smaller businesses with lower output. Businesses will pass those extra costs to their customers since these costs will become part of the price of the final product. Then the customer chooses to pay or not the higher price necessary to cover the cost of food safety management. The investment in FSMS will depend whether managers are convinced about the long-term benefits compared to the costs behind it. The adoption of smart solutions can bring efficiency to the FSMS which will lead to reduced expenditures. A small reduction in FSMS costs has a large financial impact on the overall costs and the final price of the food products. (Kane K., 2011)

For a better decision-making process, a cost-benefit analysis is important since it evaluates the different risks and incorporates all factors related to the investment. It's helping in risk prioritization and better understanding of the consequences behind the investment in implementing a food safety management system.. (Caswell J., 2008)

1.3 Traceability in the Food Safety Management System

Traceability is an integrated part of the food safety management system as it traces the life cycle of a product and records its history along the supply chain. Local and regional regulations require the availability of a strong traceability system; moreover the international standards related to this sector are emphasizing on the traceability at all levels of the food supply chain. From the raw material to the finished product, all records should be available and documented to guarantee consumer protection against foodborne incidents. (Ababio et al., 2013)

Primary investigation after the occurrence of an incident is to carry out a root cause analysis in order to identify the source of contamination, to enable products recall and to take the necessary actions for the correction and the improvement of the system. The documentation and records are the key material support used to provide evidence for an incident's investigation; they are important tools for internal and external communication in the system to keep the team, customers and inspectors up-to-date about all the measures. As an example, a contaminated raw material may be accidentally used in the production process. Thanks to a traceability system, it's possible to get all the information related to the supplier and the conditions of receiving the material. Plus, to identify the customers who have received the final product, so it will be easy to determine the extent of the product recall. If the information on a product's traceability is lacking, the investigation of outbreaks becomes more difficult. (Motarjemi, 2016)

Smart solutions are already invented to make data detection related to the food product automated with alerting methods allowing the prevention of food safety hazards, the immediate identification of deviations and non conformities. Thus it helps in reducing food products recall. (Ababio et al., 2013)

Transparency of food product' data is highly required by regulations and consumers making it clearly defined in food policies, trade standards, certification schemes, food safety standards and regulations. (Ringsberg H., 2014)

Food product traceability represents a form of inter connected data network between the different elements of each process. All the data is centralized in a shared system allowing all actors to access the data. The efficiency of a traceability system is measured by how the information related to the product is precisely and quickly shared. (Engelseth et al., 2014)

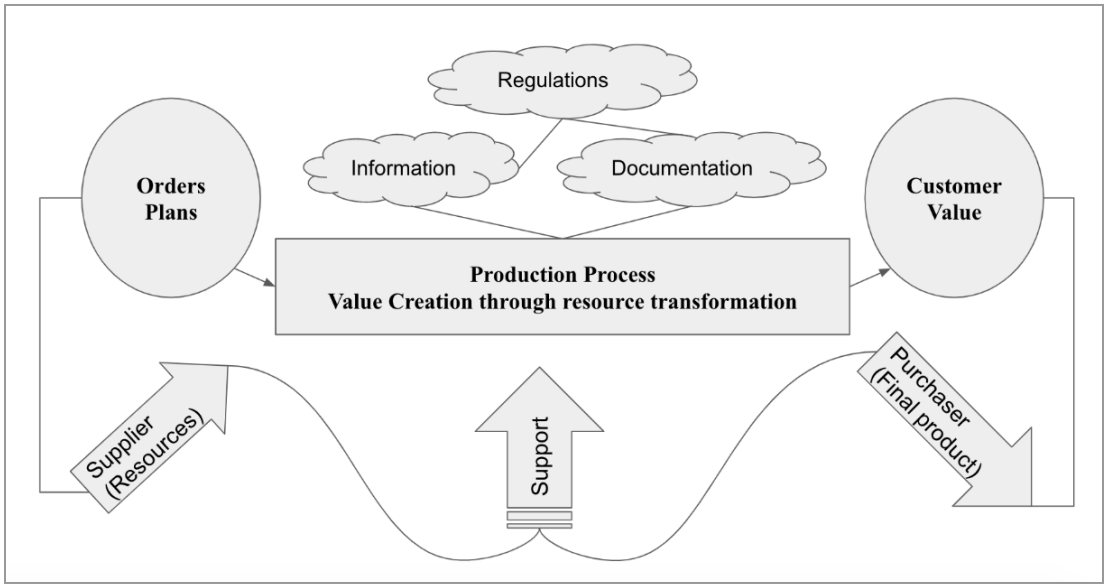

Figure n° 3: Interconnected traceability between the elements of process (Engelseth et al., 2014)

2. DIGITALIZATION OF FOOD SAFETY MANAGEMENT SYSTEMS

2.1 Selection of scientific papers related to the implementation of digitalization in the food safety management systems

The objective of the literature review is to provide an objective summary of the state of application of digitalization for food safety management focusing on the traceability procedure.

Though, several papers described the improvement of efficacy of traceability systems thanks to the integration of digitalization. However, few studies have conducted direct research to show the impact of using digital tools on the efficiency of food safety management systems.

We followed a six step strategy starting by identifying research questions, choosing the keywords, determining the searching databases, applying criteria to filter the useful papers, summarizing relevant studies, and reporting findings.

To have a wide range of references, we choose to search keywords based on different digital tools, and food safety management systems.: Big Data, BlockChain, Internet of Things (IoT), Software, Artificial Learning (AI), Computing, Network, Augmented Reality, Virtual Reality, Smart/Intelligence, Smart sensors, Digital. The second component of the topic we focused on is related to: Food Safety Management System Efficiency, Food Safety Management System Cost or Waste, Food Traceability, Quality Management Efficiency, and Quality Assurance Efficiency.

Although a lot of papers were found focusing on food safety, the search extension was reduced by limiting the focus only for scientific papers related to the application of digitalization for food safety traceability rather than digitalization applied for the technologies of testing or analyzing of food products. Then, we read the abstract of each paper to evaluate its correlation to our study, and to exclude some papers because they were beyond the scope of our study.
This collection process was conducted in November 2021, and we found 27 papers that directly matched our topic context and several others related to it in some way. .

Table n°2: Principle selected papers related to the application of digital tools and their impact on the efficiency of food safety management systems.

Key words	Title	Authors
Big Data Food Safety Risk Management	Big Data Impacting Dynamic Food Safety Risk Management in the Food Chain	John A. Donaghy Michelle D. Danyluk Tom Ross Bobby Krishna and Jeff Farber (2021)
Big Data Food Safety Management	Research on the Application of Big Data Technology in Food Safety Management	Lifu Chen and Yanchun Ruan (2021)
Big Data	Reflection on Quality Assurance System of Higher Vocational Education under Big Data Era	Xinlan Jiang (2015)
Blockchain Food safety	Application of blockchain technology in food safety control current trends and future prospects	Yan Xu, Xiangxin Li, Xiangquan Zeng, Jiankang Cao & Weibo Jiang (2020)
Blockchain Cost Food traceability	The impact of blockchain technology on the cost of food traceability supply chain	Shu Xu Xiye Zhao Zhe Liu (2020)
Blockchains Food Chain Traceability	On the benefits and challenges of blockchains for managing food supply chains	Panagiota Katsikouli Amelie Sina Wilde Nicola Dragoni Henning Høgh-Jensen (2021)
Internet-of-things Smart Traceability Food Safety	Smart traceability for food safety	Zhilong Yu, Dongyun Jung, Soyoun Park, Yaxi Hu, Kang Huang, Barbara A. Rasco, Shuo Wang, Jennifer Ronholm, Xiaonan Lu & Juhong Chen (2017)

Continuation of Table n°2:

Internet of Things Food Safety Management	Internet of Things Based Systems for Food Safety Management	Mihai DOINEA, Cătălin BOJA, Lorena BATAGAN, Cristian TOMA, Marius POPA (2015)
Traceability **RFID** **IoT** **Machine learning** Perishable food supply chain	Improving efficiency of RFID-based traceability system for perishable food by utilizing IoT sensors and machine learning model	Ganjar Alfian Muhammad Syafrudin Umar Farooq Muhammad Rifqi Ma'arif M. Alex Syaekhoni Norma Latif Fitriyani Jaeho Lee Jongtae Rhee (2019)
Information system Food Safety Data Flow	Research on the Food Safety Information Management System based on the Data Flow Technology	Zhang Yonghua and Liu Yongwei (2015)
Information system Food Safety	Information systems in food safety management	T.A. McMeekin, J. Baranyi, J. Bowman, P. Dalgaard, M. Kirk, T. Ross, S. Schmid, M.H. Zwietering (2006)

Digitalization has become an important part of human modern life: in the household sphere, the education and health system, transport, etc.... This diffusion of digital technologies takes place in the production systems and business too, known as "digitalization of industry". There is no doubt that it becomes a sign of competitiveness and prospects for companies, industries and national economies. (Antipov et al., 2020) Digital transformation in the food industries and food supply chain facilitates the data management in this sector which leads to a better risk management system. It allows an automated adjustment for deficiencies, real-time traceability and monitoring of quality parameters, defect rate reduction, and trend analysis. The integration of digital tools in the food safety management systems needs the collaboration between data scientists who participate in collation, combination and visualization of different data sources, and between food experts such as microbiologists, who have the role of assessing and interpreting the collected data for proper risk management and effective decision. (Donaghy et al., 2021)

2.2 Food Information System: European Union as a case

Food information traceability system is a complex procedure, used for recording and tracking every segment of the food chain from production to final consumption, plus creating a detailed and continuous information flow. Such a method is helpful for confirming every segment of food production, as well as their sources and usages while monitoring and analyzing timely and accurately. The information flow is moving in a bidirectional flow mode. From production and later segments, data is collected sequentially in a positive direction flow while the negative flow is when information backtracked in the opposite direction to downstream segments. There will be many databases or files stored in the information grid. Several actors of the food chain with their different departments will need to analyze their own data in the nodes, so we can design some node flow that is managed by a data integration process called ETL, which stands for Extract, Transform and Load data from every node flow. (Yonghua & Yongwei, 2015)

The European Union (EU) has established a food safety database that contains EU food safety-related policies, all food regulations, food ingredients and features in one database. This information system gathers all actors of the food chain and gives them access to an updated platform, also it enables researchers to analyze various data and to study the changes impacting human health and help food businesses in developing new products and making food labels that are in accordance with laws and regulations. Public consumers can search for detailed information in food monitoring reports of previous years from the concerned websites. A Rapid Alarm System for Food and Feed (RASFF) is developed by the EU and gathers the European Food Safety Authority (EFSA), European Food Management Committee and all member countries of EU. It is a large and rapid food safety alarm system, used in case of the appearance of food safety incidents that may threaten human health, in any member countries of EU or third party countries, to immediately share the scoops with all EU countries and prevent the proliferation of dangers. The European Food Law requires all food businesses to identify their supplier and customer and provide any demanded information to the competent authorities in case of a food borne incident and in order to withdraw from the market a product or a production lot that is suspected of being hazardous to consumer health. (McMeekin et al., 2006)

HACCP is the international reference system for food safety management, a structured approach to identify hazards, critical control points and their critical limits based on recording all details and actions to provide documentation essential for a full control of hazards in food processing. Several dedicated HACCP's software has been developed to facilitate the application of this approach. They typically provide step-by-step instructions for development and documentation of HACCP plans, facilitate record keeping, and make internal and external auditing processes more efficient. Information like the origin of raw materials and processing history, will be entered in the electronic system rather than being written down in papers each time a raw material or product enters a new production cycle. This may reduce errors and result in savings, in some steps of a supply chain. The system relied on bar codes to identify traceable units for internet-based transfer of data between operators. The system not only locates a product but also allows temperature measurements, or any other information, to be transmitted along the whole chain in real time. (McMeekin et al., 2006)

Technology	**Big Data**	**Internet of Things (IoT)**	**BlockChain**
Features	Integration of huge volume, velocity, variety, and veracity of data.	Sensors-based and Wireless-based detection of data.	Connecting blocks of data through cryptography methods.

Table n°3: The different digital tools applied in the food safety management system according to the scientific literature.

2.3 Big Data

Big data is the integration of massive amounts of data using high technology tools for better business decision-making and better management in the enterprises. This technology protects data from abstraction, treatment, manipulation or storage in different time and from wrong users. Big data is a volume of data having four basic features; "Velocity" which related to the high speed of data streaming; "Veracity" that describes the uncertainty of data; "Variety" related to the different type of data (structured and unstructured data); and the ultimately value of data for actionable insights and information. In the food sector, data has a huge volume, velocity, variety, and veracity since several actors can interfere at all stages of the food value chain. Data sources could come from food production, food consumption, public health, agriculture, environmental conditions, logistics, social media, etc.….This technology helps in the determination of

pathogens presence or any kind of contamination, by linking environmental data with the pathogen growth parameters or the hazard occurrence possibilities. For example, weather information used to identify high-risk periods. Thus, the areas with an increased potential of aflatoxins can be identified before the crop enters the food chain. The same collected data is useful for further applications to support crop production or livestock breeding, to improve food safety and economic returns. (Donaghy et al., 2021)

Data collecting devices will be interconnected to provide voluminous structured and unstructured databases. The data collected at the farm level for example, could be: crop worker health status, water quality parameters, meteorological information, real-time livestock health status, animal health records, veterinary medicine prescription records, animal movement records, animal feed quality and usage, and farm audit certification records. However, it must be acknowledged that some data, e.g., related to personnel (health/medical status) will be inaccessible. Accordingly, if we can estimate the overall potential for pathogen growth, compared to pathogen inactivation in a food product or a food process, we can begin to estimate the risk of illness to a consumer. (Donaghy et al., 2021)

2.4 Internet of Things (IoT)

Considered one of the trends in digitized food traceability, Internet of Things (IoT)-based sensors or Wireless-based detection technology consists of the detection and collection of information about food property using sensors, detectors or specific devices then wirelessly transfer the data for further analysis. This technology is usually used for food packaging processes. The collected food-safety related data, such as pH level or temperature, will be analyzed to help in the prediction of product's shelf-life. Without the use of any additional circuits, the device can wirelessly transfer the collected data in either a passive or active way thanks to the introduction of flexible and self-healing electrodes (Xu, Zhu, and Yu 2017). The advantages of this technology are its mobility and its ease-of use. Therefore it saves time, saves money and increases collaboration.

The passive sensor consisting of an interdigital capacitor and a spiral inductor is usually designed on the inner wall of food packaging. When the capacitance of the interdigital capacitor changes, a hand-hold detection coil, which is interrogated with a special resonant frequency of the capacitor, can measure the difference. By monitoring the capacitance changes caused by food properties like humidity, conductivity, or oxidation products, the response of a passive sensor can be correlated with specific safety or quality parameters. Meanwhile, the active wireless sensor can send the collected data to receivers by wireless transmission, such as Bluetooth and ZigBee. (Yu et al., 2020) The most widely used passive wireless sensor is based on radio frequency identification (RFID) tags. It is a contactless technology for automatic identification and it is associated with a transponder that is called "tag". This auto identification technology can be utilized for traceability systems in the food supply chain. It stores data in tags' memory and the RFID reader then captures the tag data and transfers it to the back-end databases for further assessment. (Alfiana et al., 2019)

Data could be collected from gateways of food production industries, supermarkets, connected refrigerators; transportation vehicles or from any actor of the food chain, in order to record food products' history from production to consumption. Temperature and humidity are the most critical parameters impacting food safety and quality. (IoT)-based sensors could be used in temperature monitoring systems for an efficient food quality assurance. (Alfiana et al., 2019)

Large farm owners could use wireless IoT technology to collect data regarding the location, wellbeing, and health of their cattle. Biosensors and wearable technologies used to identify unhealthy animals. Thus, it helps managers to separate unhealthy animals from the herd. (Donaghy et al., 2021)

RFID is utilized to track and trace products while IoT sensors are utilized to gather the environmental conditions. . The data collected from RFID and IoT sensors will be transmitted to the web service to be stored in the server-side database. Thus, this web-based traceability system could be used for a real-time management of movement of tagged products and environmental conditions. (Alfiana et al., 2019)

2.5 BlockChain

Block chain technology (BCT) consists of connecting blocks of data through cryptography methods. Each one contains all the data information of the system within a certain period and generates digital signatures to verify the validity of information and links to the next data block to form the main chain, which is known as block chain (Xu et al., 2020). It is a distributed, decentralized, public database for permanent and verifiable record-keeping across the food chain. BCT provides the opportunity to access and use data, shared by connected partners (public and private) in the food supply chain. It is foreseeable that upstream food safety parameters, collected and logged in BCT ledgers, could be analyzed and used as part of a risk-based inspection system downstream in the supply chain. (Donaghy et al., 2021)

The structure of the block chain is a tree of blocks, from the base genesis block to the top where the block contains the most recent transactions. The timestamp is generated with the block, which corresponds to the authentication of each transaction record, proving the authenticity of the transaction record. As soon as the timestamp written in the blockchain changes, the generated hash value changes and becomes invalid data. Each timestamp also writes the previous timestamp to the random hash value. The blockchain uses the Merkle root tree structure to store the values of all leaf nodes and generates a uniform hash based on this (Khan and Salah 2017).
The BlockChain infrastructure consists of six layers, Each one has a core function, and they are cooperating with each other to realize a decentralized trust mechanism: **Data layer** is the physical form of blockchain technology, **Network layer** includes point-to-point transmission technology, propagation mechanisms, and verification mechanisms that allows information sharing between nodes in the network, **Consensus layer** enables highly decentralized nodes in decentralized systems to efficiently reach a consensus on the validity of the block data. **Incentive layer** where economic factors are integrated with blockchain technology is to provide certain incentives to encourage other blocks to participate in the security verification of the blockchain and to attract participants to contribute to the computing power. **Contract layer** mainly refers to various script codes, algorithmic mechanisms, and smart contracts, which establish regulated and auditable contract specifications. The last layer is called the **Application layer.** (Xu et al., 2020)

BlockChain technology is characterized by a distributed decentralization: where there is no need for a third-party intermediary or trust institutions or a control center. By using mathematical encryption algorithms to regulate the behavior of transactions, the operating rules are open and transparent, and the data exchange between nodes does not require mutual trust. This technology is Tamper Resistant: it uses the asymmetric cryptographic hash algorithm to encrypt data, and the powerful algorithm formed by the consensus algorithm is used as a protection from external attacks, destructive or forgeable modification. (Xu et al., 2020)

Using blockchain in the establishment of traceability across the food supply chain gives consumers a complete sharing of information and reliable channels to track the source of products. This technology allows actors to upload information anonymously keeping the privacy of participating enterprises and focus only on the transaction process. When the blockchain is combined with the Internet of things devices, it protects databases and prevents the creation of wrong records and tampering with the data source. All nodes at all levels of the chain can see the relevant information about transactions on the chain which guarantees the openness and transparency of information. Thus, it provides a credible way for audit, operation records, logistics tracking and other activities.(Xu et al., 2020)

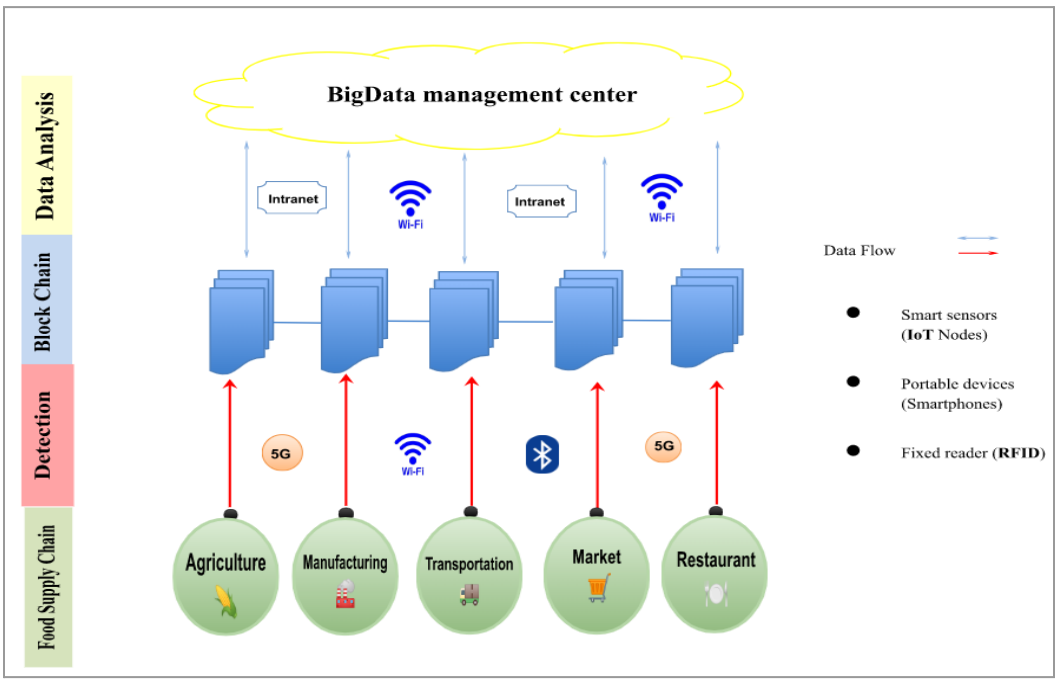

Figure n°4: A schematic overview of a digitalized food traceability system in the food chain (Yu.Z et al.,2020)

2.6 Impact of digitalization on the cost of the food safety management system

Most of the current traceability systems are self-built by the company that modify or hide the data depending on its self-interest. Thus, it leads to low accuracy of data, producing delays or misunderstanding in the supply chain. (Xu et al., 2020) In case of a safety incident, it's difficult with the traditional food traceability to determine the responsible person in the chain, which will lead to the "black pot" phenomenon. The integration of a digital technology reduces the uncertainty in the food chain's environment by providing reliable and real-time data within a safe and transparent business atmosphere. Thus, it helps for a better decision-making efficiency, optimizes decision-making process, improves supply chain flexibility, reduces supply-demand differences, and saves time and money. (Xu et al., 2020)

Reducing transaction's costs

Digital technologies track in real-time the product's circulation across the food chain which leads to reducing the data transaction cost between the main actors. Moreover it limits the uncertainty of behavior.

Sufficient information available through blockchain databases helps reduce the governance cost of selecting suitable supply chain partners since the ability of reviewing all needed data like product source, production process, and improper behaviors can be seen and tracked. Thus it helps in saving the cost of information collection, monitoring and controlling.

The history of records used by suppliers and sellers as a proof of reputation and proof of product's quality enables them to strengthen trust and sign contracts with potential business partners. Thus, to avoid transaction costs in uncertain environments, such as contract's design costs, and contract continuation and renegotiation costs. (Xu et al., 2020)

Reducing the quality cost

Introducing digital tools in the traceability system enables the reduction of quality control costs from the inspection of suppliers, verification of production process, and product's quality.

The obtained data from this smart system will greatly reduce the defective rate of products; reduce the return cost and internal loss, Notable reduction also on the cost of external losses. Since the responsibilities between the actors are clear and supported with undeniable proof, the disputes are limited in case of food incidents.(Xu et al., 2020)

Reducing time cost

The rapid upload of information into the traceability system permits a real-time tracking of products and enables a quick identification of defects which will lead to the reduction of the cost of time. (Xu et al., 2020)

Activity-based cost

Supply chain activity-based cost could be related to supplier, distributor, and customer. Thanks to blockchain technology, suppliers will remotely calculate the procurement costs of different suppliers and select the suppliers with low supplier management cost. With the flow of transparent data across the chain, manufacturers get access to customer information directly through distributors which will reduce the management and maintenance costs of distributors. Finally, the blockchain builds an accurate customer database that facilitates the analysis of customer needs, thus, reducing customer maintenance costs.

Reducing additional cost

The decentralization of blockchain helps save the cost of data storage, and reduces the cost of hardware and software as additional cost. Using this technology makes all participants independent and follows the same rules and mechanisms. Each one enters and reads data, without the need of central database testing. So, it lowers the system maintenance cost. This mutual supervision with the presence of alliance members will prevent the supply chain from being controlled only by one party, (Xu et al., 2020)

3. ELEMENTS MODERATING THE IMPACT OF DIGITAL TOOLS ON THE EFFICIENCY OF FOOD SAFETY MANAGEMENT SYSTEMS

Efficiency is defined as an indicator to the quality of achieving the predetermined goals. This relation can be affected by the conditions and the environment surrounding the system. Changing the goals or the conditions can change the status of the system from efficient to inefficient. (Kazaryan et al., 2020)

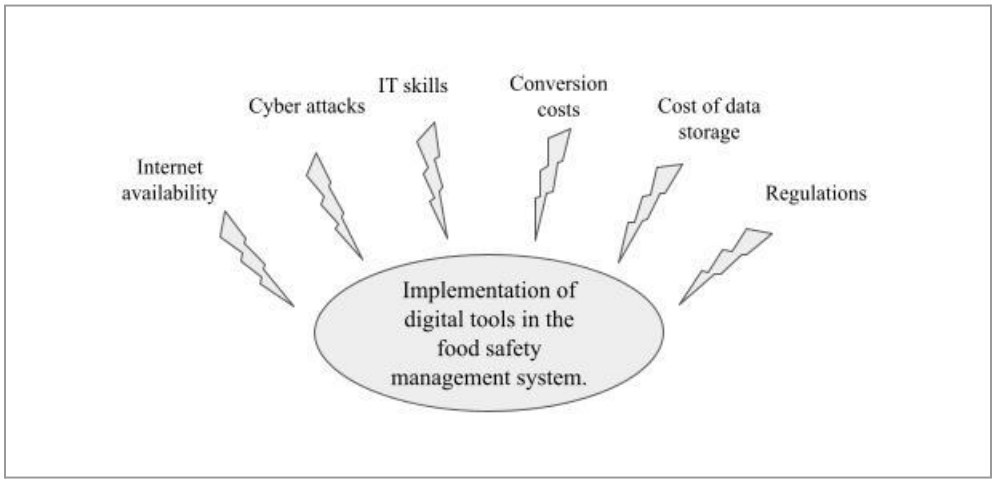

Figure n°4: Challenges related to the implementation of digital tools in the food safety management systems according to the scientific literature.

Basically the availability and accessibility to internet connection across the food value chains is a key element for the application of digital tools. The difference in quality of technical infrastructure and financial strength between developing and developed countries and between large food manufacturers and Small Medium Enterprises could create challenges.

The cost of infrastructure and technical expertise needed to digitize the food safety management system is rising. Developing countries are struggling to achieve the level of infrastructure needed, at least in the short term. This will negatively impact the integration of these countries into the same international market with developed countries which may exclude important parts from the database. (Donaghy et al., 2021)

Most of the small and medium-sized enterprises have unclear intentions to adopt electronic data technology since some researchers found that the introduction of blockchain will increase the cost of product's quality identification and evaluation. That's why they stick to manual quality inspection to avoid excessive costs. (Chen & Ruan, 2021)

Considering the huge volume and the variety of data collected from agriculture, public health, or any actor involved in the food safety system, it is important considering the credibility of sources to avoid misstatement. Though Blockchain technology enables data protection in its system, it does not have the function of verifying whether the initial information is true or false before it is uploaded to the blockchain so there is no guarantee of data's authenticity. Therefore, opportunistic behaviors could occur, and the governance cost risk to be enlarged. Data will require validation since it is used as the basis for regulatory actions, civil suits and even criminal cases. Furthermore, a balance between transparency and confidentiality is important to consider in responsible data science. (Donaghy et al., 2021)

The introduction of blockchain to an existing traceability system could require conversion costs in case of a complex food traceability system that includes different technologies at the same time like the use of Internet of things, two-dimensional code and other technologies. Even different blockchain networks are not necessarily compatible with each other due to the no existence of universal blockchain standards.

Human resource costs could rise since high skilled technicians will be needed to promote the blockchain program and maintain the blockchain ecosystem. The periodic training will also be needed since this technology continues developing. (Xu et al., 2020)

Digitalization may achieve significant cost savings by avoiding mediators in the traceability system, but may have additional cost of storing data in an expanding ledger; moreover, the cost of data validation mentioned above. (Xu et al., 2020) Data storage management is challenging because keeping such information on a shared cloud platform leads to technical, legal, and trust-related consequences that require extended research.

That’s related also to the control of access that needed to suit the needs of all participants, offering granular control over specific parts to specific users.

Finally, the existence of diverse regulations and standards related to products with different features and different geographical origins that are in the same supply chain can lower the efficacy of the traceability system. (Katsikouli et al., 2021)

4. THEORETICAL RESEARCH MODEL

After this deep research through scientific literature and papers, the relevance of the topic is better understood. The problem and the related variables are defined in the theoretical model below showing two main variables: The independent variable (digitalization) and the dependent variable (efficiency of food safety management systems) with more focus on traceability's system as an area of application of digitalization in the food safety management system.

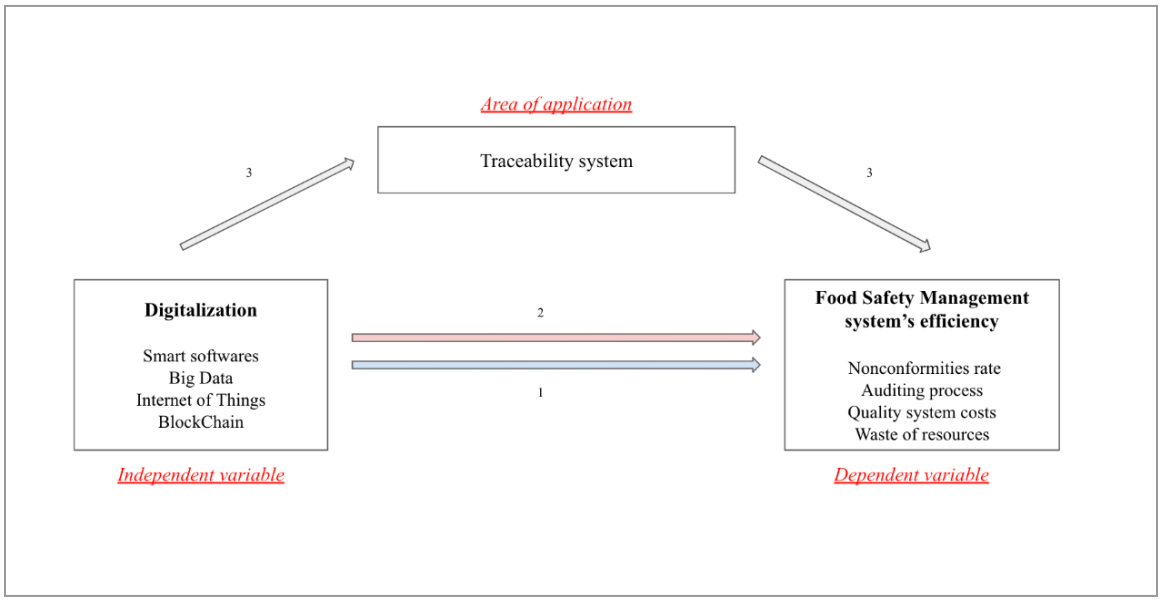

Figure n°6: Theoretical model showing the interaction between the independent variable and the dependent variable

From this theoretical model, we can determine 3 research questions:

Research question 1: What is the impact of digitalization on the efficiency of food safety management systems?

Research question 2: Which context can moderate the impact of digitalization on the efficiency of food safety management systems?

Research question 3: How Digitalization affects the traceability system which affects the efficiency of food safety management systems?

5. RESEARCH METHODOLOGY

The proposed research instrument in this paper is the semi-structured interview with experts, a qualitative research method that is admitted to reach different actors from the food supply chain in order to analyze the impact of digitalization on the efficiency of food safety management systems. My further research will offer a conceptual model that summarizes the findings and gives answers to the research questions mentioned above.

The methodology adopted here is based on three main steps: Planning interviews, conducting interviews and formulating results from interviews' transcriptions to find answers for the research problem.

5.1 Preparation

In the qualitative research method, the data is co-constructed by the researcher and the interviewee through limited-time interaction between them and it is difficult to predict the quality of the dialogue or the analytic value in advance. (*Malterud K. et al, 2016)*

Researcher should challenge his or her participant to develop empirical data and should avoid reproducing information that is already given. (*Malterud K. et al, 2016)*

The final sample size is evaluated continuously during the research process. The results formulated at the end will demonstrate whether the actual sample is sufficient or not to achieve the aim of the research. (*Malterud K. et al, 2016)*

Purposive sampling is a non probability method and a subjective strategy that considers small samples of knowledgeable people or specific experts within the population of interest to cover the study's objectives. (Syron L. et al., 2019)

Participant eligibility criteria is having at least one year of experience managing companies that produce digital tools or managers of quality systems in food industries or food safety specialists and researchers that worked on the application of digital tools for managing food safety systems.

The researcher contacted experts by LinkedIn, providing the study goal and the interview guide to the selected participants. All policies and procedures surrounding research ethics, including participant confidentiality and data were taken into consideration.

To formulate interviews' questions it is important to list all information needed to get from interviewees. The literature review of scientific papers gives a good understanding of the topic and helps to be familiar with the problem and to get the answers this research is looking for.

Since the protocol has different categories of interviewees, the questions should be adapted to the nature of respondents.

The chosen format is "semi-structured" interview protocol which allows the interviewee to express freely his point of view while keeping within the context.

The interview starts with broad questions about the topic then to go with more detailed ones. It's important to keep them as clear and direct, not containing a lot of concepts at the same time, moreover to avoid leading questions that give already answers and request only for confirmation. It would be better to give the interviewee the opportunity to describe his own experience and opinion without judgements or control.

One-time semi-structured interviews were conducted by the researcher from May 2022 to October 2022. Interview questions covered six chapters: Participant/Company Background, Digital tool Characteristics, Digital tool application in FSMS, Impact on the efficiency of FSMS, Challenges: Regulation/Resources/Workforce, and Opportunities.

5.2 During Interview

The interview starts by welcoming the interviewee and thanking him for attending the interview. After that is to give an overview of the topic, to show the theoretical model, and what would be the main points discussed during the interview. It's important to know about the interviewee's path and to explain why he was chosen to participate in this research. It will be more professional

to explain recording procedures and the responsibility to protect identity or other privacy issues that interviewee mention. The general structure of interview' questions is presented below:

I. Participant/Company Background

1. What is your current job title/ position?
2. How long have you worked in this industry?
3. What are the products/services you work on?
4. Are you involved in the control of this product/service's quality/Customer satisfaction?

II. Digital tool Characteristics

1. What is the digital tool/What is the technology used? How does it work?
2. How does the Traceability system/Tool/Service works at your company/in general?

III. Digital tool application in FSMS

1. What is the digital tool used for the purpose of your food safety management system?
2. Tell me about your experience using that tool?
3. What impact do you notice on the performance of the FSMS? (Regarding the level of compliance to the requirements, the integrity of the traceability system, the level of connectivity with customers, suppliers, and other stakeholders, the quality of internal and external communication, and the speed of responding to non-conformities)
4. Could you give me some examples of companies that are using this tool?

IV. Impact on the efficiency of FSMS

1. What resources are required for running/ better use of this new technology?
2. How do you see the evolution of quality-cost report after implementing this digital tool in the traceability system?
3. Could you classify the resources/reasons behind this cost change after using this technology in FSMS, from the most important factors to the less impacting ones?
4. What are the changes noticed on the efficiency/the cost of quality/waste of resources after the integration of this digital tool in the FSMS?

V. Opportunities

1. What is the best way to keep using technological tools for FSMS while keeping good efficiency and positive quality-cost reports?
2. Which digital technology do you think is the best to use for a traceability system to ensure better effectiveness and better efficiency of the FSMS?
3. Is there anything else that you would like to mention related to the impact of this digital tool on the efficiency of the Food Safety Management System?

Interview questions inspired from Appendix A. Interview Guide (Syron L. et al., 2019)

Some good manners appreciated during the interview to make the interviewee more comfortable, are to give them the time needed to think about their answers or to offer them the possibility to answer later for some tough questions and to accept silence moments between questions. It's important to show natural body language and to be flexible with the order of questions. To listen more and give full attention to the interviewee will prevent the interviewer from asking something already answered.

Interviews are conducted over video call, using MS-TEAMS and GOOGLE-MEET platforms and the expected duration of an interview is around 30 to 40 minutes.

5.3 After Interview

After receiving the answer for the last question, it's time to conclude the interview by summarizing the shared ideas and by thanking the interviewee for his contribution in this research work. The expected minimum output from the interview is to get to know the smart solution and to understand the technology behind it. The answers collected should show in general the impact of the digitalization on the efficiency of the food safety management system by presenting the different functionalities of this smart solution, their usefulness and their real impact on the activities and the personnel of the organization. Some examples of users or customers giving their feedback after the experience with this digital tool, can prove this impact on their food safety management system or any related activities. Numbers or statistics or any other arguments are appreciated also to strengthen the results.

6. THE ANALYSIS OF RESEARCH RESULTS OF THE IMPACT OF DIGITALIZATION ON THE EFFICIENCY OF FOOD SAFETY MANAGEMENT SYSTEMS

After several interviews, the results' formulation process starts with preparing interviews' transcriptions to collect information, arguments and data, then to merge similar responses and present the output in a model that lists the different digital tools and their impact on the efficiency of food safety management systems.

6.1 Experts and their organizations

The experts interviewed were representing different organizations that offer smart solutions to improve the food safety management systems, a food-industries auditor and a quality manager.

Expert 1 is the Chief Customer Officer with more than 5 years experience at a company that offers a cloud-based application and a platform for retailers. Its main services are risk mitigation via compliance management automation and advanced commerce solutions including scan-based trading and automated ordering. The expert explained how this integrated platform is helping retailers optimize sales, sourcing, and quality. Thus, it contributes to improving food supply chain efficiency by giving more transparency and better communication between suppliers.

Expert 2 is the Business Development Executive with almost 2 years experience at a company that offers multi-device cloud-based computing software with fifteen models that cover different tasks of the food safety management system, inside small and medium scale food processing industries, helping them in the compliance to the requirements of the Safe Quality Food (SQF) Program which is a world-wide recognized food safety certification. The different models cover:
"Smart Audits": Audit Readiness, Digital Audit Records, Customized audit programs, Offline Auditing, NC Management, Scores and Rating, Audit Scheduling, Dashboard and Reporting
"Smart CAPA": Manage the effectiveness of Corrective Actions and Preventive Action, Complaint Management, Product Hold and Release, Deviations Management, Root Cause Analysis, Reporting & Trend Analysis.

“Smart Compliance”: Automate Product Release, Material & Product Verification, Real Time Product Compliance, Manage wastes, Manage Product Non compliance, Generate Compliance Certificate, Supplier Compliance Reports

“Smart Docs”: Document Creation, Document Life Cycle, Advanced Search, Global Quality & Food Safety Standards, Backup documents by exporting or downloading to copies.

“Smart Farm”: Field Mapping, Crop Management, Blockchain-Enabled Traceability, Manage Harvesting, Packing, Shipping and Trace through QR codes, Weather Integration, Dashboard and Reporting, Offline Mobile Application.

“Smart HACCP”: Digital HACCP plan and templates, Process Flow Diagrams, Regulatory Compliance, Hazard Database, Critical Parameters Monitoring, Customized Risk Matrix.

“Smart Lab”: Laboratory Management, Customer Portal, Quote Management, Laboratory Integration, Invoicing, Lab Asset Management

“Smart Recall”: Single Source of Recall Data, Recall Alerts, Customized Notifications, Recall Management, Regulatory Compliance

“Smart Supplier”: Supplier Risk Assessment, Approval and Performance, Supplier Engagement Portal, Approval Scores & Ratings, Notification system for Communications, Non Compliance Management, Dashboard and Reporting, Alerts and Notifications, Cost Savings

“Smart Training”: Course Creation, Create training courses with our drag and drop course creator or from our existing course library, Self Learning, Group Learning, Training Skill Matrix, Onboarding Training, Refresher Training, Dashboard and Reporting, Scheduling, Virtual Library.

Expert 3 is a Technical Auditor with almost 4 years experience at a company that provides the services of Halal certification of meat, dairy, hygiene and pharmaceutical products’ manufacturers by assessing their conformity to the Halal standards throughout all stages of production. This expert has access to multiple food industries and their food safety management systems thanks to her activity of audit. She was sharing different cases from her experience about food industries that are using smart technologies to manage food safety systems.

Expert 4 is the Head of Sales with one and a half years of experience at a company that offers a real-time traceability platform for food supply chains. Combining blockchain networks with big data in a ready solution, this expert was open to share the features of this digital tool and he explained how it enables secure and transparent traceability between actors of the food supply chain and towards consumers.

Expert 5 is the Communication Manager with more than 4 years experience at a company offering a smartphone application for managing HACCP (Hazard analysis for critical control point) procedures intended for restaurants, hotels, retailers and schools. The smart application presents several features: Temperature monitoring, Digital labeling, Nonconformities management, Cleaning plan, Checklist for audits. Her company also offers some devices connected to the smart application like Tablet, temperature Sensors and LabelerR. The expert demonstrated the impact of her company's product on improving the efficiency of the food safety management system and she was also mentioning testimonials and she was sharing the feedback of some of the company's customers.

Expert 6 is the Senior Marketing & Public Relations Manager with almost 2 years experience at a company that offers advanced food production software helping food processors and producers to manage their food business. The different functionalities of this software were presented by the expert: Planning & Costing, Traceability, Quality Control, Supplier Management, Inventory, Production, Maintenance, Sales & Orders, Audit Management, IoT & Logging, Occupational Health and Safety. She explained how this smart technology is helping food chain actors to simplify operations and ensure compliance with the latest industry standards.

Expert 7 is the Quality Manager and HSE officer with more than 11 years experience at a multinational food industry producing baking aids, cake and dessert including mixes for tiramisu, marble cakes, and chocolate muffins. This expert is working on implementing, monitoring and certifying the food safety management system in this plant. This company is adopting a digital platform connected with their ERP to manage the challenges related to the food safety management system so this expert was open to share her experience with this digital tool and its impact on different parts of the system.

6.2 Impact of digitalization on the efficiency of food safety management systems

All the experts agree that the food supply chain is a complex system with multiple actors where each one is generating huge amounts of data that are, in most of the cases, uncontrolled or untracked at all. The characteristics of the information depends on the type of the product and its composition: raw material, semi finished or finished product, plus the specific process to where it belongs: logistic, production, environment. Moreover, the multiple suppliers and the different locations this product originated from. All those conditions and more, are behind the complexity faced by food supply chain's actors to manage food safety and to achieve the efficiency of their systems. This creates the urge to use digitalization in its different forms and tools to support the improvement of the food safety management system's efficiency.

This paper narrows the focus on the efficiency of the Food Safety Management System (FSMS) itself, rather than company's general efficiency, thus, the KPIs here will be based on the general aspects and principles of a FSMS. The experts were explaining the impact of digitalization on the efficiency of several elements of the food safety management system focusing mostly on: Supply chain management, documentation management, communication between departments, involvement of managers and the personnel, traceability system, monitoring of critical parameters, cleaning program, auditing, certification and the impact on the overall cost of the food safety management system.

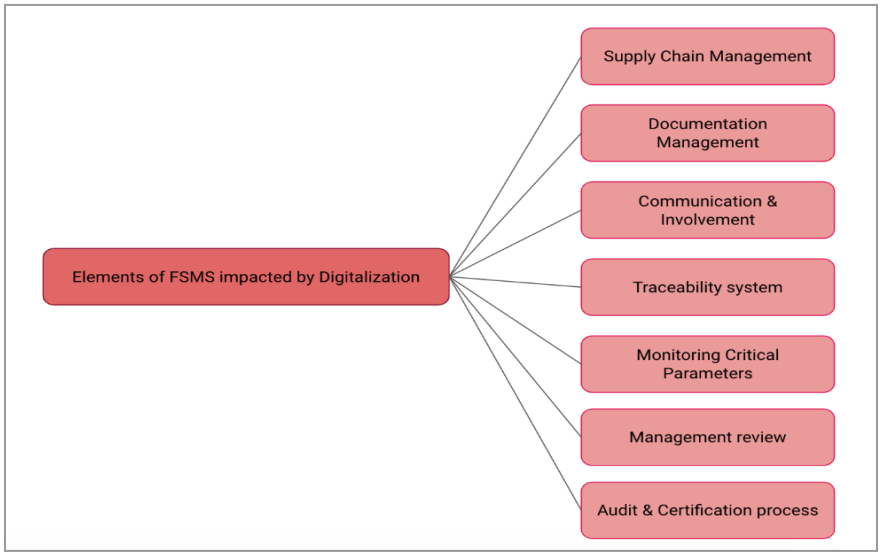

Figure n°7: Elements of the food safety management system impacted by digitalization according to interviewees.

Supply chain management

Digitalization is proving its important role in supply chain management thanks to smart data collection and fast documents' sharing between manufacturers and retailers. "Our platform, a retail management software, is helping retailers and suppliers to sell more, stock less and see everything happening in the supply chain." as Expert 1 said. The Enterprise Resources Planning (ERP) software is keeping all departments interconnected with each other and bringing transparency of data from the reception of raw materials to the shipment of finished products. Expert 7 added: "The warehouse management software we use allows smooth stock management and the respect of quality rules like First In First Out."

Usually each supplier is using his own internal computerized systems to track and document his activity. For compatibility and security issues, these internal systems can not be connected to others from outside the organization, and it's almost impossible to interfacing two systems between two companies. "Even inside your own organization, you can use different internal systems: ERP, SAP, MES, etc…many kinds of softwares to monitor your system. In order to make connections between them, it costs a lot of money. Usually the IT team struggles with this." as expert 4 explained. Also, expert 7 mentioned during her interview That internal communication is somehow under control but the external communication can't be reached: "Using this digital platform, we manage well our internal communication between the departments, but we are not satisfied about external communication since this software or our ERP are not connected to external organizations like suppliers, customers or even colleagues from the same multinational group that we belong to,....Unfortunately, we keep using emails to communicate with them."

Blockchain technology comes as a solution for the several challenges mentioned above with a platform that combines different products from different systems and links between them to rebuild trust with all interested parts and stockholders also, to comply with the strict regulations. In a multi-stakeholder environment, each actor has his own node and pushes inside it the amount of data he wants to share with full control of giving the accessibility to the viewers or other actors. Expert 4 explaining the security of data through blockchain: "Any actor remains the owner of his data in a secure way, when he uploaded it in this node of blockchain, we convert it

to encrypted codes and characters which will make it unpredictable and securely transferred between other nodes inside the network of supply chain."

Table n°4: Impact of digitalization on the efficiency of supply chain management within a food safety management system.

Element of FSMS /Category	**Digital tool**	**Impact on the efficiency/ Sub-category**
Supply Chain Management	● Browser-based platform connected to the ERP ● BlockChain platform ● Smartphone Application	**Fast communication** between manufacturers, retailers and suppliers ⇒ Reduce time of investigation after the appearance of incidents or non-conformities (Expert 1) **Automated ordering and Real-time tracking** of data related to the supply chain plans, materials' availability and suppliers' approval ⇒Smooth stock management and efficient warehouse management. (Expert 1& 7) **Data security**: Each actor remains owner of his node where his data is stored in a secure way using encrypted characters. He chooses to give access to the specific viewers and with a limited amount of data. ⇒ Reduce mistakes on entering the data and avoid falsifying data. (Expert 4)

Documentation management

The documentation process includes the creation, the verification and the approval. Using this software, this process is getting faster and more efficient. Technical specification files are approved by managers easier through electronic signature and they are shared immediately with the related personnel. Not only that, but the software is showing if the document is viewed or not by the concerned person. ``We constantly receive positive feedback from external auditors about the digital tools and they keep showing their appreciation of this technology on every visit." as expert 7 had mentioned in the interview. Expert 7 is using a quality management software in the

form of a cloud-based platform allowing different users from the same organization to handle documentation electronically, to monitor the predefined KPIs, to share audits' findings and to manage non-conformities.

The cleaning and disinfection system is considered an essential element in HACCP procedures and one of the basic conditions for a safe operational environment. The smart application offers Cleaning-plan functionality that allows users to organize and track the cleaning tasks. Expert 5 mentioned "The automated system sends notifications to all the assignees as a regular reminder. Any other schedules and/or follow-ups related to the sanitary control plan can be adopted." This smart solution avoids using papers which create an environment friendly process and reduce the costs related to printing and lower the risk of non-conformities with non-updated papers.

Table n°5: Impact of digitalization on the efficiency of documentation management within a food safety management system.

Element of FSMS/Category	**Digital tool**	**Impact on the efficiency/Sub category**
Documentation Management	● Browser based Platform connected to the ERP	**Fast and easy management of all documentation** ⇒Faster approval of documents (Procedures, Instructions, Standards, Policies) through electronic signature feature. ⇒ Rapid access to the documents: reduce the time to look for the concerned document. (Expert 7) **Low cost and Environment friendly tool** ⇒Reduce the waste of paper and money. (Expert 6)

Communication and Team's involvement

The internal communication between the different company's departments is a very important part of the system and it should be established and maintained in the most efficient way to avoid any gaps that can lead to non conformities. Expert 6 explained how her company is offering a smart Enterprise Resources Planning (ERP) software, that besides the automated production planning functionality, it helps in keeping processes interrelated across departments. A tea manufacturer confirmed to the expert 6 once that this digital tool is helping the company manage complex issues at multiple facilities with ease thanks to real-time alerts in the group.

For big chains of shops, restaurants, workshops, the smart application gives group managers an overview through a dashboard to see the current state of different sales points about completing the daily tasks and routines, making management involvement easier in the food safety management system. Expert 7 mentioned that the digital platform they use at her company brings a shared dashboard for all users, teams and managers to have an overview of the current situation of the food safety management system. It shows the percentage of progress and fulfillment of the assigned tasks leading to a better monitoring of KPIs. The use of smart technologies will allow the involvement of all actors with a clear responsibility and real-time traceability.

Table n°6: Impact of digitalization on the efficiency of Communication & Involvement within a food safety management system.

Element of FSMS/ Category	**Digital tool**	**Impact on the efficiency/ Sub-category**
Communication & Involvement	• Software-based platform connected to the ERP	**Better communication with internal partners:** To combine in one platform data from different internal systems that can not be connected directly to each other. ⇒ Fast communication and exchange. (Expert 7)

Continuation of Table n°6:

Communication & Involvement	• Software-based platform connected to the ERP	**Continuous involvement**: the platform offers a digital dashboard showing the overall status of KPIs at different sales-points, franchise, group's entities. ⇒ To keep teams and managers updated about the current situation of the food safety management system. (Expert 6 & 7)

Traceability system

During recall process management, companies should be able to send information to the interested parties in a few hours, what batches are related and all information related to its circulation along the food chain, so they can take it out from the market immediately. "Ten years ago, one of the big food industries multinationals had a dangerous food incident within baby milk bottles, and with a weak paper-based traceability system, they were not able to have clear information about the full traceability of the concerned product. Blockchain technology is 100% a driver of efficiency. They need strong traceability, it's not a question of efficiency only, there is no choice to use or not, it's mandatory, and regulations are going in the direction of making technology mandatory." Explained by expert 4.

This technology makes all parts view the owner of it so they can accord the full responsibility to the owner for all topics involving this actor. Expert 4 added "QR codes are associated with each actor which will give consumers the ability to see the actor's contact and data through mobile application, thus improving the transparency and trust in the food supply chain".

A strong food safety management system is linked directly to a strong traceability system which tracks the product at all levels. Raw materials, semi-finished and finished products, everything should be recorded with a timestamp. "Thanks to the smart Labeler we offer, a labeling machine connected to the application to easily print secondary expiration dates" as expert 5 mentioned.

This option ensures traceability from the recipe sheet to the delivery time covering the expiration date, batch numbers and allergens that can be found there, etc…. The big memory of the application allows users to store the data for five years. "At every reception of raw materials, the related data are entered to the ERP, and that latter keeps tracking the expiration date of them. The suspected products are automatically blocked in the system until approval by the quality manager." explained by expert 7. In the case of non-conforming product or material, the smart system is allowing its detection not only by batches but also by its position inside the warehouse. Thanks to those digital platforms, food industries are ensuring synchronization between departments and the full quality control of materials, products and the food safety system.

Table n°7: Impact of digitalization on the efficiency of Traceability system within a food safety management system.

Element of FSMS/ Category	**Digital tool**	**Impact on the efficiency/Sub category**
Traceability system	• BlockChain Platform • Smart platform connected to the ERP	**Data transparency:** real-time tracking of the product through all the supply chain with exact time and responsible actors ⇒ reduce the time of recall procedure and improve communication.(Expert 4) **Rapid detection**: Immediate localization of non-conforming products. ⇒Avoid non-detection of deviations related to the non-conforming materials or products. (Expert 7) **Full traceability** of the product: from the reception of materials to the shipping of the final product. thanks to the automated labeling tool and to the connected ERP system. ⇒Rapid extraction of data during incidents, audits or for any other needs. (Expert 5 & 7)

Monitoring of critical control points

Temperature is a critical parameter, for most food-related goods, that should be monitored continuously in order to keep the products safe. Assigning someone from personnel to do this hourly check of temperature at a certain level and record it manually on paper will not be that much efficient since the assignee will be busy with other tasks and can skip the recording at the exact time. Moreover, the huge amount of paper that will be created and stocked for years.

Thanks to the temperature sensors connected to the smart application, the temperature will be automatically and continuously recorded. Even if the internet connection is interrupted, the smart sensors will keep recording temperature and data will be transferred to the system when the internet is restored. What makes this application more practical is the automatic notification system, via SMS and Email, when temperature is reaching non-conforming levels. “One of our customers revealed the positive impact of our application when the notification system alerted his team immediately that the refrigerator is disconnected, while no one was in place which helped in avoiding the loss of goods with a value of one hundred thousand euros by a prompt intervention” as the Expert 5 mentioned. The user will have a Temperature reading Manual where he can centralize all temperature recordings at any time/date, helping in saving space, time, resources and being accessible in two clicks. This rapid function is needed to find easily old records specifically in case of inspection by the hygiene control agent. At any level of the activity, the customer chooses where to implement this smart technologie: control of raw materials’ reception, monitoring of production according to the Time-Temperature pairs (rapid cooling, reheating, cold connection, hot connection, operating temperatures).

Table n°8: Impact of digitalization on the efficiency of Monitoring of critical control points within a food safety management system.

Element of FSMS/ Category	Digital tool	Impact on the efficiency/Sub category
Monitoring of critical control points	• Internet-Of-Things Smartphone application	**Automated and continuous monitoring**: Ensuring the full recording of critical parameters thanks to the smart sensors connected to the application. ⇒Ensuring an efficient HACCP system without waste of paper, time or workforce. (Expert 5) **Immediate detection of any deviation** in the parameters with an automated notification system**.** ⇒Reduce the risks or consequences from deviation of parameters from their acceptable limits. (Expert 5)

Audit planning & Non-conformities management

For the different audits conducted in our plant: internal, external or daily hygiene inspections, the smart system is helping the quality manager to plan the audit's activities and to do its reporting more efficiently. During audits, inspection or simple verification, it's useful to have a checklist based on the requirements of the assessment. For regular use, personnel find difficulties filling in paper-based checklists due to time and also the unclear input due to different fillers. According to expert 5, the smart application provides users with checklist functionality that allow them to create their own template and share it with their team members to standardize checklists in all the organization and avoid any difficulties mentioned above. Non-conformities reported during audits are shared electronically in this platform with the concerned people in the plant and the actions are assigned immediately to the responsibles with specific due dates.

The smart software keeps monitoring the open actions and sends regular notification to the responsibles for the overdue ones. This method is helping the quality manager to handle non-conformities more efficiently and ensure better involvement of all teams. As expert 7 mentioned: “This digital tool is helping me a lot to ensure the fulfillment of tasks efficiently.”

Table n°9: Impact of digitalization on the efficiency of Audit planning & Non-conformities Management within a food safety management system.

Element of FSMS/ Category	**Digital tool**	**Impact on the efficiency/Sub category**
Audit planning & Non-conformities Management	● Smart Platform connected to ERP ● Smartphone Application for HACCP system	**Easy auditing** thanks to the ready templates and checklists for internal audits and the Scheduling feature. ⇒ Reduce the time of audit planning by directly filling in the ready templates. (Expert 5) **Continuous readiness** of the food safety management system for any incoming audit. ⇒It reduces the audit time on itself thanks to the fastest access to data. (Expert 7) **Efficient reporting**: Fast and clear reporting of the findings directly in the system at the same time of the audit. ⇒Reduce the time of reporting audits. (Expert 7) **Non-conformities management**: The deviations are highlighted immediately in the system (based on the defined parameters) and the actions are assigned immediately to the responsibles with specific due dates. ⇒Avoid forgetting some findings and ensure the full control of nonconformities. (Expert 7)

Management review

Management review is an important part of the food safety management system and of the certification process in general. The smart software helped the quality manager to speed up the duration dedicated for the preparation of this step from the average of 45 days in 2019 to the average of 15 days in 2022. The more users are involved in this smart platform, the more data is shared between teams, the easier the communication in the system. Thus, the collection of data, the documentation management, and the overall food safety management system will be improved. Expert 7 said "If 100% of the personnel are involved and using this software, the average duration that I will take to prepare a management review for example will be 2 days. Managers are engaged to invest in buying more sessions of this software to involve more users from our people and it's my challenge to convince them about the benefit of investing in this technology."

Table n°10: Impact of digitalization on the efficiency of Management review within a food safety management system.

Element of FSMS/ Category	**Digital tool**	**Impact on the efficiency/Sub category**
Management review	● Smart Platform connected to ERP	**Faster preparation** of the management review: from 45 days using paper-based system to 15 days or less with digitalized system. ⇒Avoid wasting time in selecting the concerned papers. (Expert 7)

Certification process

Expert 2 explained how his smart software can support an efficient food safety certification process "With 15 models available in one platform, covering different tasks related to SQF program, our customer choose the combination of models he needs: Documentation, Recording, Training, Auditing, Supplier management, Smart Lab, Scheduling features, etc….". The smart software offers ready templates and clear steps for the related activities. Expert 3 also confirms from her experience with food industries "Warehouse management system, digital record of temperature or training employees, these smart solutions are more efficient methods than using

paper-based methods which can lead to wasting time and missing some data" Expert 6 added that their digital system helps in the process of food safety certification, according to international standards like SQF and BRC, by maintaining the readiness of the system for any incoming audit. It reduces audit preparation time and it reduces the audit time on itself thanks to the fastest access to data. The expert gave the example of one of their clients who is producing frozen food products that by using her company's automated ERP system has helped them reduce audit time by 88% : "They were able to easily and quickly collect the data needed for the auditor".

Table n°11: Impact of digitalization on the efficiency of Certification Process within a food safety management system.

Element of FSMS/ Category	**Digital tool**	**Impact on the efficiency/Sub category**
Certification Process	• Browser-based Software • Smart application • Automated ERP system	**Efficient certification process:** 15 models available in the smart platform covering all the requirements and elements of the SQF programs helping quality managers to prepare their system for the certification process. =>Ensure efficient preparation for the audits and reduce their time by 88%. (Expert 2 & 6)

Cost of digitalization in the food safety management system

The experts confirm that their smart technologies are improving efficiency not only by reducing the cost of papers used or the cost of time consumed for traceability process, but also with few resources needed to implement this technology: No extra IT skills or headcounts needed to manage these platforms and no regular maintenance is required as the supplier of digital tools provides a complete training in the beginning of the project, and they are available to support anytime the users in case of updates needed or any other challenges they face. It works on laptops, tablets, smartphones or any type of devices so food companies will not need any extra investment, except the monthly or yearly membership they pay to use these digital tools.

6.4 Conceptual model

Below is the conceptual model constructed as a summary of this scientific research's results which are based on data collection from experts of the food supply chain:

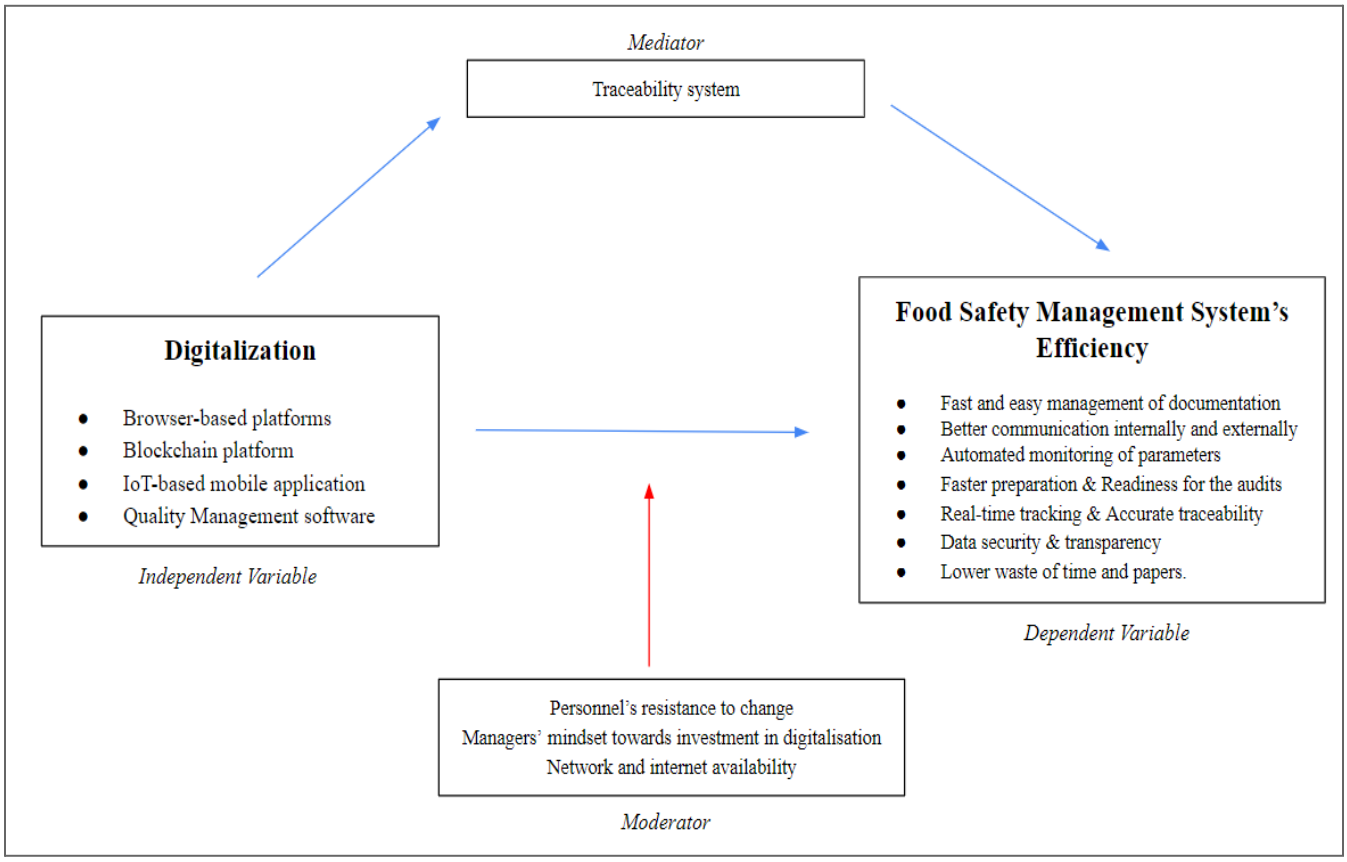

Figure n°8: Conceptual model showing the positive impact of independent variable (digitalization) on the dependent variable (efficiency of food safety management system) with traceability system as a mediator and the appearance of some moderators.

As shown in the conceptual model, the results of this research bring answers for the research questions: Digitalization clearly improves the efficiency of food safety management systems through improving the traceability system and other elements of the FSMS. Experts interviewed believe that those digital tools allow rapid data detection, fluent sharing between actors and accurate traceability systems without requiring a lot of resources. The digitalization is an efficient solution that lowers the food safety management system's cost by reducing documentation costs related to paper and time. This improvement is realistic and can be proved from the first months after implementing these smart tools.

The expert 5 said: “We keep getting positive feedback from our clients, they told us that they receive compliments about their food safety system from auditors because everything is organized, all the documentation is there, it’s just one click and they can see everything.” Nevertheless, some moderators mentioned by experts could lower this positive effect like internet availability, leaders' mindset toward digitalization and the resistance to change from workers in the food industry.

Expert 7 said “Despite the advantages of those digital tools, I feel the resistance to change from the personnel, they don’t appreciate how this software keeps reminding them constantly about the open actions through an automated notification system. Moreover, the transparency that it is bringing by making their behavior, toward tasks, directly viewed by their managers.”

“The investment in digitalization depends on whether the top-management mindset is oriented to continuous improvement and long-term vision.” as mentioned by Expert 3. The budget is the most common barrier against investing in digitalisation since those tools need monthly or yearly subscription and their price can rise by the number of users in the company. Expert 7 explained indirectly that their managers are more open to invest in digitalisation of the food safety management system thanks to their belonging to a multinational company and that working with local managers will make the challenge more tougher. Expert 3 added: “From my experience with several food industries, Family-Businesses believe in the old methods that brought them profit and success. In this type of company, it's harder for quality managers to convince their leaders to invest in digitalization.”.

Although the availability of the internet is a key element for using these digital tools, the experts confirm that their products are able to run in an offline mode which will be useful especially for farmers. Expert 4 supports this idea by one example “In Cameroon, we work with the Agriculture ministry, helping them to track livestock transportation between North and the south of the country. Farmers from North move livestock to the south where markets. A lot of mafia are threatening this process by stealing cows in the middle of the road, there is a big loss. To identify where this event happened, they decided to put checkpoints where agents are using our application to count the livestock in the truck at each checkpoint in REAL TIME and follow the

traceability. Sometimes, with no connection there, our solution allows data to be registered in offline mode, and after internet recovery, data will be uploaded. We need to be creative depending on the challenges that our customer faces".

The results of this research are a good reference to form constructs for further quantitative research based on analyzing the variable efficiency and directly measuring one or more KPI's trends inside one of the food industries. This further research can confirm objectively the effect of using digitalization in the food safety management system's efficiency and shows measurable results in a specific timestamp.

The collection of data in this research was mostly from providers of digital platforms and few interviews were conducted with the users who can give their feedback and more realistic answers through their experiences with those smart tools. Plus, the number of interviews was limited to 7 interviews in total which is acceptable according to the research requirements however, with more interviews we will have a richer understanding of the impact of digital tools on the efficiency of food safety management systems. Moreover, this paper showed the different digital tools that are currently used in the food supply chain but other smart technologies like Artificial Intelligence (AI) or Machine Learning are not yet widely used in the food safety management system or their related smart solutions are still under development.

7. CONCLUSIONS AND RECOMMENDATIONS

1. Food safety management systems are following local rules and international standards that are in continuous updates to follow the changes in hazards and challenges related to the food supply chain. Food quality assurance is associated with a strong traceability system to ensure that food-borne illness' risks are eliminated or reduced to a minimum level. A complex network like the food supply chain is generating huge amounts of heterogeneous data like multiple ingredients with different specifications coming from different suppliers, and different geographical origins. Current food safety regulations are not considering digitalization as a mandatory method in the food safety management systems. Nevertheless, it is always a big challenge to provide the full data related to a specific product from all steps of the food supply chain and it is always a struggle for quality managers to reach the system's efficiency with the paper-based method.
   The scientific literature analysis has shown that some scientists discussed the advantages of using digitalization in the food safety management systems but they didn't present a full explanation on the impact of those tools on the efficiency of food safety management systems and this research paper comes to understand the impact of several digital tools and smart technologies on the efficiency of the food safety management system.

2. The qualitative research process adopted in this paper was based on interviews that are conducted with different experts from the food supply chain revealed that digitalization improves the efficiency of food safety management systems, not only by enhancing the effectiveness with an accurate and fast traceability system but also by eliminating the waste of time or resources compared to the traditional methods. Though, investing in digitalization depends on several factors like the mindset of the management level or the resistance to change in the organization, food safety management systems are in need of digital tools to meet the requirements efficiently.

3. Different digital tools: Browser-based platforms, Blockchain platforms, IoT-based mobile applications, Quality Management softwares make positive impact on the different esfficiency's aspects of the food safety management system with a fast and easy management of documentation, better communication internally and externally, automated monitoring of parameters, faster preparation and readiness for the audits. Some tools make significant improvement on real-time tracking and accurate traceability that guarantee data security and transparency, all of that with lower waste of time,papers and any related resources which improve the overall efficiency of FSMS. There are elements that moderate this positive impact of the digitalization on the food safety management system like internet availability, leaders' mindset toward digitalization and the resistance to change from workers in the food industry.

4. Thanks to the digitalization, and in the case of foodborne incidents, the responsibles for the root causes behind it are easily identified, without extended investigations or exchange of unnecessary paperwork. It is recommended for food supply chain actors to use digital tools in their food safety management systems since they help in avoiding several intermediaries through direct collaboration between different parties despite their locations or their internal systems. This investment contributes to minimizing transaction duration, data duplication, paperwork, and communication overheads. Thus, taking effective actions and protecting consumers' health.

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SKAITMENINIMO ĮTAKA MAISTO SAUGOS VADYBOS SISTEMŲ EFEKTYVUMUI

Youssef JMAL

Magistro baigiamasis darbas

Kokybės vadybos programa

Vilniaus universitetas

Ekonomikos ir verslo administravimo fakultetas

Vadybos katedra

Darbo vadovas: **prof. D. Serafinas**

Vilnius, 2023

SANTRAUKA

59 puslapiai, 11 lentelių, 8 paveikslai, 26 literatūros šaltinių nuorodos, 3 priedai.

Pagrindinis šio magistro darbo tikslas – nustatyti kaip skaitmenimas daro įtaką skirtingiems maisto saugos vadybos sistemos efektyvumo aspektams. Magistro baigiamasis darbas buvo pradėtas nuo gilios mokslinės literatūros analizės, siekiant nustatyti įvairias skaitmenines priemones, naudojamas maisto saugos vadybos sistemoms, ir ieškoti esamų darbų, susijusių su maisto saugos vadybos sistemų efektyvumu, išvadomis. Po to autorius atliko kokybinį tyrimą, kuriame dalyvavo su skaitmenines maisto saugos vadybos sistemai skirtas priemones siūlančias įmones atstovaujančiais ekspertais, maisto saugos auditoriais ir maisto pramonės įmonių kokybės vadovais, pateikia atsakymus į tyrimo klausimus. Atliktas tyrimas atskleidė, kad skaitmeninimas padeda pagerinti bendrą maisto saugos valdymo sistemos efektyvumą per stiprią atsekamumo sistemą visoje maisto tiekimo grandinėje. Taip pat pašalinant laiko ar išteklių švaistymą, palyginti su nesuskaitmeniniais metodais.

Ekspertai mano, kad šį teigiamą skaitmeninimo poveikį maisto saugos vadybos sistemos efektyvumui stabdo kai kurie veiksniai, tokie kaip vadovų požiūris į skaitmeninius sprendimus ir personalo pasipriešinimas pokyčiams.

Reikšminiai žodžiai: Maisto Saugos Valdymo Sistema, MSVS, skaitmeninimas, efektyvumas, poveikis.

THE IMPACT OF DIGITALIZATION ON THE EFFICIENCY OF FOOD SAFETY MANAGEMENT SYSTEMS

Youssef JMAL

Paper of the Master‘s degree

Quality Management Master‘s Program

Vilnius University

Faculty of Economics and Business Administration

Department of Management

Supervisor – **prof. D. Serafinas**

Vilnius, 2023

SUMMARY

59 pages, 11 tables, 8 figures, 26 references, 3 annexes.

The main purpose of this master thesis is to understand the impact of digitalization on the different efficiency aspects of the food safety management system. The Master thesis started with a deep scientific literature analysis to identify the different digital tools used for the food safety management systems and to look for the finding of existing papers concerning the efficiency of food safety management systems. Following this, the author carried out a qualitative research using interviews with experts representing companies that offer digital tools intended for the food safety management system, food safety auditors and quality managers of food industries who have presented answers to research questions. The performed research revealed that digitalization helps in improving the overall efficiency of the food safety management system through a strong traceability system across the food supply chain. Also by eliminating the waste of time or resources compared to the non-digitalized methods.

The experts believe that this positive impact of digitalization on the efficiency of the food safety management system is moderated by some factors like the mindset of the management toward digital solutions and the resistance to change by the personnel.

Key words: FSMS, food safety management system, digitalization, efficiency, impact.

ANNEXES

Annex 1. Example of interview proposal sent to experts

"Dear Mr. (name of expert),
Thank you for accepting my request to be connected with you on the LinkedIn network.

My name is Youssef Jmal and I'm a Quality Management master's student at Vilnius University working on a research project about "The impact of digitalisation on the efficiency of food safety management system".

After searching for companies that offer advanced solutions for food safety management, I found that (name of the company) is offering an advanced solution for digital documentation in the food supply chain.

Our research work needs collecting information from experts who deal with digital tools intended for food chain actors. Mr. (name of the expert), as a (position) at (name of the company), you are an interesting profile to discuss with him about this software, its features and specifically about its impact on the efficiency of the food safety management system.

I would be honored to share with you a 40-minutes online-interview and I'm hoping you can comment specifically, on:
_The different services or products at (Company name).
_The technologies used for this software and its characteristics.
_Perception of food actors and their experience with this application.
_Impact of this new technology on the efficiency of food safety management systems.
_Challenges related to the implementation or to the use of this application.

I suggest that we have a meeting on Tuesday, May 24th, at 4 PM (GMT-3) or Wednesday, May 25th, at 4 PM (GMT-3). Please feel free to suggest a different date or time that is more convenient for you.

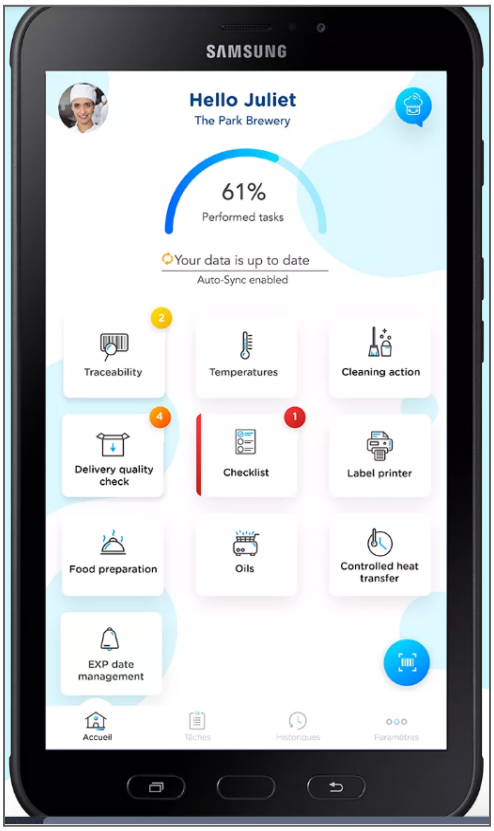
Please note that we respect privacy and ethics, moreover the personal data are protected whether it concerns your company or your person.. Our target is not to look for any detailed or numerical data, we just need general knowledge about this new technology applied for the food safety management systems and to get your point of view as you are an expert in this field.

Once the research work is completed, I would be pleased to share an electronic copy with you to see your contribution.

Thank you for considering my request. I hope to hear your response as soon as possible.
My best regards,
Youssef Jmal"

Annex 2. Smart HACCP application

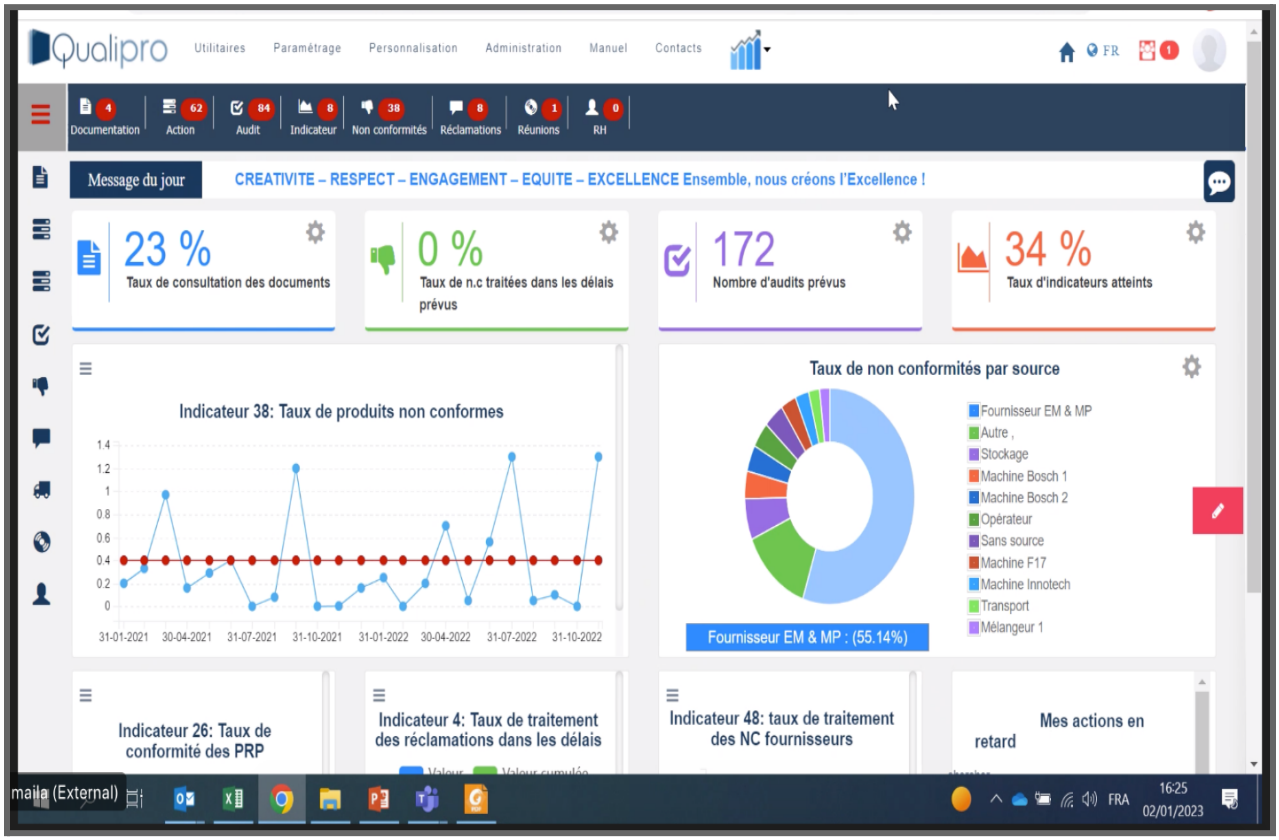
Figure 1: The different functionalities that a smart mobile phone application is offering to manage the HACCP system. This product is offered by the company represented by the expert 5.



Source: Shared by expert 5.https://www.traqfood.com/en/

Annex 3. Quality management software

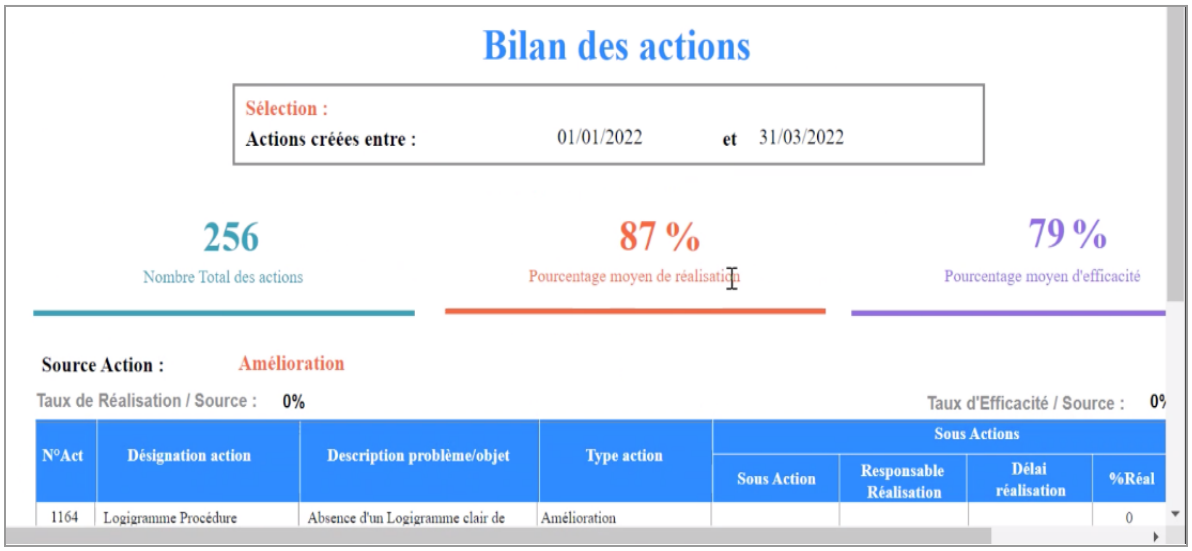
Figure 2: Below is an example of dashboard with an overview to the overall KPIs of the food safety management system accessible by the personnel of a food industry, that expert 7 represents, it's showing the yearly trend of non-conformities, the number of upcoming audits, and different other KPIs, plus a notification system for several functionalities.



Source: Shared by expert 7 during the interview.

Below are two examples of reporting extracted from the quality management platform.

Figure 3: The overall actions' report with percentage of the completed and the open ones. (The language inside the figure is French)



Bilan des actions

Sélection :
Actions créées entre : 01/01/2022 et 31/03/2022

256
Nombre Total des actions

87 %
Pourcentage moyen de réalisation

79 %
Pourcentage moyen d'efficacité

Source Action : Amélioration

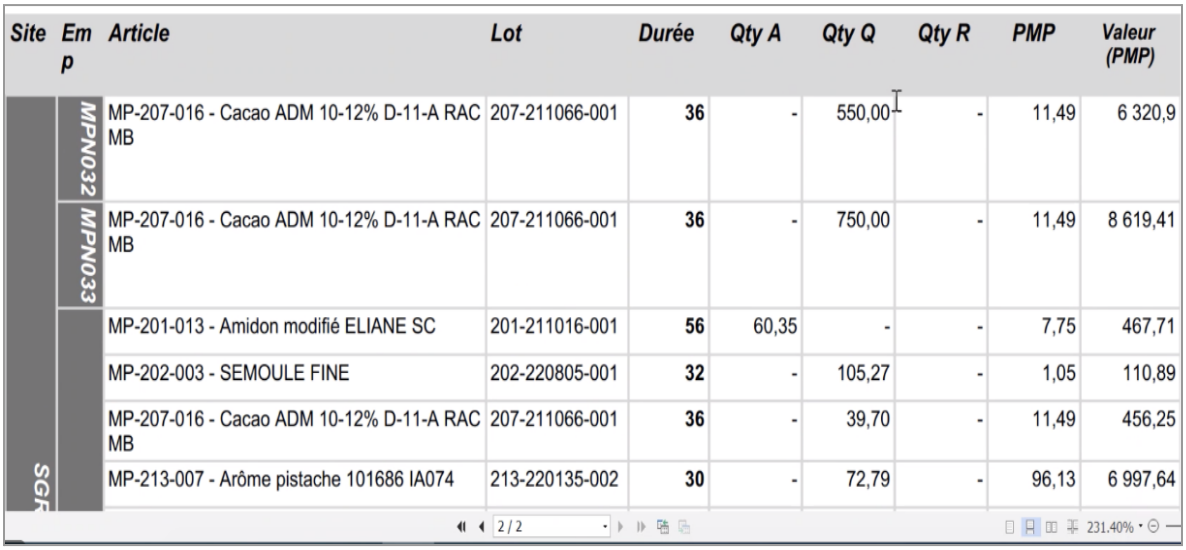
Taux de Réalisation / Source : 0%

Taux d'Efficacité / Source : 0%

N°Act	Désignation action	Description problème/objet	Type action	Sous Actions			
				Sous Action	Responsable Réalisation	Délai réalisation	%Réal
1164	Logigramme Procédure	Absence d'un Logigramme clair de	Amélioration				0

Source: Shared by expert 7 during the interview.

Figure 4: The reporting option related to the stock of raw materials sorted by the expiration date and giving other related characteristics. (The language inside the figure is French)



Site	Emp	Article	Lot	Durée	Qty A	Qty Q	Qty R	PMP	Valeur (PMP)
SGF	MPNO32	MP-207-016 - Cacao ADM 10-12% D-11-A RAC MB	207-211066-001	36	-	550,00	-	11,49	6 320,9
	MPNO33	MP-207-016 - Cacao ADM 10-12% D-11-A RAC MB	207-211066-001	36	-	750,00	-	11,49	8 619,41
		MP-201-013 - Amidon modifié ELIANE SC	201-211016-001	56	60,35	-	-	7,75	467,71
		MP-202-003 - SEMOULE FINE	202-220805-001	32	-	105,27	-	1,05	110,89
		MP-207-016 - Cacao ADM 10-12% D-11-A RAC MB	207-211066-001	36	-	39,70	-	11,49	456,25
		MP-213-007 - Arôme pistache 101686 IA074	213-220135-002	30	-	72,79	-	96,13	6 997,64

2 / 2 231.40%

Source: Shared by expert 7 during the interview.