Journal of Information Systems Engineering and Management
2025, 10(5s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

To Identify Enablers to Achieve Food Security with IoT and Blockchain Technology and Revolutionise the Green Food Supply Chain Systems

Ramesh Babu M*[1] Rajeswari S [2]
Department of Computer Science, Sree Saraswathi Thyagaraja College, Pollachi, Tamil Nadu, India. *Corresponding Author's Email: merwaramesh@gmail.com

ARTICLE INFO

Received: 13Oct 2024
Revised: 09Dec 2024
Accepted: 18Dec 2024

ABSTRACT

The COVID-19 pandemic made the world encounter significant disruptions that heightened the previously faced issues associated with food security. The aspects of food safety, quality, and accessibility are impacted in such a manner, necessitating green food supply chain management (GFSCM) supported by technologies like blockchain and IoT. Nine GFSCM enablers identified and critically discussed in the context of better food security through the attainment of SDG 2. Based on the ISM technique, this study analyses the relationships and influential factors among these facilitators. The findings have emphasized that blockchain and IoT are an essential mechanism for promoting transparency and traceability and reducing food waste in the supply chain of food. Adding to the present literature, this paper develops a conceptual framework that helps managers implement digitization enablers and thus support sustainable food security. These pave the way toward the success of the United Nations in achieving sustainability through food quality and safety.

Keywords: IOT, Blockchain, Green supply chain management, Food Security, Interpretive Structural Modelling.

INTRODUCTION

In 2020, there were 3.1 billion people worldwide who couldn't afford healthful food, up from 112 million in 2019. (FAO et. al., 2022). The massive impact on global nutrition and food security caused by the COVID-19 pandemic and the measures implemented by nations to control it is seen here. People are food secure if their income, food costs, the robustness of their food supply networks, and the consistency of all three of these characteristics across time allow them to affordably get, store, and consume food. There will be changes to food supply and demand because of pandemic effects on processing, production, and distribution.

The COVID-19 pandemic was one of the world's longest and most severe, prompting India to implement a lockdown on March 24, 2020. The protracted shutdown is unfortunate for India's economy, which has a GDP growth rate of 4.7% in 2019 and has been declining since 2016. Similarly, the currency embargo of 2016 disenfranchised the informal economy's reliance on cash, and small firms had only just started to recover (Anand & Kumar, 2016). World Bank also reported that the jobless rate hit a 45-year high in 2019. The already-weak economy would undoubtedly take a further hit because of the lockdown and the COVID-19 outbreak. Plus, food insecurity was already a major problem in India prior to the lockdown and it worsened after lockdown. There are growing environmental problems with food insecurity, food fraud, distribution of low-quality food, and food waste.

More and more people are worried about the planet's natural resources and trying to keep costs down that can't be recovered. Environmental consequences, societal hazards, and economic failures all contribute to and amplify these costs. From raw material procurement to end-user consumption, a green supply chain management (GSCM) approach can help achieve sustainability goals (Hervani, 2017). To lessen the impact on the environment and cut down on waste, the idea of GFSCM has emerged, with an emphasis on using green resources. (Luo et al., 2022). Carbon emissions (CEM) and environmental pollution have been a problem for developing countries' economies and food security in the last few decades (Masipa, 2017). Currently, FSCs are facing difficulties in reducing carbon emissions through the implementation of environmentally friendly practices (Luo et al., 2022). In addition, the GFSCM makes use of technology from the current digitalisation industry 4.0 (I4.0) age to improve food quality and security (Kayikci et al., 2022). For food security objectives, the most frequent technologies used in the food sector are the IoT and blockchain. The Internet of Things (IoT) serves as a backend system, while blockchain technology offers security by improving traceability (Trollman et al., 2022). This research on supply chain modernisation aims to identify GFSCM enablers that can improve food security using blockchain and the Internet of Things. GFSCM enablers based on technology provide food security and contribute to SDGs including SDG 2 (stop hunger) and SDG 3 (promote good health and wellbeing).

To better serve its clients, the FSC collaborates with numerous stakeholders, such as farmers, producers, warehouse workers, distributors, retailers, and consumers (Demestichas et al., 2020). The delivery of safe, secure, and high-quality food is the responsibility of every link in the supply chain. Increasing processing delays are associated with an increase in food theft and tampering (Onyeaka et al., 2022). Consumers value safe and high-quality food, say van Rijswijk and Frewer (2008). By monitoring every aspect, FQS is enhanced in the modern digital era by 14.0 technologies. Transparency, real-time control, and traceability are essential for 14.0 technologies such as blockchain and the Internet of Things (Hrouga et al., 2022). According to (Dwivedi et al., 2022) and (Kayikci et al., 2022), the 14.0 technologies provide quality and safety while improving FSC performance. Since green supply chain techniques improve food quality and waste management, achieving zero hunger and reducing food waste are essential for food security.

Public health and wellbeing are negatively impacted by food insecurity, low quality, and lack of safety. This leads to an increase in food wastage and hunger. According to (Charlebois et al., 2016), businesses, regulatory authorities, and consumers are increasingly focused on food authenticity and labelling. The food industry is manipulating its products by altering or replacing quality ingredients with cheaper ones to set prices that appeal to their target demographic or increase their profit margins. A major threat to human health exists because of this occurrence. This study is driven by a need to examine the effects of blockchain and the Internet of Things (IoT) on food security, quality control, and safety, as these technologies are widely used in food processing plants. The green food supply chain is likewise being transformed by these advances. What are the GFSCM food security enablers that can help achieve zero hunger through GFSC transformation? The answer to the question is given in this publication.

As the farm-to-fork movement gains momentum, many are concerned about food safety and quality certification. Blockchain technology follows food from its origins in seeding factories all the way to the plates of consumers (Manpreet, 2022). Internet of Things (IoT), artificial intelligence (AI), big data, and blockchain are being used by the Food Safety Council (FSC) to monitor operations in real-time, verify the authenticity of products, and decrease food waste. Manufacturers and customers alike are won over by the FSC's commitment to traceability, which enhances food quality and safety. By enhancing the traceability of FSC certification, blockchain and the internet of things allow for real-time monitoring of food supplies.

According to recent research, GFSCM and FCS benefit from supply chain digitisation tools like the Internet of Things (IoT), blockchain, big data analytics, etc. (Chan et al., 2020) failed to examine novel agricultural supply chain technologies that could have contributed to environmental sustainability and food security. What they're getting at is that new tech will make things safer. Organisations in the food supply chain have challenges when attempting to enhance supply chain safety, security, and quality through the use of blockchain and the Internet of Things. We can show how blockchain and the IoT may transform the GFSCM by examining food security enablers. We provide answers to research questions that managers can use to build and enhance their sustainable food supply chain. While blockchain technology can revolutionise sustainable agricultural supply chains and achieve net-zero emissions, very few research has examined this possibility (Saha et al., 2022). They haven't, however, made any serious efforts to investigate the key facilitators that digitally modify the GFSC to improve food quality. This research intends to fill that information vacuum by determining whether GFSCM enablers can improve food security using blockchain and the Internet of Things.

1.1 Research Objectives

1. To identify current GFSCM enablers for food security.
2. To create a model of contextual relationships that support food security.

2. Literature Review

2.1 Green supply chain management (GSCM)

A new environmental innovation, GSCM brings environmental considerations into the supply chain management process. Academics and practitioners alike have taken an interest in GSCM (Noor Aslinda Abu Seman, 2012). According to Sustainable Development, modern economic activities and ways of living must be environmentally friendly. As a result, Green Design should be applied throughout the entire product life cycle. (Yuan & Tang,2021). Put simply, green design is an approach to product development that aims to enhance biological quality while reducing the environmental impact of products at every stage of their life cycle. Choosing vendors and products that don't harm the environment is known as "green sourcing" (Sarkis, 2017). This necessitates the acquisition of materials that are both multipurpose and non-toxic. Reduced demand for finite, non-renewable resources is a direct result of increased efficiency in the utilisation of materials with many uses and subsequent recycling. This also implies that you can purchase ecologically safe materials from vendors who aren't sure if their products are eco-friendly or not, if you, the consumer, are certain about the products' environmental friendliness. To achieve this objective, the food industry makes use of green techniques such as sustainable packaging, transportation, procurement, and waste management.

2.2 Concerns about food safety in the context of the GFSCM and the SDGs

When people can count on a steady supply of food from socially acceptable sources, enough to sustain an active and healthy lifestyle, we say that they have food security. For the food production system to be sustainable, it must provide an adequate supply of food for both present and future generations. There is no life without high-quality, safely prepared food. Quality, safety, and security should be available to everyone. Providing customers with safe, secure, and high-quality food is an important job for the FSC. The purposeful and malicious substitution, alteration, or misrepresentation of food items for financial benefit is known as food fraud. There is less of a chance that food fraud will be discovered because, due to economic incentives, thieves look for opportunities to conduct fraud rather than targeting particular items. Despite its monetary motivations, food fraud can have negative effects on consumers' health. For this reason, safeguarding both customers and the supply chain begins with food authentication. As food fraud becomes more common, there is a growing emphasis on detecting and preventing it, and in response, food manufacturers, processors, and merchants are fighting back. Prioritising food safety and food security are essential for producing nutritious and long-lasting food. As a new and serious issue in the food supply chain, food insecurity requires immediate government action. According to (Montangnini and Metzel 2017) the objective of zero hunger is to end hunger in all its manifestations by 2030 through the provision of sufficient food and the creation of long-term solutions. We will promote SDG 3 by doing everything we can to guarantee that everyone has access to enough healthy food to maintain a healthy lifestyle. We can get there if we make sustainable agriculture a top priority and try to increase food accessibility. Sustainable food production systems, resilient farming techniques, equal access to land, markets, and technology, and increased incomes and productivity for small-scale farmers are all necessary to reach this objective. (Movilla-Pateiro et al., 2021; Montagnini and Metzel, 2017). For developing countries to increase their agricultural output, more funds need be dispersed via international cooperation. Tolerance for hunger is no longer correlated with availability of food (Movilla-Pateiro et al., 2021). Political instability and natural or man-made calamities have contributed to food insecurity, which has affected large portions of the population in many countries. Consequently, the ultimate objective of eradicating global hunger was not achieved (Shi et al., 2019). The availability, quality control, and safety of food have all been improved by new technological advancements. In their list of technologies, Saurabh and Dey (2021) include blockchain, AI, the Internet of Things (IoT), and big data analytics. The IoT and blockchain technology are game changers when it comes to food security, authenticity, and quality. The transparency and authenticity they offer are second to none. The uses of these technologies in earlier publications will be covered in the section that follows.

2.3 Implementation of blockchain and the Internet of Things in the food distribution network

Already, blockchain and the Internet of Things are finding their way into food and agricultural supply systems. Data integrity, transparency, and decentralisation are all assured in a blockchain system. The innovative application of blockchain technology in food traceability has the potential to revolutionise quality assurance. Food traceability solutions aren't up to scratch in terms of data quality, scalability, security, and reliability. There are extensive and intricate procedures in place for tracking food. Supply chain traceability is set to be revolutionised by blockchain technology. To better monitor the shelf life of perishable foods, a blockchain-IoT-based food tracking system combines the two technologies. Considerations for food traceability include shipment volume, stakeholder evaluation, and transit duration. For sensor data to be immutable and resistant to tampering, it must be collected in real-time and recorded in the blockchain. Internet of Things deployments based on traceable resource units are in sync with blockchain data flows. The food supply chain decision support mechanism can help businesses maintain quality by utilising reliable and accurate data to modify shelf life. (Saurabh and Dey, 2021). Data manipulation, integrity, and single points of failure are some of the major issues plaguing present provenance and traceability systems for Agri-Food supply chains that rely on the Internet of Things (IoT). Distributed ledger technology, or blockchain, is at the heart of cryptocurrencies like Bitcoin and offers a fresh perspective on how to build decentralised, trust less networks. In fact, this digital technology's built-in features allow for autonomous transaction executions, coherent digital representations of physical assets, full traceability of stored transaction records, fault tolerance, and immutability of records. Many people are interested in how Blockchain technology could improve supply chain management. In the case of soybeans, for instance, it shows how the Ethereum Blockchain might be integrated into the supply chain to do away with middlemen while still facilitating commerce and tracing (Salah et al., 2019). Several researchers are contemplating incorporating pertinent technologies into GFSCM traceability systems considering the proliferation of the Internet of Things. (Folinas et al., 2006) states that the ability to track and trace each product and logistics unit is crucial for a traceability system's efficiency. This allows for continuous monitoring from primary manufacture all the way to the user's disposal.

The food and agriculture industries are in dire need of additional analytical and empirical study, even though frameworks for applications such as blockchain and the Internet of Things are easily accessible, according to new studies. In the 14.0 era, it is necessary to identify both physical locations and entities to trace the supply chain of food. (Rizwan, 2023) investigated the latest developments and examined the ways in which blockchain fits in with other new technologies that are coming out of Web 3.0 and Industry 4.0. Blockchain technology is essential for supply-chain operations and food traceability. Many advantages can be gained by digitising the supply chain using blockchain and other Web 3.0 and Industry 4.0 technologies. These include better management, automation, efficiency, sustainability, auditability, tracking, transparency, traceability, and reaction times. Additionally, the food supply chain's provenance can be better documented. Using information technology, the current digital revolution called as 14.0 enables the company to monitor industrial equipment in real-time and how it interacts with other services. Due to its immutability and transparency, blockchain technology is gaining traction in the IoT industry (Reyna et al., 2018; Mishra, 2022). Thanks to 14.0 technologies, the FSC has a leg up when it comes to food security, quality, and safety (Lezoche et al., 2020). The Internet of Things (IoT) and blockchain technology are being used by food industries to facilitate product tracking. The food business is increasingly focused on consumer satisfaction and recognises the importance of swift action in handling food-related events and crises. Good traceability systems serve to minimise the probability of unwanted publicity, liability, and recalls by reducing the manufacturing and distribution of dangerous or poor-quality commodities. There is no way to ensure the genuineness, excellence, and security of food with the current system of food labelling. So, food safety and quality are guaranteed, and consumers' trust is earned, using traceability. That is according to Aung and Chang (2014). In industries where consumer safety is paramount, such as food and pharmaceuticals, traceability has grown in importance as a component of supply chain management. (Casino and Thomas, 2019) state that smart contracts and blockchain technology can be used to create a distributed functional model that automates and decentralises FSC traceability. Based on what has been said so far, blockchain and the Internet of Things could solve problems with food quality, safety, and security; however, these technologies are not yet extensively used. To regulate food quality, eliminate food insecurity, and end hunger, researchers like (Saurabh and Dey, 2021), (Khan et al., 2020), and (Rana et al. ,2021) propose that digital transformation is necessary to encourage greater technology adoption in GFSCM. What follows is a discussion of some of the identified gaps in the research.

2.4 Research gaps

Fresh, high-quality food is more important than ever after the recent COVID-19 pandemic disruption. (Ji and Ko, 2021). The most important thing for consumers is food security, so it's the responsibility of FSC managers to provide safe, high-quality food. All agree that consumers' right to a safe and nutritious food supply is of the utmost importance, and that FSC managers have a responsibility to guarantee this. In its mission to end world hunger and improve people's health, the United Nations places a premium on safe, high-quality. According to (Thapa Karki et al., 2021), achieving the zero-hunger aim by 2030 is made more challenging by food insecurity and thievery.

Inadequate waste management also contributes to the problem of food going to waste. Using environmentally friendly supply chain practices is crucial for fixing problems with food quality, safety, and security. Improvements in transparency, HACCP management, food fraud prevention, and food safety certification (FSC) tracking have all been made possible by recent advances in information and communication technology. (Arora et al., 2022). Instability in food supplies and subpar food quality contribute to food waste and public health issues. Blockchain technology and the internet of things are going to completely alter the green supply chain, according to (Xu et al., 2021). The quality and safety of the food supply will be ensured by this modification. Though research on green food supply chains is limited, what little there is points to blockchain and the IoT as key components in guaranteeing product safety. For contemporary GFSCM food security enablers, FSC green practices are necessary. As of the now, studies on the contemporary GFSCM food security enablers for SDG2's zero hunger goal are non-existent. Only by immediately investing in research into supply chain concerns connected to food quality and safety can digital transformation and environmentally conscious food supply chain management be achieved.

3. Methodology

The study identified the contextual interaction among the GFSCM facilitators of food security using a two-stage analysis that used the Internet of Things (IoT) and blockchain technology. Table 1 displays the results of a comprehensive literature review and expert debate that led to the identification of nine performance enablers. Following the selection of enablers, they conducted expert interviews will be conducted to ascertain their views on the interdependence of the chosen enablers and to implement the ISM methodology.

3.1 Identifying technology-based GFSCM enablers for food security.

For GFSCM to achieve food security, food quality and safety must be prioritised. These elements are essential for achieving sustainable development with the help of 14.0 technologies. Like HACCP, GFSCM facilitates sustainable growth by reducing waste, using eco-friendly and hygienic packaging, increasing product shelf life, and decreasing emissions of greenhouse gases. The primary function of the enablers is to improve the FSC performance, which in turn helps to fulfil the aims of a sustainable supply chain with less environmental impact and to increase food security. The entire product supply system hinges on inventory management, making it a crucial enabler alongside logistics efficiency. More GFSCM enablers that help with food security and sustainable development include making food more traceable, making it last longer, and using packaging that is both sanitary and environmentally friendly. The most used technologies include radio frequency identification (RFID), the Internet of Things (IoT), and blockchain to improve system traceability, prevent food fraud, and promote safety. Improve food quality and safety by using the Internet of Things to undertake HACCP analysis. In Table 1 we can see all the GFSCM performance enhancers that contribute to better food safety.

Table1: Facilitators of GFSCM with the Use of Technology for Food Security

Enablers	Description	Source
Inventory Management INM	Reducing waste, optimising resource utilisation, and minimising environmental impact are all achieved through effective inventory management in the GFSC	(Parashar et al., 2020);
GHG emission: GHG	For the green food supply chain to be truly sustainable and effective in combating climate change, GHG emissions must be carefully controlled at every stage.	(Barbosa, 2021)
Hazard Analysis Critical Control Point: HACCP	Methodically controlling dangers at every stage of manufacturing is achieved using HACCP, which ensures food safety. To make sure their products are safe to eat, the food sector uses it.	(Y. Xu et al., 2022)
Food Safety's	Environmental and human health are being more and more linked to green food supply chain management and food safety, according to mounting data. A more stable and long-lasting food economy can be achieved through these methods.	(Khan et al., 2020)
Blockchain technology: BC	The food supply chain tracking industry stands to benefit greatly from the efficiency, security, and transparency that blockchain technology offers.	(Barbosa, 2021;)
Internet of Things (IOT)	With the help of real-time data, operational efficiency gains, and improved food safety and quality, the food supply chain is greatly improved by the Internet of Things (IoT).	(Balamurugan et al., 2022)
Waste reduction: WSR	Reducing food supply chain waste is essential for improving sustainability, efficiency, and the environment. All the way from manufacturing to consumption, along the intricate food supply chain, there is a way to cut down on food waste.	(Parashar et al.,2020)
Traceability: TRY	"Traceability" involves following food as it travels from the farm to the table in the food business. The dependability, quality, and safety of food are dependent on it.	(Rainero and Modarelli,2021)
Food quality: FQL	Sourcing commodities in an environmentally responsible manner without sacrificing their freshness or safety is what "food quality" refers	(Balamurugan et al., 2022)

	to in the context of green food supply chain management.

3.2 ISM

To model several aspects, including enablers, difficulties, and crucial success factors, ISM (contextual interrelationship modelling) is used. ISM ranks the significance of each aspect in a set of interrelated relationships and presents a hierarchy of those relationships based on context. One more analytical method that is utilised to model the elements is structural equation modelling (SEM). If you want to assess the relationship's significance level, SEM needs a big dataset, but ISM just needs a small dataset. When used to assess a previously constructed model, SEM techniques do not offer a hierarchical structure or a sense of priority.

Step 1. Design of the structural self-interaction matrix (SSIM)

In this stage, the authors create a lower triangular matrix based on relationships. An expert-led debate approach using expert judgement is used to generate a lower triangular matrix. A four-letter code representing the connection between the two facilitators is (A, B, C, and D). There is a distinct meaning to each of the four symbols. As an example, A means that enablers 'i' and 'j' lead to each other, B means that enablers 'j' lead to enablers 'i', C means that enablers 'T' and 'j' lead to each other, and D means that 'j' and T are unrelated. Thus, using these four symbols yields SSIM.

Step 2. Conversion of SSIM into initial reachability matrix (IRM).

It will be necessary to transform the alphabetic characters into binary digits (0,1) after the development of SSIM. Presented below are the fundamentals for decoding binary numbers from alphabetic symbols.

The values at i,j and j,i are 1 and D, respectively, if the value in cell (i,j) is 'A'.

For every 'B' entry in the cell at (i,j), the values at (j,i) and (i,j) are 0 and 1, correspondingly.

There is one entry at (i,j) and one entry at (j,i) if the value in the cell at (i,j) is 'C'.

If the value in the cell at (i,j) is "D," then both the (i,j) and (j,i) entries are zero.

Step 3. Determining the final reachability matrix (FRM)

If there is a transitivity relationship, it should be verified to acquire the FRM. By going over each non-zero IRM input value by hand, we were able to deduce the transitivity relationship. For an enabler 'P' to be in a transitivity relationship with an R, it follows that two enablers 'Q' and 'P' must be in a relationship with each other, and that 'Q' must be in a relationship with R as well. If '0' is the value that 'P' enters 'R,' then '1*', which denotes a partial relationship, needs to be replaced.

Step 4. Dividing levels and creating a hierarchical framework.

An important step in achieving a hierarchical structure is to partition the FRM. The antecedent set was generated from the level partitioning reachability set by row- and column-wise matching of the entry values. Before building the intersection set, we checked the antecedent and reachability sets to see how much the junction item was worth. Pick the enabler whose intersection set entry value is equal to their reachability set value, starting with the most basic level. After an enabler is selected, it is removed from consideration for the subsequent iteration, and so on, until the final enabler is selected. We have established a hierarchical structure for our organisation. This hierarchy places the enabler chosen for the first level at the highest level and the one chosen for the last level at the lowest level. The placement of level enablers that are identical to one another is standard practice.

4. Discussions and implications

The purpose of this research was to examine blockchain-integrated GFSCM enablers for IoT-based food security using ISM methodology. This research examined the potential of disruptive 14.0 technology to enhance food security in relation to the SDGs, namely the goal of ending world hunger. The study's authors had previously considered potential research topics. Here, they go over the results and talk about them. Finding the GFSCM enablers of food security with blockchain and the IoT should be the primary focus of everyone working to accomplish the SDGs. Inventory management, greenhouse gas emissions, food safety, the internet of things, waste reduction, traceability were some of the enablers identified in the study, which was based on literature reviews and interviews with academics and industry professionals.

5. Implications

The primary contribution of this study is the identification and prediction of nine innovative GFSCM enhancers powered by technology centred around food security. Conversations with experts in the field provided the basis for all the facilitators. These enablers have tremendous technological potential to improve food quality and safety. Improvements in food security made possible by the IoT and blockchain have increased FSC's productivity.

Using the ISM method to probe the interconnections of the highlighted facilitators, the writers contributed to the current corpus of knowledge. Each enabler's significance, reliance, and driving force regarding food security are highlighted by the ISM method.

Thirdly, there have been articles published recently that investigate the connection between food security and web 4.0 technologies like blockchain and the Internet of Things. The study found that the two most significant components of GFSCM that enhance food security were blockchain technology and the Internet of Things.

Managerial implications

Managers and decision-makers can utilise this study's findings to identify the technological and food security-related elements that support GFSCM. The study's findings are helpful for managers because they illuminate the relationships and interdependencies among the enablers.

6. Conclusion

This study examined the GFSCM components that contribute to food security using the ISM framework. With an emphasis on food security and the connection between blockchain and the Internet of Things (IoT), this project aims to find GFSCM enablers with the goal of achieving zero hunger (SDG2). The purpose of this research is to fill gaps in our understanding of how blockchain and the Internet of Things (IoT) might enhance the GFSCM's safety and security features. Based on expert guidance and existing literature, the research focused on nine GFSCM enablers to assure food safety, security, and quality.

References:

[1] Anand, G., & Kumar, H. (2016). Indian vendors see empty stores and blame a rupee ban. The New York Times.

[2] Astill, J., Dara, R.A., Campbell, M., Farber, J.M., Fraser, E.D.G., Sharif, S., Yada, R.Y., 2019. Transparency in food supply chains: a review of enabling technology solutions.TrendsFoodSci.Technol.91, 240-247.

[3] Balamurugan, S., Ayyasamy, A., Joseph, K.S., 2022. IoT-Blockchain driven traceability techniques for improved safety measures in food supply chain. Int. J. Inf. Technology.

[4] Barbosa, M.W., 2021. Uncovering research streams on agri-food supply chain management: a bibliometric study. Global Food Security.

[5] Blesh, J., Hoey, L., Jones, A.D., Friedmann, H., Perfecto, I., 2019. Development pathways toward "zero hunger. World Dev.

[6] Brooks, & Parr. (2021). A review of food fraud and food authenticity across the food supply chain, with an examination of the impact of the COVID-19 pandemic and Brexit on food industry. *Food Control*, 10-22.

[7] Casino, F., Kanakaris, V., Dasaklis, T.K., Moschuris, S., Stachtiaris, S., Pagoni, ML, Rachaniotis, N.P., 2020. Blockchain-based food supply chain traceability: a case study in the dairy sector. Int. J. Prod. Res.

[8] Chan, H.Y., Abdul Halim-Lim, S., Tan, T.B., Kamarulzaman, N.H., Jamaludin, A.A., WanMohtar, W.A.A.Q.I., 2020. Exploring the drivers and the interventions towards sustainable food security in the food supply chain. Sustainability 12 (19), 7890.

[9] Charlebois, S., Schwab, A., Henn, R., Huck, C.W., 2016. Food fraud: an exploratory study for measuring consumer perception towards mislabeled food products and influence on self-authentication intentions. Trends Food Sci. Technol

[10] Demestichas, K., Peppes, N., Alexakis, T., Adamopoulou, E., 2020. Blockchain in Agriculture Traceability Systems: A Review. Applied Sciences, Switzerland.

[11] FAO, IFAD, UNICEF, WFP, WHO. FAO; Rome: 2022. The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable.

[12] Folinas, D., Manikas, I., Manos, B., 2006. Traceability data management for food chains. Br. Food J. 108 (8), 622-633.

[13] Hervani A.A., Joseph S., Marilyn M.H. Environmental goods valuations for social sustainability: a conceptual framework. *Technol. Forecast. Soc. Change.* 2017;125(December 2017):137–153.

[14] Hrouga, M., Sbihi, A., Chavallard, M., 2022. The potentials of combining Blockchain technology and Internet of Things for digital reverse supply chain: a case study. J. Clean. Prod. 337, 130609
[15] Ji, Y., Ko, W.H., 2021. Exploration of constructing the catering quality indices of university canteens in China from the viewpoint of food safety. Br. Food J.
[16] Kaur, Amanpreet & Singh, Gurpreet & Kukreja, Vinay & Sharma, Sparsh & Singh, Saurabh & Yoon, Byungun. (2022). Adaptation of IoT with Blockchain in Food Supply Chain Management: An Analysis-Based Review in Development, Benefits and Potential Applications. Sensors. 22. 8174.
[17] Kayikci, Y., Subramanian, N., Dora, M., Bhatia, M.S., 2022. Food supply chain in the era of Industry 4.0: blockchain technology implementation opportunities and impediments from the perspective of people, process, performance, and technology. Prod. Plann. Control 33 (2-3), 301-321
[18] Kayikci, Y., Subramanian, N., Dora, M., Bhatia, M.S., 2022. Food supply chain in the era of Industry 4.0: blockchain technology implementation opportunities and impediments from the perspective of people, process, performance, and technology. Prod. Plann. Control 33 (2-3), 301-321
[19] Khan, P.W., Byun, Y.-C., Park, N., 2020. IoT-blockchain enabled optimized provenance system for food industry 4.0 using advanced deep learning. Sensors 20 (10).
[20] Krishnan, R., Agarwal, R., Bajada, C., Arshinder, K., 2020. Redesigning a food supply chain for environmental sustainability-An analysis of resource use and recovery. J. Clean. Prod. 242.
[21] Lezoche, M., Hernandez, J.E., Alemany Diaz, M., del, M.E., Panetto, H., Kacprzyk, J., 2020. Agri-food 4.0: a survey of the supply chains and technologies for the future agriculture. Comput. Ind. 117, 103187.
[22] Luo, N., Olsen, T., Liu, Y., Zhang, A., 2022. Reducing food loss and waste in supply chain operations. Transport. Res. E Logist. Transport. Rev. 162, 102730
[23] Montagnini, F., Metzel, R., 2017. The contribution of agroforestry to sustainable development goal 2: end hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
[24] Movilla-Pateiro, L., Mahou-Lago, X.M., Doval, M.I., Simal-Gandara, J., 2021. Toward a sustainable metric and indicators for the goal of sustainability in agricultural and food production. Crit. Rev. Food Sci. Nutr. 61 (7), 1108-1129.
[25] Mukucha, Paul & Mushanyuri, Bongani & Jaravaza, Divaries. (2021). Green Sourcing: Effects on Supplier Performance Metrics in Fast Food Restaurants in Frontier Markets. Logistics, Supply Chain, Sustainability and Global Challenges. 12. 47-59
[26] Onyeaka, H., Ukwuru, M., Anumudu, C., Anyogu, A., 2022. Food fraud in insecure times: challenges and opportunities for reducing food fraud in Africa. Trends Food Sci. Technol. 125, 26-32.
[27] Rana, R.L., Tricase, C., De Cesare, L., 2021. Blockchain technology for a sustainable agrifood supply chain. Br. Food J.
[28] Reyna, A., Martin, C., Chen, J., Soler, E., Diaz, M., 2018. On blockchain and its integration with IoT. Challenges and opportunities. Future Generat. Comput.
[29] Saha, A.S., Raut, R.D., Yadav, V.S., Majumdar, A., 2022. Blockchain changing the outlook of the sustainable food supply chain to achieve net zero? Sustainability 14 (24), 16916.
[30] Salah, K., Nizamuddin, N., Jayaraman, R., Omar, M., 2019. Blockchain-based soybean traceability in agricultural supply chain. IEEE Access 7, 73295-73305.
[31] Saurabh, S., Dey, K., 2021. Blockchain technology adoption, architecture, and sustainable agri-food supply chains. J. Clean. Prod.
[32] Saurabh, S., Dey, K., 2021. Blockchain technology adoption, architecture, and sustainable agri-food supply chains. J. Clean. Prod
[33] Saurabh, S., Dey, K., 2021. Blockchain technology adoption, architecture, and sustainable agri-food supply chains. J. Clean. Prod.
[34] T.S. Masipa, The impact of climate change on food security in South Africa: current realities and challenges ahead, Jamba J. Disaster Risk Stud. 9 (1) (2017) 1–7
[35] Thapa Karki, S., Bennett, A.C.T., Mishra, J.L., 2021. Reducing food waste and food insecurity in the UK: the architecture of surplus food distribution supply chain in addressing the sustainable development goals (Goal 2 and Goal 12.3) at a city level. Ind. Market. Manag. 93, 563-577.
[36] Trollman, H., Garcia-Garcia, G., Jagtap, S., Trollman, F., 2022. Blockchain for ecologically embedded coffee supply chains. Logistics 6 (3), 43

[37] Trollman, H., Jagtap, S., Garcia-Garcia, G., Harastani, R., Colwill, J., Trollman, F., 2021. COVID-19 demand-induced scarcity effects on nutrition and environment: investigating mitigation strategies for eggs and wheat flour in the United Kingdom. Sustain. Prod. Consum. 27, 1255-1272
[38] Vogliano, C., Murray, L., Coad, J., Wham, C., Maelaua, J., Kafa, R., Burlingame, B., 2021. Progress towards SDG 2: zero hunger in melanesia - a state of data scoping review. Global Food Secur.
[39] Xu, Z., Elomri, A., El Omri, A., Kerbache, L., Liu, H., 2021. The compounded effects of COVID-19 pandemic and desert locust outbreak on food security and food supply chain. Sustainability 13 (3), 1063.
[40] Yuan, Q.h & Tang, L.Y. (2021). The Principles in Green Design. E3S Web of Conferences. 259.