Big Data in Food Industry: A Technical Summary of Modern Approaches Used in Data Extraction

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The food industry has consistently ranked among the most important industries, providing essential goods for consumption and satisfying the primary needs of individuals, as outlined in Maslow's Pyramid. Access to basic resources, such as water, housing and shelter, is necessary for individuals to meet their basic needs and normally function. While the higher levels of the Pyramid may be achieved through personal and professional growth and education, the foundational elements are essential for human survival. Given the critical importance of this industry, continuous investment in efficient methods of production is justified. In recent years, technology has played an increasingly significant role in the food industry, enabling optimization of various processes, greater control over production and transport, and faster promotion, resulting in increased sales volumes. This article aims to identify and analyze the advantages and disadvantages of different methods and technologies employed in the food industry. The goal is to capture the data necessary for technological solutions that simplify, expedite or reduce the cost of processes, while maintaining or even improving quality standards.
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1 Introduction

The food industry includes various processes that can be classified into separate subfields. Due to its diversity, it involves the identification of basic products, such as vegetables, fruits and cereals, which serve as the foundation for the production of other foods. Additionally, processed products also play a crucial role in completing the industry's offerings. Managing the production, processing, distribution and marketing of food products is complex due to the vast variety of options available.

To streamline the management of the food industry, various solutions have been sought to reduce costs, increase production and improve the efficiency of the various processes. With the evolution of technology and its integration into numerous areas of the economy, it has become impossible to ignore its potential benefits in the food industry. This has provided an opportunity to reorganize and automate processes that were previously deemed defective or generated losses in terms of costs or time. By integrating different technological approaches into specific stages of the product chain management, significant improvements have been observed in the way processes are implemented, leading to the transition to a digitally governed industry.

By examining each essential stage of the food industry, it is possible to identify the significant changes that digitalization has brought about and how it has influenced their development.

The agriculture sector involves a complex production process that covers monitoring activities, cultivation, growth and physical labor, required to care for products. These activities can generate intense physical and financial efforts. As such, it has become necessary to implement solutions that reduce the impact of different elements on the final result of the production process.

The implications of tech approaches in agriculture has facilitated the transition to industrialization, enabling the production of food in large volumes, oriented towards globalization and exportation. Various solutions have been implemented to enable agriculture to be carried out on an industrial level, leading to an easier transition to the processing stage, also marked by the use of technology in the transformation of products. Additionally, careful

monitoring of the factors that influence the development of a product, such as water, soil, climate and other external factors, is crucial to obtain the best results. To achieve this, different methods of retrieving data related to the listed factors have been sought to provide the best growth parameters.

In this context, sensors and data extraction techniques have played an important role in agriculture. The concept of Big Data has practical applicability in the monitoring and control of elements that can influence the production stage in the food industry [1].

The distribution of food products is an area of the food industry that has benefited from numerous technological advancements, which are described in specialized literature. It plays a crucial role in ensuring the delivery of high-quality products that comply with established standards and regulations. The transportation of goods via air, land or water is a sensitive stage that must guarantee the safety and efficient delivery of large quantities of products to their destination, while preserving their quality. Obtaining data that allows the monitoring and calculation of all the parameters involved in the controlled and correct transport of goods is essential. The use of sensors or components to collect data on transport speed, temperature, humidity, air quality and other environmental factors that may affect the quality of the products, is of utmost importance. Technology can also be used for tracking products, maintaining inventory records and optimizing the distribution route to ensure cost-efficient and timely delivery.

In addition, digitalization has transformed the way food products are marketed, impacting consumer preferences and purchasing habits. It facilitates the promotion of food, ensuring a faster purchase process, controlling the availability of products in stores and integrating principles and regulations that promote healthy eating habits. The use of technology in neighborhood stores or supermarkets has led to a rethink of the traditional operating principles of trade. The trend towards cashless payments has increased in recent years, making it necessary to ensure that all components that enable the purchase of goods and services through electronic means, such as cards or smart devices, are available.

Furthermore, it was imperative to secure the products that were sold in order to prevent any potential losses. Consequently, integrating technology to track products and monitor them from purchase until their exit from the store ensured a safe shopping environment. The labeling of products through technological means, which allowed the acquisition of purchase data, enabled the creation of consumer profiles. This facilitated retailers in identifying which products their customers prefer, thereby revolutionizing marketing strategies. These profiles were integrated into the development of advertising campaigns, commercial offers and store layouts, aimed at attracting the attention of desired products and observing a varied range of offerings to arouse curiosity about other products. This approach was applied in stores like Ikea [2].

All of these stages involved integrating technological concepts to redefine processes, maximize profits and reduce costs. Obtaining data is crucial in any technological activity, as it needs to be translated into computer systems to facilitate desired optimizations. As mentioned earlier, large volumes of data can be obtained from the environment by monitoring transport, measuring product parameters or by following buying trends. These require a specific extraction process for Big Data, which can be carried out using various technologies. This paper will explore some of these technologies, analyze the advantages and disadvantages they offer and provide a synthesized analysis of the most efficient ways to optimize the most important stages and methods.

2 Literature review

2.1 Product chain management in a technological approach

When discussing the food industry, it is essential to consider all the elements and processes involved in its smooth development, including the activities dedicated to managing a product's transition from its basic, natural state to its processing one and eventual sale in stores. In this context, the importance of product direction in the proper management of the

food industry is emphasized, as it is an integral part of facilitating the fulfillment of people's basic needs, as previously presented in Maslow's Pyramid of Needs [3].

The product chain management involves a comprehensive understanding of all the necessary stages required to provide a finished product, characterized by quality and possessing all the promised features. From the production stage, including substages such as obtaining or purchasing the fruit of labor in agriculture, to processing, stock accumulation, management, organization of transport and distribution processes, each of these stages represents a well-defined step that, when correctly and timely fulfilled, ensures efficient management.

Although some activities involved in product chain management require human interaction and are most easily achieved through collective work, such as identifying and establishing relationships with suppliers, negotiating transport, distribution and commercialization contracts, certain processes have shown delays or losses when performed by workers. To streamline and obtain a result with the highest level of quality, efficient solutions have been sought to balance physical work and demanding or unsustainable activities that cannot be consistently fulfilled by people. In recent years, technology has played a significant role in rethinking some of these activities, impacting every area of product chain management and offering various opportunities for development. This has forced companies to rethink their policies and work practices, integrating new technological concepts into predefined processes [4].

As a result, numerous technologies have been approached in different branches to test the benefits they can offer and how they can bring about positive changes in the industry. Firstly, technology has brought with it the term automation, allowing activities that were previously carried out with human effort to be reinterpreted and performed on a large scale or in record time, with the help of robots [5]. Many production factories, warehouses and distribution areas now employ automated solutions that facilitate handling or packaging activities, reducing the effort generated by repeating static processes that always involve the same predefined steps.

Furthermore, the integration of technology has impacted the product chain management in several ways. Firstly, it has enabled automation of repetitive and labor-intensive tasks, reducing the costs and effort associated with these activities. This has been achieved through the usage of robots in production factories, warehouses and distribution areas, where handling or packaging activities can now be carried out more efficiently.

Secondly, technology has allowed a better control of the environment in which the activities of the product chain management take place, resulting in reduced costs and losses, associated with non-compliant products. Through the use of sensors and monitoring solutions, raw materials and external sources can be controlled and verified, thereby reducing the presence of counterfeit products. Additionally, by monitoring parameters such as temperature, humidity, heat or light, there is an economy regarding these resources, which are dosed according to needs, while also ensuring a comfortable and controlled work environment for employees.

Thirdly, technology has enabled real-time data collection related to products, allowing for a permanent record of stocks, of the products presence in warehouses and of the routes they travel from source to destination. This data can be accessed from different areas or locations through the integration of it over the Internet. Thus, the product chain management can be efficiently managed in a centralized manner, including each step, by integrating these steps into an Enterprise Resource Planning (ERP) system [6].

2.2 Internet of Things in food industry: a practical approach using RFID

The concept of the Internet of Things (IoT) gained traction from its novel approach of integrating natural objects via the Internet, stimulating interest and offering opportunities for development. By enabling the interconnectivity of physical objects with software applica-

tions through sensors and technological functionalities, the IoT permits the extraction and translation of data in the digital environment, based on a principle of using the Internet for communication between components. This automatic approach does not require human intervention, and the opportunity was identified to observe and monitor the products, the environment, their condition, the degree of development or other characteristics that contribute to agriculture and the food industry's stages [7], [8].

Sensors are the primary feature of IoT operations, serving as the link between the environment and its parameters and the software solutions that allow monitoring, starting from the transmitted data. As a result, IoT-enabled solutions have been developed to monitor the conditions of food growth, transport between producers and distributors, storage, and even location in stores until purchase [9]. With their assistance, savings have been achieved in preserving product integrity by reducing the factors that can lead to spoilage. Sensors have also been used in stock management, monitoring available quantities, and thus eliminating the risk of theft or fraud, as well as that of insufficient storage space. In this context, they can be used to manage transport and identify situations where supply is not necessary, redirecting resources to areas where transport and distribution are needed.

Nonetheless, it should be noted that the Internet of Things (IoT) is not solely dependent on sensors, and its applications extend to various domains, including the food industry. In this regard, the IoT can be leveraged to create personalized marketing campaigns that cater to specific customer segments in a particular store, by analyzing the products they purchase and developing consumer profiles. This can be accomplished through product monitoring and digital recording of the customer's purchases, as indicated on the tax receipt. To expound on this process, a novel technology referred to as Radio Frequency Identification (RFID) is introduced [10]. RFID facilitates communication via radio waves and relies on two crucial components: the tag and the reader. Every product with an appropriate label that emits radio waves can be read once it comes within range of a designated reader. This concept can be incorporated into cash registers to offer customers a digitalized shopping experience. Several global retail chains have implemented RFID-based stores that automatically identify products in the shopping cart when placed in the reader area, providing a summary of the customer's purchase without requiring employee scanning or customer effort, particularly when discussing self-checkout shops that pioneered this technological approach [11]. Through the development of deliberate solutions, aimed at generating marketing reports, data can be collected and consumer profiles can be created from the moment products are placed at checkout until purchases are completed [12]. Furthermore, in addition to the benefits outlined above, RFID can use the same principles of product identification near the reader to monitor inventory and provide real-time statistics of products in the store. This solution can be easily integrated into the websites or dedicated applications of large store chains, providing up-to-date information on product availability. Therefore, if RFID components were integrated into all stages of the food industry, in the context of the Internet of Things, the resulting benefits would be numerous, including stock monitoring and control, product traceability, inventory management, theft prevention and ensuring safety by identifying, for instance, expired products [13].

2.3 Blockchain in food industry

The blockchain has instigated a paradigm shift across various sectors, including technology enthusiasts, by providing an alternative to traditional transactions, which are conducted through banks and authorized intermediaries. It enables the use of a virtual currency that guarantees the same transaction veracity as those undertaken through known methods, but without third-party involvement and with absolute control over the exchanges made. From its inception to its current application in diverse domains of the global economy, only a

transition phase was required to study its applicability. This technology, which relies on a decentralized database formed by a chain of blocks containing data that are linked to one another in a chronological and unique manner ensures the veracity of the context in which it is used [14]. It has made its presence felt in various sectors, such as finance, healthcare and food, transforming the way processes are approached in these areas.

In the realm of the food industry, the use of blockchain technology is not commonly known to the general public, as it is more frequently associated with the banking and transaction sectors. Nevertheless, stakeholders in the food industry have taken notice of the possibility of ensuring traceability throughout each stage [15] of production, distribution, and marketing, recognizing the presented opportunities and the financial impact they can anticipate, especially when discussing large-scale, industrialized food production and the marked profits outlined by such enterprises. By leveraging blockchain technology, it becomes feasible to append information related to the origin of basic food products, their processing routes, stages of transport and distribution, and sales areas, thereby obtaining a chronology that provides detailed descriptions of the product, ensuring its authenticity and quality by providing all relevant information related to the parties involved [16]. By making such details accessible to consumers, their loyalty is further ensured, while food industry companies can promote healthy lifestyles and eliminate preconceptions related to product contents, as well as other substances that may not be listed on product labels. Thus, a clean product label can be ensured, detailing all elements used to obtain the final product, which can be compared with the information stored in the blockchain.

Incorporating blockchain into the food industry has the potential to significantly reduce, if not entirely eliminate, the sale of counterfeit products, which can pose a serious threat to consumer health and falsely claim to offer specific benefits. For instance, a diabetic person who relies on products with reduced sugar or 0% sugar content could be adversely affected by a counterfeit product marketed as such. Similarly, an athlete who requires precise nutrient intake may experience negative effects on their well-being and performance if they consume a counterfeit product that provides false information regarding its contents [17].

Given these concerns, it is imperative to identify effective solutions for eliminating counterfeit products in the food industry and blockchain technology offers a promising option. Its ability to ensure the authenticity and uniqueness of products is especially valuable, as information added to the blockchain cannot be erased or replaced with data from a contaminated product [17].

3 Methodology

To identify the means by which technology can promote the growth of the food industry and to compare the technological approaches available in order to determine the most appropriate techniques for each process, it is crucial to begin with an analysis of the potential for technological development and integration in different countries. With a focus on the European Union, Eastern Europe and Romania, this article will undertake a quantitative analysis of the implementation of technology and digitalization in the food industry, by taking into account the amount of money dedicated to research. The analysis will draw on data provided by The National Institute of Statistics, taking into account trends observed both within Romania and at the European level. One indicator measured by The National Institute of Statistics, as reported through the Romania-Durabila initiative [18], pertains to the support provided by state institutions for research and development in the agricultural sector, which may include investments into technology.

Hence, the data acquired during the 2004-2020 period indicates an overall upward trend in investments made by government institutions in the agricultural sector of the European Union, with a temporary decline observed in 2012, as illustrated in Figure 1. Despite the increasing values, projections for the 2020-2023

period suggest a slower growth rate due to unforeseen circumstances faced by the European Union, namely the management of the coronavirus pandemic and the implications arising from the Ukrainian war. In contrast, investment prospects in Romanian agriculture are not aligned with those in the European Union.

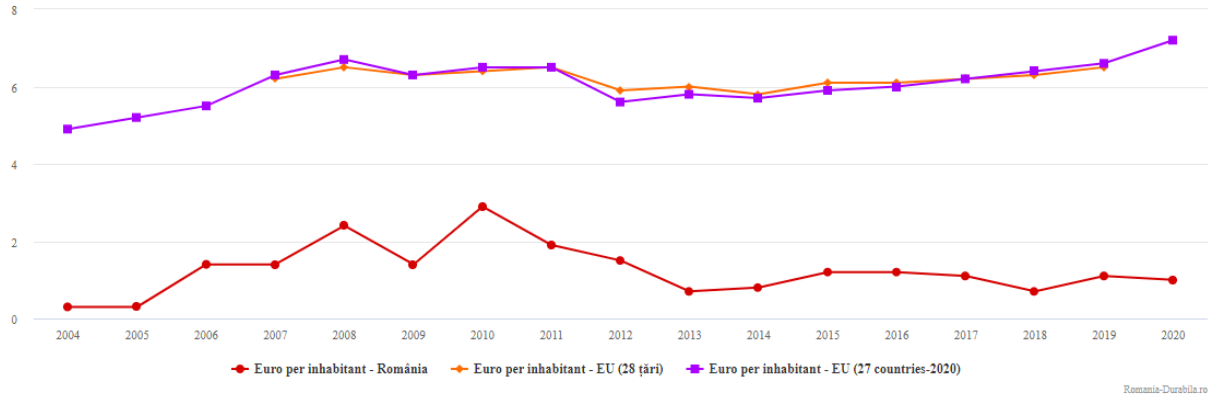

Fig. 1. Governmental investments in agriculture in EU and Romania (Adapted from [18])

Romania experienced growth peaks in 2008 and 2010, but faced periods of decline and stagnation thereafter. Notably, in 2020, the per capita investment in Romanian agriculture was a mere 1 euro, which is seven times lower than the 7.2 euros invested in the European Union. Consequently, various arguments arise concerning the insufficiency of technological advancements in the food industry at present, even though nascent initiatives have gained momentum, presenting a broad scope for exploration with respect to digital investments.

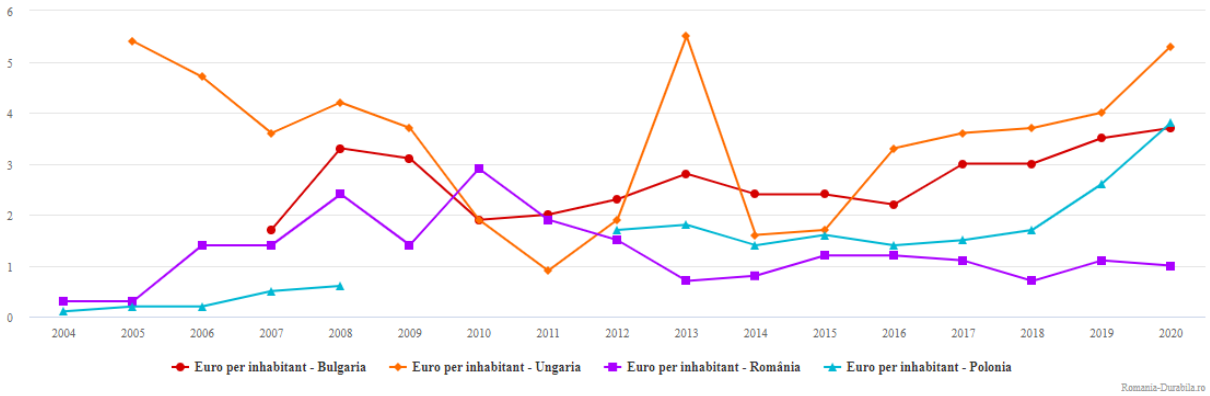

Fig. 2. Governmental investments in agriculture in Eastern Europe (Adapted from [18])

Furthermore, upon analyzing the neighboring countries of Romania in Eastern Europe, as illustrated in Figure 2, it is evident that Bulgaria, Hungary, and Poland have exhibited a rapid increase in government investments in agriculture in recent years, with the year 2020 almost reaching the average euro per inhabitant value of the European Union. However, all these countries are facing similar prospects in the last three years and the current period, which are being influenced by the coronavirus pandemic and the war in Ukraine, necessitating massive investments in areas such as health and national security, resulting in a reduction in the budget allocated for agriculture. By comparing Romania's progress with other Eastern European countries, it is clear that the level of investments is significantly lower. This can be viewed positively as an opportunity to explore and analyze new technologies and their effectiveness in the food industries of other countries, enabling the analysis of advantages and disadvantages and the use

of the most suitable solutions to ensure the digitalization and modernization of all stages related to the food industry, including agriculture, by increasing investments in this area.
Moreover, in order to ascertain the demands of the populace for contemporary alternatives in the realm of food, a survey was conducted among a sample of 35 individuals in Bucharest, Romania, who were aged between 25-45 years and had completed higher education. The participants were requested to indicate which aspect of the food industry could be improved by integrating technology and the outcomes were represented as percentages in Figure 3. Out of the 35 respondents, 8 believed that technology could enhance food safety, while 10 respondents stated that a digital approach could increase productivity. In addition, 6 participants believed that technology could aid in tracking products across all industry-specific stages, thereby facilitating more transparent processes, while 5 respondents believed that contemporary solutions could ensure real-time monitoring.

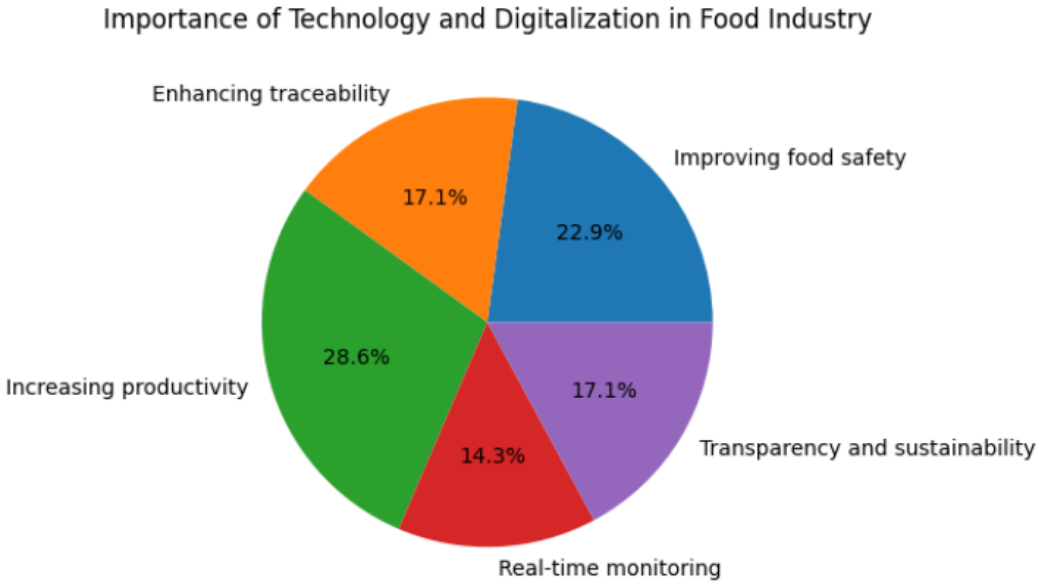

Fig. 3. Importance of technology and digitalization in food industry

The remaining part of the questionnaire was centered on each potential avenue for industry development through technology. Its purpose was to determine the level of conviction of respondents regarding the efficacy of modern solutions, to gauge skepticism, and to determine the number of individuals who believe that technological implementations do not alter the current state of the industry. The results revealed a consistent weight of approximately 65%-70% for those who affirm the potential for digital improvements in the food industry. This underscores the necessity, as identified by this article, of comparing various technological approaches to identify reliable solutions that can be applied across the food industry and also have relevance to Romania.

4 Discussions

The field of Big Data encompasses various techniques used for processing large data sets in a fast and efficient manner to achieve a specific goal. The initial step to attain the objectives of Big Data involves extracting the data that needs to be processed and this can be accomplished using diverse methods, which may range from traditional to modern techniques, depending on the technologies used. In the context of the food industry, as highlighted in the literature review, several technologies play a crucial role in obtaining vast quantities of data from the environment or the objects that form the focus of the industry. This, in turn, facilitates rapid transmission and real-time access to all the information that is

necessary to ensure the appropriate functioning of the relevant processes and practices.
Based on the technologies that were identified, namely blockchain, Internet of Things, and the integration of this concept with RFID, this article will proceed with a technical summary, aimed at data extraction. To achieve this objective, a SWOT analysis [19] will be implemented for each technology separately, following the stages depicted in Figure 4. The purpose is to provide a clearer understanding of the recommended use and in what context it is favorable. The main concepts characterizing each category in the analysis will be summarized in a tabular format to highlight the advantages and disadvantages in a straightforward, logical, and comprehensible manner.

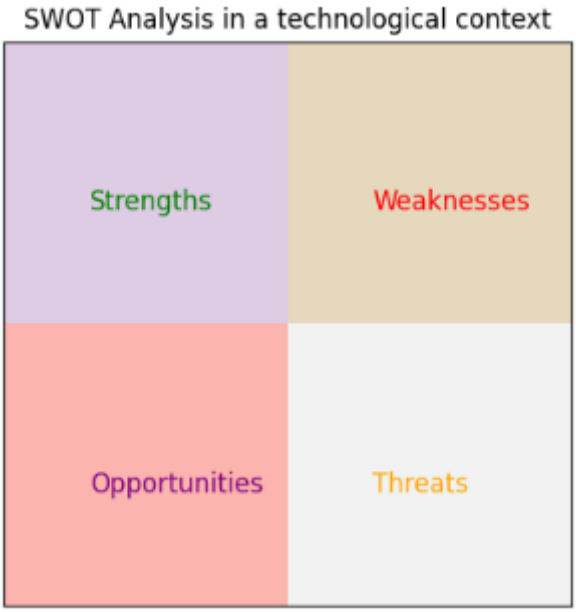

Fig. 4. SWOT analysis

Regarding blockchain technology, the SWOT analysis on its implementation in the case of data extraction, in a Big Data context, resulted in Table 1.

Table 1. SWOT analysis of blockchain technology in food industry

• uniqueness of the data • a history that respects the evolution over time due to the insertion in the chain according to this criteria • the verification mechanism when inserting a new element in the chain • the development of sustainable practices in the specific processes of product chain management	• high costs • the need to implement security policies to protect data • the rigorous and complex definition of the rules that allow insertion into the chain • the complexity of technological implementation and the lack of variety of specialists in the field • delays in processing very large volumes of data
• observing product traceability • clear image of the product label, which reflects in an honest manner all the ingredients used	• security breaches • the lack of the necessary budget for large-scale implementation

• transparency by providing access to all stages of the product chain management • guaranteeing the authenticity of the products, having a great impact in the case of those with the PGI (Protected Geographical Indication) or DOP (Protected Designation of Origin) indicator	• lack of necessary resources, implicitly energy, for continuous use • incompatibilities with the food industry regulations that may appear • disconnection from technology, even for a short period of time, can impact the business environment

Since the use of blockchain presents both advantages and disadvantages for every step in the product chain management, a detailed analysis being necessary and balancing of strengths and weaknesses, integrated in the context of the food sector, the study continued with the SWOT analysis applied to the implementation of the IoT concept, integrated with RFID technology, as detailed in Table 2.

Table 2. SWOT analysis of RFID technology, in an IoT context, in food industry

• real-time location near RFID readers • monitoring environmental factors by integrating sensors in RFID implementation • connecting RFID readers to the Internet and centralizing the retrieved data • easier technological integration within existing solutions • remote access to data, due to their transfer via the Internet	• the need to use specific RFID tags, in order to identify the products • the cost associated with changing product labels, by adding specific tags • the cost associated with the use of RFID readers • the price increases with the performance, so RFID tags and readers that can be used for long distance are even more expensive
• defining consumer profiles by following buying trends • efficient management of stocks by real-time access to data related to their number • securing products found in a warehouse, store or even in a distribution stage	• lack of usage standards • dependence on the correct functioning of tags, sensors and readers, 24/24 • security breaches

Thus, despite the identification of numerous strengths and opportunities in both presented analyses, it is possible to compare the less favorable aspects, namely those related to weaknesses and threats. Regarding blockchain, higher costs and greater complexity in implementation or integration into existing solutions were noted. Conversely, in the context of using RFID in conjunction with IoT, costs are limited to the efficiency of the tags and readers used, and in the food sector, significant results can be achieved using low-cost options.

5 Conclusions

The use of cutting-edge technologies in various sectors of the economy is a preferred strategy for countries continuously investing in their development, digitalizing numerous processes. By comprehending the indisputable advantages that technology brings and analyzing in detail all defined characteristics, the optimization of activities and the attainment of best results are ensured, enabling cost reduction and maximization of quality offered.

The present article aims to create a connection between the multitude of technologies that can be implemented in the food industry, the variety of processes and activities that this sector offers and that deserve to be comprehensively

presented, by emphasizing the concrete elements that can be used in the food area to offer the expected advantages. The possibility of data extraction related to production, environmental factors, transportation and distribution stages and consumer profiling was explored. Well-known activities were highlighted, which are extensively studied in the specialized literature, with the intention of presenting a relevant analysis of them and synthesizing the situations in which the best way of using technology is identified. Thus, through SWOT analysis, both strengths, which are always discussed at any stage of promoting a technology, and weaknesses, which must be considered and analyzed, were observed to prevent redefinition of processes from tilting the balance in favor of disadvantages. In the current context, the objective was to analyze data extraction methods and identify the situations in which one technology or another is the most appropriate.

In a constantly evolving world deeply influenced by modernization in every aspect, conducting comparative studies that objectively present the limitations that can be encountered in the desired approaches is a necessary stage in refactoring any economic process. Ultimately, the defined goal is to optimize processes, reduce human effort, risks and costs and facilitate automatic implementation, or as much as possible in that direction, of activities that were previously carried out through effort and repetitive work.

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