World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Food safety challenges in the global supply chain

Yevheniia Kovalchuk *

LLC, Komplex D, Head of Quality Assurance and Compliance, Ukraine.

World Journal of Advanced Research and Reviews, 2021, 11(03), 527-539

Publication history: Received on 13 August 2021; revised on 23 September 2021; accepted on 25 September 2021

Article DOI: https://doi.org/10.30574/wjarr.2021.11.3.0450

Abstract

Food is more accessible and diverse than ever largely because of the food supply in the global food chain, but also are the challenges to food safety. Contamination risks, regulation differences, traceability gaps, and emerging threats (such as climate change and pandemics) exist. Contamination of one part of the world can quickly affect consumers worldwide, creating health crises and loss of trust, and taking a financial toll on businesses. Some of the major challenges are biological hazards such as *Salmonella and Listeria*, chemical contamination such as from pesticides and toxins and inadequate traceability systems. The regulations are very much country based and as a result of this we have enforcement gaps and it becomes very hard for business to comply. Food security is also exacerbated by climate change, which changes the way we grow, keep and transport food, and recent events like the COVID 19 pandemic have forcibly demonstrated weaknesses in ability to move and follow food around. On top of that, there's food fraud: products being intentionally misrepresented to make a buck, at the expense of consumer health. In order to handle these challenges, innovative technologies and global cooperation are necessary. The use of blockchain and IoT helps in increasing traceability and allows the real time monitoring of the food quality. With artificial intelligence, we can predict risks that will happen before they happen, precision farming to ensure they're sustainable and safer, and waste reduction. But if these solutions are going to be effective, governments and international bodies need to line up their food safety standards and deal with them together. Concluding, this study emphasizes on the collaboration that regulators, businesses and consumers need to come together. Through technology, harmonization of regulations and favoring sustainable practices, the food industry can develop a safer, more transparent and resilient supply chain. Through these efforts, we can safeguard public health, ensure public confidence in consumers, and confront the escalating intricacies of global food systems.

Keywords: Global Supply Chain; Food Safety; Contamination Risks; Traceability; Regulatory Compliance

1. Introduction

The food industry has been completely disrupted through globalization of trade and advances by supply chain logistics over recent decades. Today's food supply chains support the movement of agricultural products and meals fabricated from them around the globe, presenting buyers with greatly improved access to a vast quantity of various foods irrespective of seasonal or geographical boundaries. These developments in food sector have transformed the whole food system, yet have brou*ght another dimension of complexities, specifically food safety. The food safety and quality is a very global issue. The consumption of contaminated or unsafe food can lead to widespread illness and even death. Our globalized food systems have the consequence that contamination or adulteration in one region can spread instantly to the whole world reaching the consumers. Risks associated with foodborne illnesses, cross contamination and fraud are exacerbated in the context of the complex international food supply chains, says Aung and Chang (2014). Supplier networks, distributors and retailers are complex networks, and standards vary across countries making for a number of vulnerabilities.

* Corresponding author: Yevheniia Kovalchuk

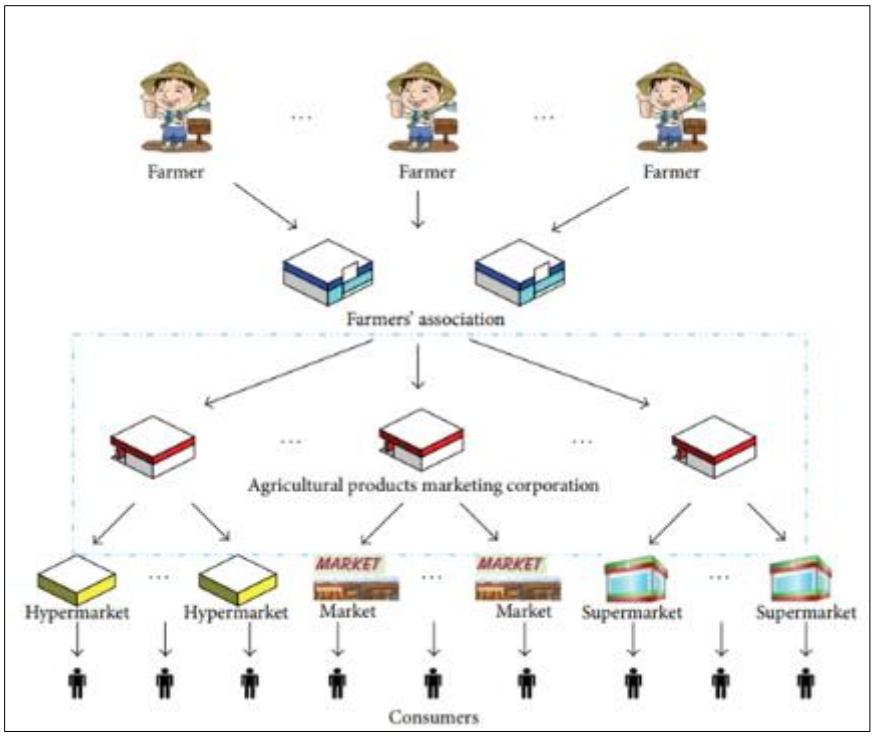

Figure 1 The global food supply chain

For example, *Salmonella, Escherichia coli,* and *Listeria monocytogenes* are kinds of foodborne pathogens that actually may result in large scale outbreaks resulting in serious and severe consequences. These incidents damage public health, and negatively impact consumer confidence, and cause substantial economic losses through recall, legal liability, damage to reputation (Tian, 2017). With a growing global population, changing dietary preferences, the challenges posed by food safety become more and more important in supporting both public health and trade stability.

1.1. Importance of Food Safety in the Global Supply Chain

Food safety is the set of practices followed by a manufacturer to avoid or eliminate any hazards present that may cause injury to the consumer. Food safety in global supply chains requires observance of many processes and safeguards at all stages of the chain, from production and processing, to storage, transportation and retail. At the same time, food supply chains are global in nature and this creates unique challenges. Through multiple countries, products frequently move between countries with separate food safety regulations, inspection protocols and quality standards to comply with. If safety measures are to be consistent this lack of uniformity complicates their implementation. According to Gereffi and Lee (2012), risk can breed from the fragmentation in the regulatory framework between nations because weak links in the chain can jeopardize the whole system.

In addition, food safety failures can be devastating. The World Health Organization (WHO) estimates that about 600 million people contract foodborne illnesses each year, and an outsized proportion fall on children under the age of five. Food safety beyond public health issues also affect global trade, where contaminated products raise the costs of recall efforts and block exports. Incidents in the news show that robust systems need to exist to enable food safety all along the supply chain.

1.2. Emerging Challenges in Food Safety

Climate change, pandemics, sophisticated food fraud schemes: all pose serious emerging challenges to the global food supply chain. Regarding climate change, it has been demonstrated to alter prevalence of foodborne pathogens, pesticide efficacy and toxin production (Tirado et al., 2010). Contamination risks involved in storage and transport of perishable items are exacerbated by higher temperatures and extreme weather events. In addition, pandemics like COVID-19 also have caused disruptions in the food supply chains which revealed vulnerabilities related to logistic, labor availability, and regulatory oversight. According to Aday and Aday (2020), the pandemic has exacerbated fears about food safety notably related to transnational inspections and food system traceability. Furthermore, e-commerce and home delivery

services have relied more on the e commerce and home delivery services has also increased the risks with packaging, handling and transportation.

Yet another important challenge is food fraud, that is intentionally adulterating or misleading consumers with regard to food related matters in order to gain more money. Food fraud compromises integrity of supply chains and places consumers' health at risk, claim Spink and Moyer (2011). The case of melamine tainted milk circulating in China recently serves as a gateway to bringing home the need for heightened efforts in detecting and preventing fraudulent activities.

Objectives

This article seeks to offer basics of food safety within the global supply chains. More specifically, it wants to demonstrate the linkages between global food systems and what it means for food safety. Key stakeholders in maintaining food safety include producers, distributors, regulators, and consumers and their roles should be identified. Examine the problems presented by elongated supply chains, legislations differences, and new risks like climate change, and pandemics. We set the stage for chapters that follow to discuss specific challenges, impacts, and potential solutions.

Significance of This Study

Food safety is not only a public health issue, but has become a trade issue, an economic issue and a development issue. This study examines food safety challenges from the perspective of the global supply chain, to highlight its systemic vulnerabilities that threaten food safety. This highlights the importance of international collaboration and regulatory harmonization. To improve traceability and avoid danger, it suggests to become advocates for adopting various innovative technologies, such as blockchain and Internet of Thing (IoT) (Tian, 2017). The food safety challenges being confronted by the global food industry demand concerted efforts between all the three stakeholders—governments, businesses, and consumers. In this study, I seek to contribute to these efforts by synthesizing a broad swath of cutting-edge research and best practices into a sort of 'state of the art' view of the ongoing issues and the potential solutions to them.

2. Overview of the Global Food Supply Chain

2.1. Structure and Dynamics of the Global Food Supply Chain

A global food supply chain is the network of interconnected complex systems provided for the production, processing, distribution, and consumption of food products around the world. It is a multi-stage process, including agriculture, manufacturing, logistics, retail, and finally consumption, with each level of participants. The food supply chain is dynamic as demonstrated by the work of Trienekens and Zuurbier (2008) and results from the interplay between technological, economic and legislative factors.

Primary producers include farmers and agricultural businesses that grow crops, and raise livestock. The raw materials are transported to these processing facilities, which have stages of processing, packaging and preservation of these items before they are finally made available for use. Wholesalers and retailers distribute processed food products before they get to end consumers. Because this system is global the opportunities and challenges include products (often) passing through several countries and several regions before consumption.

Key factors driving the complexity of the global food supply chain include:

- **Globalization:** The increasingly interdependent nature of the world in terms of its countries' food imports and exports.
- **Consumer Demand:** A greater inclination for having year-round availability of a variety of food products.
- **Technological Advancements:** In the area of logistics, innovations in refrigeration, and information systems.
- **Regulatory Frameworks:** Variations on the standards for food safety and inspection procedures between countries.

Figure 2 Food Supply Chain Management

2.2. Role of Stakeholders

The food supply chain is a global phenomenon, which involves a great number of stakeholders that play a vital role in guarantee of food safety and quality. These stakeholders include:

- **Producers:** Crop or livestock growers and agricultural businesses. They are the roots of supply chain who practice has great influence on food safety and quality.
- **Processors and Manufacturers:** Raw agricultural products into finished goods are the organizations that transform. There can be critical safety measures, like pasteurization, sterilization and packaging to this stage.
- **Logistics Providers:** Food products moving and storage companies. Proper temperature control and handling during transit are necessary to provide food safety.
- **Regulatory Bodies:** Government agencies and international organisations concerned with setting or enforcing the standards of food safety. For example, the Codex Alimentarius Commission and the U.S. Food and Drug Administration (Henson & Reardon, 2005).
- **Retailers and Wholesalers:** Companies responsible for distributing food products generally to consumers. Without it they monitor quality and ensuring compliance with food safety regulation.
- **Consumers:** People who buy and use food products. They improve their awareness and practice, appropriate storage and preparation which are essential to food safety.

2.3. Trends Shaping the Global Food Supply Chain

There are several 'socioeconomic and technological' trends that are driving the ever-evolving global food supply chain. The most current contributors may be the following:

2.3.1. Increasing Demand for Traceability

Traceability is the capacity to follow food products through their supply chain. With more consumers and regulators calling for increased transparency, companies are putting money into more advanced technologies, including blockchain and radio frequency identification (RFID), to boost traceability. Robust traceability systems reinforce consumer confidence and provide a rapid response to a food safety incident, Bosona and Gebresenbet (2013) argue.

2.3.2. Sustainability and Ethical Sourcing

The global food industry is increasingly turning its focus to sustainability, with big businesses embracing environmentally friendly food practices including ethical sourcing. This growing importance of corporate social

responsibility (CSR) in supply chain management in order to address concerns such as deforestation, water usage and labour conditions is expressed by Maloni and Brown (2006).

2.3.3. Digital Transformation

The global food supply chain is being transformed by digital technologies, including the Internet of Things (IoT) and artificial intelligence (AI). These innovations allow environmental conditions to be monitored in real time, equipment to be monitored predictively, and logistics to be optimized. According to Tian (2017), blockchain can increase the traceability and decrease the fraud in a food supply chain.

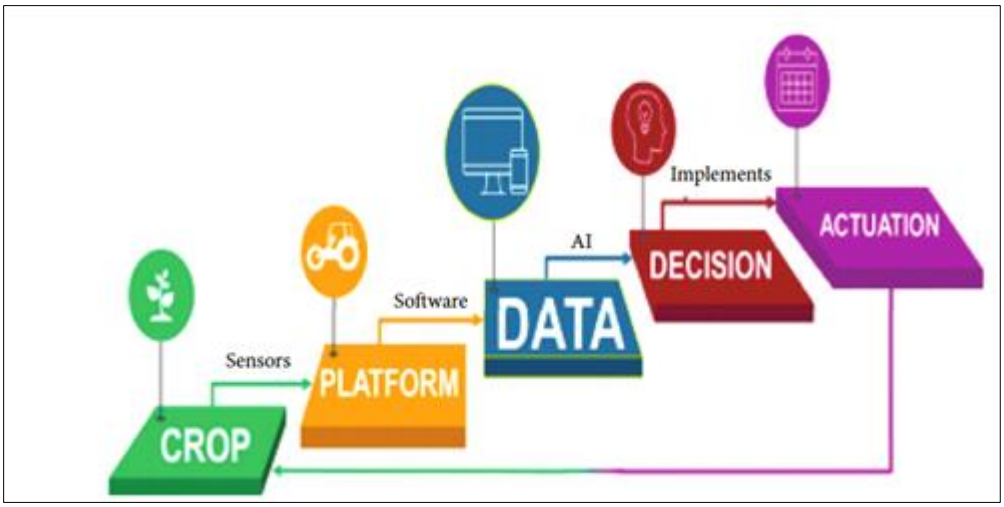

Figure 3 Information-based management cycle for smart agriculture

2.3.4. Impact of Climate Change

Agricultural productivity, distribution, and food safety risks are all changing as a result of climate change. Rising temperatures, changed precipitation patterns, and altered ecosystems are making foodborne pathogens, mycotoxins, and other safety issues more prevalent, say Tirado et al. (2010).

2.4. Challenges in the Global Food Supply Chain

The benefits of a global food supply chain are many, but the opportunity for contamination, fraud and adulteration rises with shrinking distance and growing complexity. The food safety measures among countries differ in their standards and methodologies in enforcement. Implementing advanced safety measures in developing countries is also constrained by resource limitation. Poor infrastructure, dangerous temperature control equipment and inadequate transport systems pose food safety and quality problems. COVID 19 events illustrate bottlenecks throughout the supply chain, including labour shortages and disruptions to cross border trade (Aday & Aday, 2020).

2.5. Significance of Effective Supply Chain Management

Supply chain management becomes important for assuring food safety and taking risk on mitigation. Trienekens and Zuurbier (2008) argue that safety concerns can be substantially reduced by adoption of best practice in logistics, quality control and stakeholder collaboration. In addition, international organizations also serve to harmonize standards and foster cross border cooperation. A significant benefit from the convergence of sustainability and food safety in supply chain management is to protect public health and to make global food systems more resilient. They (Beske, Land, and Seuring 2014) argue that sustainable supply chain management practices can deliver value for all stakeholders at the same time as they seek to address environmental and social concerns.

3. Key Food Safety Challenges

3.1. Introduction

Global food supply chain faces many and increasingly complex food safety challenges. These are not just technical challenges, but economic, social and environmental ones with serious implications for public health, consumer trust and trade.

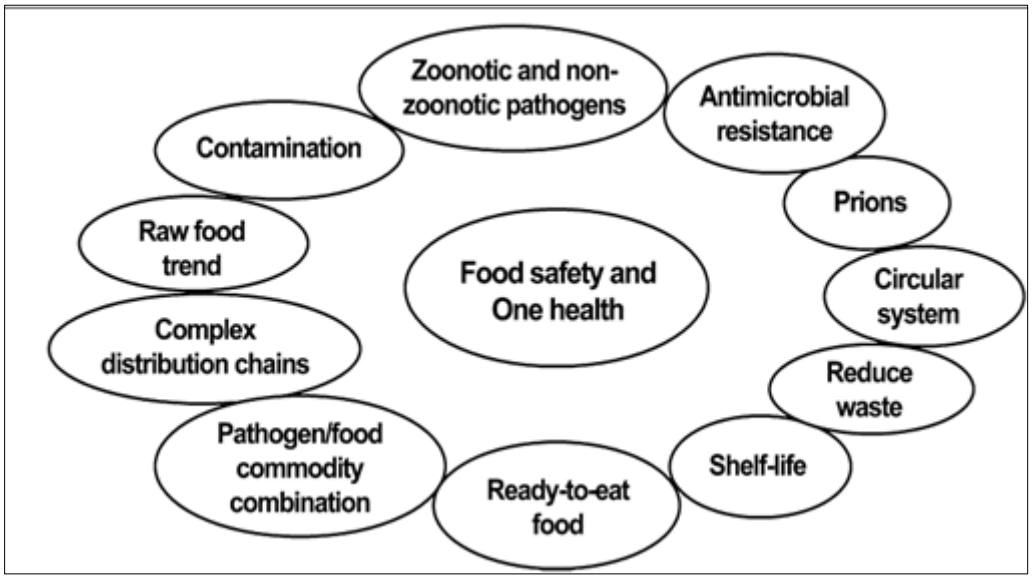

Figure 4 Key aspects related to food challenges

Food safety concerns are compounded by a number of factors as the global food system continues to become more interconnected including contamination risks, fraud, differences in regulatory standards, climate change and the ongoing development of food safety standards. In this chapter, we examine the major food safety problems of the worldwide food supply chain: their causes, consequences, and how they can be dealt with.

3.2. Contamination Risks

Contamination is one of the most common and most pressing food safety concerns in the world. Pathogenic microorganisms, like bacteria, viruses, parasites, and fungi, continue to cause foodborne diseases which pose major public health risks. The most common food pathogens such as *Salmonella, Listeria and Escherichia coli* are routinely added onto foods throughout the spectrum of the food supply chain, from the farm to the processor to wholesaler. Improper handling and processing are one of the major reasons for biological contamination. For instance, microbial contamination can result from poor hygiene practices among workers, improper cooking temperatures, and improper sanitation at food processing plants. This risk is increased still by inadequate storage, requiring improper refrigeration, and cross contamination during transport. Such widespread issues mean that problems often go unnoticed until consumers get sick, and can cost companies heaps in recalls, regulatory fines, and lost reputations.

Other similar concerns include chemical contamination. The risks from pesticides, heavy metals, industrial chemicals and food additives to the food safety are very great. Chemical contamination may be from agricultural chemicals used in excess of safe residue levels. Mycotoxin includes aflatoxins, which are also increasingly a concern, especially with respect to developing countries where agricultural storage practices may be inadequate (Kumar et al. 2017). These toxins are carcinogenic and when consumed, the implications are evident, as the consumption of these toxins over time can be associated with serious health risk and require thorough monitoring and control of these not only in production but in the whole food supply chain.

3.3. Traceability Challenges

Food safety is maintained throughout the supply chain by traceability systems. When contamination or foodborne illness outbreaks occur, these systems help track and identify food products such as where they were produced and

where consumed, while offering vital information. Many confound factors however complicate the achievement of effective traceability in global supply chains.

With global food trade expanding, many products move through multiple jurisdictions and associated regulations, standards and technological infrastructures. For example, a product made with food can be produced in one country, travel through several others and finally reach the consumer. When traceability systems are inconsistent and not well standardized, timely responses to food safety incidents cannot be made in these cases. Without an effective traceability system, contamination source and potentially hazardous products cannot be traced.

However, even more attention to the importance of the use of traceability is still not accompanied by the development of appropriate technological infrastructure in many regions. New technologies like blockchain, RFID (Radio Frequency Identification) and IoT (Internet of Things) are deployed to support traceability which can help trace the food products in real time (Tian, 2016). Yet, adoption of these technologies is still scarce, and the investment needed for adoption in developing regions is high and extensive, requiring collaboration across the supply chain. Moreover, the absence of harmonized standards makes such technologies unduly difficult to replicate at the global level, making these parts of the barriers to effective traceability as Bosona and Gebresenbet (2013) provide.

3.4. Food Fraud and Adulteration

In recent years food fraud, deliberate misrepresentation, substitution, or adulteration of food products, has become a prominent issue in global food systems. Economic gain motivates most of fraudulent activities, which also turn to compromise on food products' safety and quality. Food fraud commonly occurs in ingredient mislabeling, substitution with cheaper raw materials, and addition of harmful substances in food products.

A case of food fraud that can be cited is the horse meat scandal that was uncovered in Europe in 2013. It took the fraudulent substitution of horse meat for beef in frozen meat products to draw attention to the weaknesses in the food supply chain, as well as to the security of food labels. Melamine contamination of milk products, especially in China, is another example of food fraud having damaged consumers and public trust in food safety systems substantially (Spink & Moyer, 2011). Food fraud presents a real public health risk particularly when substandard or toxic ingredients are incorporated into foods. For example, accursed honey should contain harmful rotor parts, heavy metals or antibiotics and olive oil – counterparts of more cheap oils. To detect food fraud sophisticated analytical techniques will be required along with more transparent and accountable supply chains. To combat fraud, tighter regulations, better monitoring systems and the utilization of advanced technologies like DNA barcoding and chemical fingerprinting to authenticate food products should be implemented.

3.5. Regulatory Disparities

Regulations of the global food supply chain are drawn in a fragmentation regulatory environment, which has a significant difference in standards and practices from one country to another. The fact of the matter is that no one regulatory system is able to cover all foods without excluding certain foods altogether so these regulatory disparities pose a challenge for companies having to deal with two food safety systems – even as they try to sell across borders.

The Codex Alimentarius Commission, established under the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) of the United Nations (UN) is an essential institution to promote establishment of international food safety standards. Yet, as Henson and Reardon (2005) press, this is frequently only the case for countries that are still developing. Different standards concerning pesticide residues, food additives and acceptable levels of contaminants may be developed by each country which will cause confusion and may cause trade barriers. Compliance with a patchwork of regulatory frameworks is costly and time consuming for multinational food companies. Additionally, gaps in the regulation can result in inconsistent enforcement and difficulties in resolving food safety incidents. However, harmonization of food safety standards and increased international collaboration is critical to improve food safety and minimize regulatory challenges in global food supply chains.

3.6. Climate Change Impacts on Food Safety

Climate change is proving to be one of the most important emerging risks to food safety. Temperature increases, weather extremes, and changed patterns of rainfall are already making their impact on the productivity, quality, and safety of agricultural products. Harmful microorganisms such as bacteria and molds grow in warmer temperatures and faster, unnecessarily increasing temperature doesn't help. For instance, pathogens like *Salmonella and Listeria* grow faster and faster with high temperatures making food products contaminated at the time of storage and transportation (Tirado et al., 2010). Further, altered climate patterns can hamper the growing of crops, these crops become prone to

pests and diseases and the quality of crops can also suffer. Using more pesticides to fight new threats can lead to higher levels of chemical residues and mycotoxins in crops. In addition, the changing climate impacts the food supply chain stability, especially in logistics. Floods, hurricanes and droughts can derail transportation, storage and processing, leaving us with food shortages or spoilage. However, as climate related risks escalate, it's urgent that food chains adapt by better planning, resilient infrastructure, and enhancing risk management strategies.

3.7. Pandemics and Public Health Crises

The COVID 19 pandemic clearly revealed how exposed the global food supply chain is to public health crises. The pandemic hit many parts of the food supply chain: labor shortages, transportation bottlenecks, and closing food processing plants. Besides the disruption of food availability these disruptions increased the risk of food safety incidents. COVID-19 appeared to cause restaurants to close and consumer purchasing behavior to shift, driving demand for home delivered food, reported Aday and Aday (2020). This allowed e commerce platforms to shift, raising concerns regarding food safety when it comes to packaging, handling, and delivery. Given the pandemic, new protocols had to be adopted to ensure the health of workers, new methods for contactless delivery, and increased use of digital tools for traceability and monitoring had to be adopted. Resilient food safety systems are also important in public health crisis. With the experience of COVID-19 forces us to strengthen our contingency planning, and strengthen our food safety protocols when crisis occurs.

3.8. Food Waste and Safety Risks

The food waste issue is a major one which directly affects the food safety. If food is wasted, it may wind up in the landfill, or improperly discarded, which could pose a health hazard. However, the inadequate storage and handling practices lead to the growth of harmful bacteria, thus increasing food safety concerns.

To combat food waste, there are efficient food distribution systems, recycling programs, and consumer education on proper storage and handling of food required. Parfitt et al. (2010) highlights that much food waste in supply chain occurs because of overproduction, inefficient supply chain management, or in consumer behavior. Reducing waste can also help make food systems more sustainable on the whole, and help reduce the environmental lead of discarded food.

4. Strategies for Enhancing Food Safety in the Global Supply Chain

4.1. Introduction

Developing effective strategies for the alignment of the different players towards improvement of food safety in the global supply chain is important, especially as had been highlighted the complexities and challenges in three previous chapters. These challenges can only be resolved with a multi factorial approach combining technological innovations, regulatory improvements, industry best practice, and international cooperation. This chapter provides a blueprint of strategies that can be popularized by the governments, industry players, and the consumers at different levels of the food supply chain to improve food safety at the global level.

4.2. Technological Innovations in Food Safety

Many of the food safety challenges discussed in previous chapters are addressed through technological advancements. Modern technology is able to help increase traceability, lower contamination risks and increase food quality and safety monitoring throughout the entire supply chain. Innovative technologies, which are being increasingly adopted in food supply chains, for tackling specific food safety concern are being used.

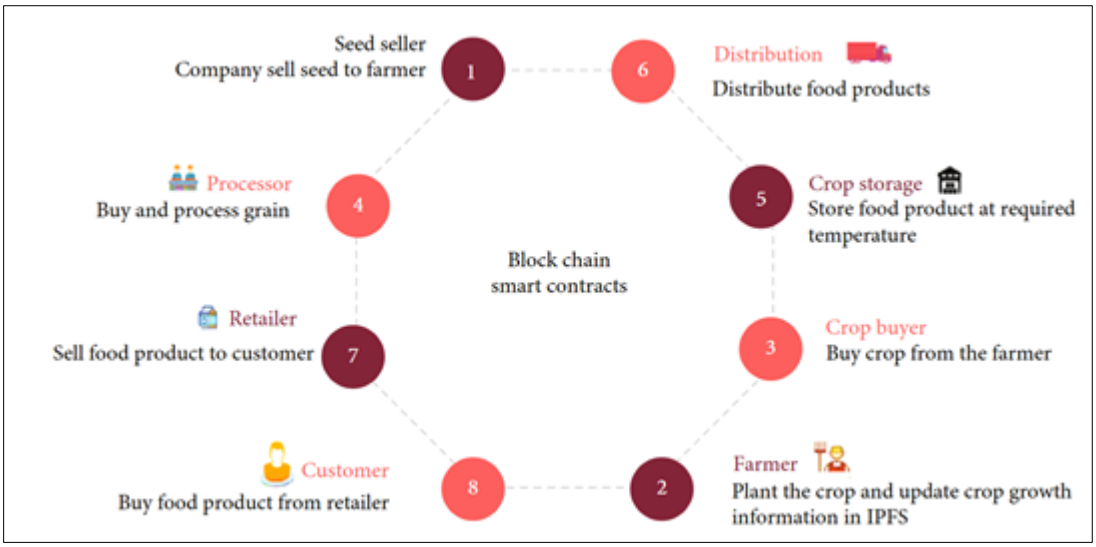

Figure 5 Blockchain-based food supply chain

4.2.1. Blockchain and RFID Technology

With blockchain technology, a solution to improve traceability in food supply chain is possible. By acting through an immutable and transparent ledger, blockchain could track the movement of products, such as food, from farm to table in real time. But this technology lets contamination sources be immediately identified when an outbreak of foodborne illness occurs, meaning faster recalls to reduce the exposure to public health risks. Combining block chain with the Internet of Things (IoT) can further improve food traceability by integrating data from different food supply chain connections, as demonstrated by Tian (2017).

Another valuable technology affecting food traceability is Radio Frequency Identification (RFID). This means RFID tags can be affixed to food items at different points in the system, allowing those food items to be automatically monitored as they flow along the supply chain. There is the technology that guarantees that food products are stored and handled in good manner so that to reduce the risk of contamination.

4.2.2. IoT and Smart Sensors

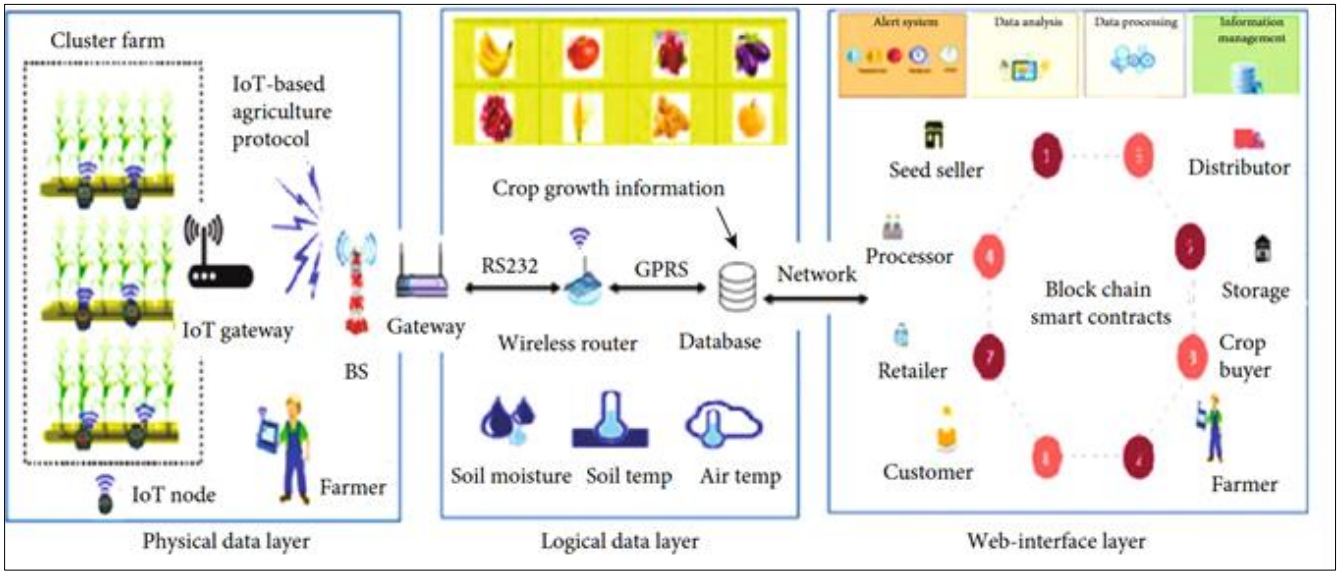

Figure 6 IoT and blockchain smart model

The Internet of things (IoT) permits the continuous monitoring of food products throughout the supply chain. Measuring temperature, humidity, and other relevant environmental factors that may affect food quality and safety,

smart sensors coupled with IoT systems can accomplish this task. This has given rise to IoT devices that provide real time data, including potential temperature deviations in, or transport of, stored products, which could result in contamination or spoilage. By taking this proactive approach we help to mitigate food safety risks and waste.

4.2.3. Artificial Intelligence and Machine Learning

More and more, AI and machine learning are being applied to detect anomalies in food safety. They can analyze massive amounts of data collected from sensors, RFID and blockchain systems to predict the potential safety risks and point out contamination sources patterns. AI models could be utilized to determine levels of risk based on history data and make suggestions for action to take to avoid it. Additionally, machine learning can help you identify frauds by sifting through inconsistencies in supply chain data, for instance, things like labeling or sourcing inconsistencies.

4.3. Regulatory Improvements and International Collaboration

Harmonization and greater international cooperation in regulation is important in strengthening food safety along all global supply chains. There are areas where food safety regulations are not standardized between counties leading to inefficiencies, confusion that is, and potential risk. Minimizing these issues and improving the safety and quality of food products around the world can be facilitated by food safety standards and regulations that are well aligned.

4.3.1. Global Standardization of Food Safety Regulations

Codex Alimentarius offers a global framework for food safety, but its guidelines are adopted on a voluntary basis and countries may adopt their own national standards. Food safety regulations are therefore different significantly between developed and developing countries. Streamlining regulations and establishing international standards for safety are a means to reduce trade barriers, enhance consumer confidence, and ease the regulatory process for firms that deal in products sold throughout the globe. Governments and international bodies should combine forces to develop clearer food safety rules — investigating everything from the way pesticides are used to the levels of food additives and contaminant thresholds that are acceptable. Further, a more integrated approach toward the inspections and the audits of food safety should be made. This would facilitate the simplification of the global food safety system by diminishing the complexity and cost of conformity for food producers as well as exporters.

4.3.2. Strengthening Regulatory Enforcement

Food safety enforcement is meant to be effective in making sure people comply with food safety regulations and so that we can be able to be sure food is of good quality and also safe. Both developed and developing countries' regulatory bodies should strengthen their capability to monitor food safety risk and enforce standards covering all stages of the food supply chain. It will mean setting up inspections regularly, imposing fines on companies which don't comply, and making sure that companies involved in the production of food follow the already established safety standards for food. Other national efforts can be supplemented by collaboration of regulatory agencies internationally as a means of increasing enforcement capabilities. Joint inspections, cross border collaboration and information sharing can be utilized to identify such risks and stop unsafe food products from getting to market.

4.4. Industry Best Practices and Corporate Responsibility

Food safety is vital throughout the supply chain and the private sector fulfills a critical function in ensuring food safety. To reduce food safety risks and to meet consumer expectations, companies involved in food production, processing and retail, in particular have to adopt industry best practices. Nowadays, initiatives of incorporation of corporate social responsibility (CSR) concerning food safety are considered to be an important component of business strategy.

4.4.1. Food Safety Management Systems (FSMS)

Prevention of food safety problems requires a robust Food Safety Management System (FSMS), such as the Hazard Analysis and Critical Control Point (HACCP) system. The HACCP approach allows businesses to identify potential hazards at every step of food production and the processing; the approach enables businesses to implement control measures to minimize mentioned risks. Following internationally recognized food safety standards, such as HACCP or ISO 22000, can guarantee that food quality and food safety will be consistent. In addition, companies are able to enhance food safety by keeping their FSMS updated in response to emerging risk and increasing scientific knowledge. It takes a proactive approach to translating food safety practices into one that is relevant and up to date in a constantly moving global supply chain.

4.4.2. Supplier Audits and Certification

Another critical strategy employed for keeping food safe is auditing suppliers rigorously and demanding that suppliers obtain certification through recognized food safety programs. Those audits can help identify supply chain risks and make sure suppliers meet safety standards as they need to. This certification by GFSI and SQF is globally recognized in the food industry as a guarantee that a company's food is safe to eat. Stronger food safety can also be strengthened through collaborative partnerships between supplier and company. Working closely with suppliers allows businesses to foster transparency, enhance traceability and guarantee that food safety practices are adhered to across the supply chain.

4.5. Consumer Awareness and Education

Consumers are an integral part of promoting food safety. Raising awareness and educating the public about safe food handling practices can help reduce the food safety risks at the consumer level.

4.5.1. Public Awareness Campaigns

Education about the importance of food safety can be undertaken by Governments, non-governmental organizations (NGOs), and business. Topics such as proper food storage, cooking temperatures, and risk of food borne illness can be the topic of public awareness campaigns. Digital Platforms and Social Media offer effective means used or communication strategies which can reach large audiences and encourage behavior change.

4.5.2. Consumer Involvement in Reporting and Feedback

Improving food safety surveillance is by empowering consumers to report about food safety case such as the finding of food contaminants or presence of unsafe food products. Companies must make accessible channels of reporting concerns and feedback of product safety accessible to consumers. If companies listen to consumers, actively, then respond to their concerns, if they respond to their concerns , they can maintain trust and continue to keep food safe.

5. Future Directions in Food Safety for the Global Supply Chain

5.1. Introduction

Advancements in technology, regulatory adaptation, and sustainable practices will determine the future of food safety in the global supply chain. Challenges including climate change, consumer demand for transparency and food fraud are yet to be resolved using emerging challenges through innovative solutions and proactive strategies to mitigate risks to ensure global food security.

5.2. Technological Innovations

5.2.1. Blockchain Technology

The Blockchain will improve both traceability and transparency, to register safely and untampered along the supply chain. The real time tracking of food products helps reduce fraud and contamination (Tian, 2017).

5.2.2. Artificial Intelligence and Predictive Analytics

Tools from today's AI can help to identify risks and better inform decisions. Predictive analytics have the capability for detecting patterns indicative of contamination or spoilage, where intervention can be made proactive (Aung & Chang, 2014).

5.2.3. Nanotechnology

Pathogens and contaminants in food products or packaging will be monitored in real time by Nano sensors embedded in the product.

5.3. Sustainability and Regulation

The sustainability efforts including precision agriculture and reduced food waste will further improve food safety by pruning pesticide use and decreasing spoilage (Parfitt et al., 2010). Furthermore, regulatory frameworks evolve to address such new and emerging risks as lab grown meats and novel foods whilst seeking global cooperation to achieve harmonization of standards (Henson & Reardon, 2005).

6. Conclusion

The problem of food safety in the global supply chain is a matter of multi aspects, where these include technological innovation, changes in the regulatory system, sustainable practices and consumer awareness, as means to minimize the risks of the huge food systems that are becoming more complicated. Global trade has expanded, introducing new food products and new and evolving challenges – climate change, pandemics and food fraud—the need for advanced food safety solutions has never been greater. Blockchain, artificial intelligence, and nanotechnology will play an important role in food safety of the future, which will enable improving traceability, predicting risks, and real time monitoring of food products from farm to the table. In order to match emerging risks and new products regulatory bodies must become more agile, while international cooperation will be essential to harmonizing safety standards across borders. Simultaneously, sustainability will be an essential aspect of food safety, focusing on decreasing environmental footprint, decreasing food waste, and enforcing ethical production practices. With consumer demand for transparency continuing to grow, adoption of these technologies and practices will be further fast tracked and food suppliers must prioritize food safety in order to retain both consumer trust and market share.

References

[1] Tian, F. (2017, June). A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things. In 2017 International conference on service systems and service management (pp. 1-6). IEEE.

[2] Aung, M. M., & Chang, Y. S. (2014). Traceability in a food supply chain: Safety and quality perspectives. Food control, 39, 172-184.

[3] Trienekens, J., & Zuurbier, P. (2008). Quality and safety standards in the food industry, developments and challenges. International journal of production economics, 113(1), 107-122.

[4] Maloni, M. J., & Brown, M. E. (2006). Corporate social responsibility in the supply chain: an application in the food industry. Journal of business ethics, 68, 35-52.

[5] Aday, S., & Aday, M. S. (2020). Impact of COVID-19 on the food supply chain. Food quality and safety, 4(4), 167-180.

[6] Tian, F. (2016, June). An agri-food supply chain traceability system for China based on RFID & blockchain technology. In 2016 13th international conference on service systems and service management (ICSSSM) (pp. 1-6). IEEE.

[7] Gereffi, G., & Lee, J. (2012). Why the world suddenly cares about global supply chains. Journal of supply chain management, 48(3), 24-32.

[8] Kuiper, H. A., Kleter, G. A., Noteborn, H. P., & Kok, E. J. (2001). Assessment of the food safety issues related to genetically modified foods. The plant journal, 27(6), 503-528.

[9] Henson, S., & Reardon, T. (2005). Private agri-food standards: Implications for food policy and the agri-food system. Food policy, 30(3), 241-253.

[10] Henson, S., & Humphrey, J. (2009). The impact of private food safety standards.

[11] Tirado, M. C., Clarke, R., Jaykus, L. A., McQuatters-Gollop, A., & Frank, J. M. (2010). Climate change and food safety: A review. Food Research International, 43(7), 1745-1765.

[12] Wagacha, J. M., & Muthomi, J. W. (2008). Mycotoxin problem in Africa: current status, implications to food safety and health and possible management strategies. International journal of food microbiology, 124(1), 1-12.

[13] Bosona, T., & Gebresenbet, G. (2013). Food traceability as an integral part of logistics management in food and agricultural supply chain. Food control, 33(1), 32-48.

[14] Parfitt, J., Barthel, M., & Macnaughton, S. (2010). Food waste within food supply chains: quantification and potential for change to 2050. Philosophical transactions of the royal society B: biological sciences, 365(1554), 3065-3081.

[15] Beske, P., Land, A., & Seuring, S. (2014). Sustainable supply chain management practices and dynamic capabilities in the food industry: A critical analysis of the literature. International journal of production economics, 152, 131-143.

[16] Carvalho, F. P. (2006). Agriculture, pesticides, food security and food safety. Environmental science & policy, 9(7-8), 685-692.

[17] Belluco, S., Losasso, C., Maggioletti, M., Alonzi, C. C., Paoletti, M. G., & Ricci, A. (2013). Edible insects in a food safety and nutritional perspective: a critical review. Comprehensive reviews in food science and food safety, 12(3), 296-313.

[18] Fulponi, L. (2006). Private voluntary standards in the food system: The perspective of major food retailers in OECD countries. Food policy, 31(1), 1-13.

[19] Sharma, H. B., Vanapalli, K. R., Cheela, V. S., Ranjan, V. P., Jaglan, A. K., Dubey, B., ... & Bhattacharya, J. (2020). Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic. Resources, conservation and recycling, 162, 105052.

[20] Newell, D. G., Koopmans, M., Verhoef, L., Duizer, E., Aidara-Kane, A., Sprong, H., ... & Kruse, H. (2010). Food-borne diseases—the challenges of 20 years ago still persist while new ones continue to emerge. International journal of food microbiology, 139, S3-S15.

[21] De Backer, K., & Miroudot, S. (2014). Mapping global value chains.

[22] Kumar, P., Mahato, D. K., Kamle, M., Mohanta, T. K., & Kang, S. G. (2017). Aflatoxins: A global concern for food safety, human health and their management. Frontiers in microbiology, 7, 2170.

[23] Spink, J., & Moyer, D. C. (2011). Defining the public health threat of food fraud. Journal of food science, 76(9), R157-R163.

[24] Yu-Chung T. (2013) Designing a Fresh Food Supply Chain Network: An Application of Nonlinear Programming

[25] Jyoti P., Manisha M., (2020). The Impact of Food Supply Chain Management on Food Safety Department of Computer Engineering, Vishwakarma Institute of Information Technology, Pune, India, : https://doi.org/10.32628/IJSRSET207454

[26] Sofa B., Karin S. and Ivar V., (2018) Food safety challenges and One Health within Europe. https://doi.org/10.1186/s13028-017-0355-3

[27] Sabir A., Sheeraz A., Fasee U., Asif N., Atif K., Uddin M. I., Abdullah A., Wael A., Hashem A., (2021) IoT with BlockChain: A Futuristic Approach in Agriculture and Food Supply Chain, https://doi.org/10.1155/2021/5580179.