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Technology Adoption in Food Supply Chain Management in Developing Countries: A Review

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***Abstract:** Food loss and waste is one of the major reasons for global food insecurity. Food losses occur at all stages of the food supply chain, including agricultural produce, harvesting, transport, storage, and processing. Food loss and waste are exacerbated by a lack of adequate and effective food supply chain management (FSCM). An effective food supply chain (FSC) includes designing processing and distribution centres, managing the cold chain, and designing reverse logistics. It also includes functions like allocating warehouse storage capacity, vehicle routing and material flow issues, delivery scheduling, and inventory management issues. Adoption of new information technology such as big data and Internet of Things can improve FSC performance and have a significant impact on reducing food waste and loss. An effective system for sharing information can enhance FCC performance, and intelligence in automated retail ordering can prevent food spoilage, while machine learning, and blockchain can improve FSC traceability. However, there are several obstacles to the use of technology in the FSC, particularly in developing countries. These are classified as technical, financial, social, operational, educational, and governmental. This paper provides an in-depth review of the existing literature on the FSC, technology applications in improving FSCM, key challenges associated with technology adoption, and interventions that may help overcome these challenges. It adds to the existing literature on FSCM, especially on issues related to technology adoption in the FSC by developing countries, and is a useful resource for students, researchers and food supply chain professionals.*

***Keywords:** Food Supply Chain Management, Technology, Iot, Developing Countries, Challenges*

I. INTRODUCTION

Food loss and waste is a major contributor to global food security (Krishnan et al., 2020 [1]). Food losses occur throughout agricultural production, harvesting, transport, storage, and processing (Gustavsson, Cederberg, Sonesson, Otterdijk, & Meybeck, 2011 [2]), whereas food waste happens during distribution, retail, and consumption. According to a recent study, 14% of global food production is lost before it reaches retailers (FAO, 2020 [3]).

The designing of processing and distribution centres, managing of cold chain, and the designing of reverse logistics network are all part of the food supply chain (FSC). It also includes functions like allocating warehouse storage capacity, vehicle routing and material flow issues, delivery scheduling, and inventory management issues (Li, Wang, Chan, & Manzini, 2011 [4]). Food loss and waste are exacerbated by a lack of adequate and effective FSCM. Such losses have been discovered to be primarily caused by elements in the food supply chain (FSC), such as a lack of transportation and distribution systems, insufficient processing and packaging, and insufficient storage facilities and techniques (Chauhan, Debnath, & Singh, 2018 [5]).

By improving FSC performance, information technology can have a significant impact on reducing food waste and loss. According to Kaipia, Dukovska-Popovska, & Loikkanen (2013)[6] an effective information exchange system and on-time deliveries can increase FCC performance, while van Donselaar et al. (2006)[7] illustrated how supermarkets can reduce food perishability by enhancing the intelligence of automated shop ordering systems.

However, there are several obstacles to the use of technology in the FSC, particularly in developing countries. These are classified as technical, financial, social, operational, educational, and governmental.

There is a lot of existing research on FSCM from the perspectives of collaboration, supply chain integration, communication, and the role of data availability in food waste management (Rosenlund, Nyblom, Ekholm, & Sörme, 2020 [8]). Recent studies focus on the question of how the FSC should use technology, specifically IoT, machine learning, and blockchain to improve FSC traceability and visibility (Zhong et al., 2017 [9]). However, there is still a lack of collation of progress in terms of technology application, challenges, and solutions to these challenges. As a result, the purpose of this paper is to review the various technological innovations that can be implemented in the FSC, as well as the implementation challenges and interventions to help overcome these challenges. The study specifically addresses the following research questions:

RQ1: What effect does effective FSCM have on reducing food loss and waste?

RQ2: How can technology help to improve FSCM?

RQ3: What are the challenges for developing countries in implementing technology in FSCM?

RQ4: How can these obstacles be overcome?

The following is how the paper is structured. The following section provides an in-depth review of the literature on FSCM, its impact on reducing food loss and waste, and the use of technology to build an effective FSCM.

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Following that, some challenges in the implementation of technology for FSCM in developing countries are discussed, as well as interventions that can help overcome these challenges. Finally, the discussion section discusses the study's practical implications, limitations, and future research opportunities.

II. FOOD WASTE AND LOSS

Food loss and waste (FLW) is a major contributor to global food security (Krishnan et al., 2020 [1]). Food losses occur throughout agricultural production, harvesting, transport, storage, and processing (Gustavsson et al., 2011 [2]), whereas food waste happens during distribution, retail, and consumption. According to a recent study, 14% of the worldwide food supply is lost before reaching stores (FAO, 2020 [3]).

Gustavsson et al. (2011)[2] classified FW into five generation sources based on each stage of the food supply chain: agricultural production, postharvest handling and storage, processing, distribution, and consumption. Stangherlin and de Barcellos (2018)[10] define food waste as "food of good quality and fit for human consumption that does not get consumed because it is discarded either before or after it spoils".

FLW worsens the already urgent global food security problem. In 2019, upwards of 690 million people (8.9% of the global population) were without access to food, according to latest figures. Two billion individuals were affected by severe and medium food insecurity (FAO, 2020 [3]). With the development of the COVID 19 pandemic, there is an increased danger of food insecurity in a number of places, notably in emerging and least-developed nations (Torero, 2020 [11]).

It is anticipated that the global population would approach 8.5 billion by 2030 and 9.5 billion by 2050. (UNDESA, 2015 [12]). Even though the world's population is 7.7 billion, upwards of 820 million people go to bed hungry every night (FAO, 2019 [13]). Consequently, it appears impossible to supply future food demand, increasing pressure on food SCM (Shashi et al, 2021 [14]). Remarkably, 30% of all worldwide food production is lost or squandered annually. This translates to 1,300,000,000 tonnes of food (FAO, 2019 [13]), $1 trillion in economic costs, $700 billion in environmental costs, and $900 billion in social costs (FAO, 2019 [13]).

In addition, this vast food waste adds substantially to global emissions of greenhouse gases and lowers the productive capacity of food systems. The carbon impact of food waste is roughly 3.3 billion tonnes of carbon dioxide (FAO, 2019 [13]). Limiting this waste would enable us to feed roughly four times as many needy people annually with the food that is wasted globally (We Eat Responsibly, 2019 [15]).

As a result, it is critical to address the FLW issue.

III. FOOD SUPPLY CHAIN

Specifically, the food supply chain (FSC) is defined as "the design and operation of efficient and effective production and logistics networks, as well as the intra- and inter-organizational management of supply, transformation, and delivery processes" (Brandenburg and Rebs, 2015 [16]).

The agriculture supply chain (ASC) concept has been around for 1,000 years, but it only gained popularity after Keith Oliver developed SCM. Tsolakis et al. (2014) [17] defined ASC as a set of activities in a "farm-to-fork sequence that includes farming (i.e. land cultivation and crop production), processing/production, testing, packaging, warehousing, transportation, distribution, and marketing".

Transportation and all related logistical processes to deliver food to the consumer are an important step in the journey of food products from farm to fork. Improving the efficiency of these processes begins with the design of the food supply chain (FSC) network, which takes into account the design of processing and distribution centres, cold chain management, and the design of a reverse logistics network. Other tactical issues associated with FSC network design include warehouse storage capacity allocation, vehicle routing and material flow issues, delivery scheduling, and inventory management issues (Li, Wang, Chan, & Manzini, 2011 [4]).

A food supply chain (FSC) is particularly complicated because it integrates diverse economic sectors (agricultural, food processing, and distribution) in a market driven by quickly changing consumer demands.

The food chain is a temperature-based supply chain that is complicated and dynamic; perishable products (fruits and vegetables) must be kept at the required temperature for quality. Food cold chain management (FCCM) is a set of SC practises that aims to keep perishable goods in a safe environment while avoiding microbial spoilage.

In recent years, the focus of SCM has evolved from economic growth to an integrated social and environmental approach (Khan et al., 2020 [18]).

FSCM has recently shifted from separate transactions to more collaborative interactions between producers, processors, manufacturers, retailers, and customers. The magnitude of the food industry's recent challenges, such as global food insecurity on the one hand and food waste on the other, all emphasise the importance of FSCM (Govindan, Jafarian, Khodaverdi, & Devika, 2014 [19]).

Food traceability, is an important aspect of SFSCM for improving food safety and increasing consumer confidence. Food traceability refers to the capability to trace and track a food, feed, food-producing animal, or substance meant to be, or anticipated to be, included into a food or feed throughout all phases of production, processing, and distribution. Incorporating food traceability technologies will provide more opportunities and information to improve food quality, reduce food waste, and improve food system sustainability and monitoring systems, all of which will help to advance the development of SFSCM.

Research shows that between 30 and 35 percent of all food produced is wasted in India and worldwide because of a lack of effective infrastructure and food processing activities (Parwez, 2014 [20]).

The FCC is a rapidly growing research field because it prevents food waste, which has numerous negative consequences.

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In fact, food waste has social and environmental consequences in addition to economic ones.

A lack of appropriate food supply chain management is one of the leading causes of excessive food price inflation in emerging nations such as India. A lack of stable cold storage and inadequate cold chain management leads to high rates of food waste and decreasing quality.

Researchers have been motivated to engage in the issue of food storage and preservation by technological advances. This significant technological advancement has accelerated and simplified the food supply chain, indicating the food supply chain's increased reliance on technology in the future. According to Chauhan et al. (2018)[5], food waste is also a waste of national resources, including seeds, fertile land, water, energy, and other resources employed in its production. In developing nations such as India, food security is attained through the administration of the food supply chain (Negi & Anand, 2014 [21]).

Because it encompasses crucial food parameters such as quality, safety, and freshness, the food supply chain is much more complex and challenging to manage than other supply chains (Zhong et al., 2017 [9]). The food supply chain involves the management difficulty of perishable items and a large number of associated entities (Ben-Daya et al., 2019 [22]). Bourlakis and Matopoulos (2010) [23] maintain that FSC requires collaboration among its stakeholders, which include various entities such as producers, processors, manufacturers, and retailers. The crucial and innate properties of food present some requirements such as safety, quality, and spoilage that add to the challenges to FSC management (FSCM). Food perishability, safety, seasonality, shelf time, freshness, storage, and environmental conditions are unique to the FSC (Affia, Yani, & Aamer, 2019 [24]). The necessity of maintaining the basic food characteristics in a limited amount of time in an efficient and effective manner is what makes FSCM more complex and difficult than non-FSC (La Scalia et al., 2016 [25]).

IV. FSCM FOR WASTE REDUCTION

The FSC's most important function is to maintain high food quality, which includes other food properties such as safety and freshness. Several studies have shown that FSCM has a significant impact on food quality (Aung and Cang, 2014 [26]). Perishable items require a temperature-controlled atmosphere throughout the whole supply chain (SC), from manufacture to consumer interaction. Cold chain management (CCM) is important in FSCM (Shashi, Centobelli, Cerchione, & Ertz, 2021 [14]) for modern global perishable product industries. CCM is a post-production cold chain (CC) for perishable and temperature-sensitive goods that is designed to maintain these goods in a conditioned environment (i.e., within optimal temperature and humidity range) in order to make sure of product safety, preservation of value, and maximisation of commercial potential. Thus, refrigerated transportation and storage are two critical aspects in preventing product quality degradation (James and James, 2010 [27]). FCC is a rapidly growing research field within the overarching research area of CC management (Göransson et al., 2018 [28]) because it prevents food waste, which has numerous negative consequences. In fact, food waste has social and environmental consequences in addition to economic ones.

While strategies to increase agricultural production can help solve the food security problem, the statistics on FLW suggest that reducing it through effective FSCM is a more efficient solution. The overall situation of food waste in poor countries can be described as legislatively mismanaged. Furthermore, most countries have not received adequate attention from stakeholders, who must be integrated and guided to resolve FLW challenges (Liu, 2013 [29]). India has extensive terrain and long distances between communities and its fresh produce business is unorganized and understaffed (Joshi, Banwet, & Shankar, 2009 [30]). A well-developed supply chain with specialist knowledge helps to reduce the role of intermediaries, which aids in waste reduction during transportation and when selling in the APMC market. Because of a lack of warehouses, cold storage facilities, and sophisticated transportation systems, one-third of fruits and vegetables are wasted as a result of storage and transportation losses.

Coordination of production and distribution activities as well as timely information sharing help decrease forecasting inaccuracies and supply chain unpredictability (price, supply, and demand uncertainty), hence considerably reducing FLW at every level.

Several studies have found that FLW is primarily driven by FSC elements such as a lack of transportation and distribution systems, insufficient processing and packaging, and inadequate storage facilities and techniques (Chauhan et al.,2018 [5]). Because of data inconsistency and unavailability, the FSC is concerned about a lack of traceability, visibility, and transparency. One of the five major challenges for reducing FLW is the availability of data for measuring and monitoring FLW. As a result, utilising and sharing data is critical for improving FSCM (Kaipia et al., 2013 [6]).

FSCM has become more complex in recent years, with more data-driven decisions (Aamer, 2018 [31]). Transparency and information, according to Astill et al. (2019) [32], are critical building blocks in the modern FSCM. As a result, stronger and more resilient FSCM tools and techniques are required (Aamer, 2018 [31]). The importance of information sharing and visibility in the FSC can be achieved through data-driven technologies.

V. HOW TECHNOLOGY CAN ASSIST

Recent technological advancements have the potential to be powerful enablers of FSCM improvement. This is due to a number of key areas where technology can assist.

According to Kaipia et al. (2013)[6], an effective system for sharing information and on-time delivery can boost FCC performance. Similarly, van Donselaar et al. (2006)[7] reached a conclusion regarding how to improve the intelligence of automated shop ordering systems in supermarkets in order to prevent food spoilage.

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Prior research has demonstrated that good information sharing systems are an efficient method for managing food waste (Kaipia et al., 2013 [6]). Similarly, recent research has demonstrated that digital networks serving as "circularity brokers" facilitate the matching of tasks to decrease food waste (Ciulli et al., 2019, p. 1 [33]).

Using data-driven decision technology for FSCM, such as Cloud Computing, Big Data Analytics, and IoT, can result in enhancements that render the food supply chain more resilient and sustainable (Zhong et al., 2017 [9]).

A. The Internet of Things (IoT)

IoT can enhance FSCM by reshaping and upgrading it to become smarter and add more value.

IoT in supply chain management has been defined as a collection of digitally connected physical items for detecting and tracking supply chain interactivity, agility, visibility, and information sharing in order to facilitate supply chain process planning, control, and coordination. IoT technology has the potential to be used in automated food processing, such as automated food waste weighting using the IoT network system and analytical functions such as shelf-life prediction using sensor data (Abdel-Basset et al., 2018 [34]).

Food waste assessment can be made more efficient by integrating intelligent containers that analyze the freshness, quality condition, visual appearance, and biodegradable characteristics of the food waste using internet of thing (IoT) sensors. In this case, inspection and assessment of food waste will be achieved more accurately with less cost and a faster pace (Fadhel, 2021 [35]).

Benefits of an IoT-enabled supply chain include cost reduction, real-time information sharing, transparency, efficiency, traceability, and sustainability (Affia, Yani, and Aamer, 2019 [24]).

B. Radio Frequency Identification (RFID)

In conceptual, theoretical, and practical research, RFID has been demonstrated to be a crucial technology in FSCM. Traceability is the primary advantage of RFID for enhancing FSCM, followed by temperature fluctuations control (Qi et al., 2014 [36]).

RFID can be deployed for tracking food and providing instant information that supports a more sustainable decision-making process (Fadhel, 2021 [35]),

RFID uses radio waves to track items wirelessly. It makes use of tags or transponders (data carriers), readers (receivers), and computer systems (software, hardware, networking, and database). The major benefits of RFID technology in the food industry are greater speed and efficiency in stock rotation and better tracking of products throughout the chain, resulting in improved on-shelf availability at the retail level and enhanced forecasting. RFID technology also provides security and safety benefits for food companies through tracking the origin of supplies. This intelligent packaging technology is also being extended to refrigeration and freezing. Appliances can communicate with the packages and identify information related to the storage of the packaged products (Patil et al., 2017 [37])

Aiello et al. (2012)[38] revealed that RFID could offer solutions to critical problems that arise in each of the FSCM functions, which are differentiated by a deterministic temperature and a stochastic interval.

C. Other Technologies

Combinations of technology such as ERP and barcode readers can facilitate the development of procedures such as "ready-to-dispose." With these procedures, dealers are able to recognize and sell the earliest made unit. Such strategies are essential for supply chains with very perishable goods (Chauhan, 2020 [39]).

In addition, electronic platforms can assist in identifying high-waste areas and enhancing demand forecasting by linking food makers with retailers or restaurants (Chauhan, 2020 [39]).

VI. DIFFICULTIES IN IMPLEMENTING CUTTING-EDGE TECHNIQUES IN DEVELOPING COUNTRIES

The difference between developing and developed countries is determined by Gross National Income (GNI). International Statistical Institute classifies countries as developing if their GDP is less than US$11905 (2014). GNP is not only one of the main factors relating to a country's FW generation rate, but it also causes specific barriers in the adoption of technology for curbing FLW through changes in the FSC (Thi, Kumar and Lin, 2015 [40]).

Child hunger continues in LDCs despite a world-wide food surplus and enhanced global trade and food assistance, and recent increases in food supply have only moderately alleviated it.

Some of the major barriers to widespread adoption of IoT technology in the FSCM, particularly in developing countries, are technical, financial, social, operational, educational, and governmental.

D. Technical difficulties

Some of the technical challenges are - hardware issues, network structure issues, possibility of interoperability and integration, big data management, and availability of Internet. A substantial amount of specialised hardware, a complex and interlaced network, and proprietary protocols are needed to set up an IoT-based FSCM (Xu et al., 2020 [41]). Some hardware issues are specific to the FSCM because it's challenging to insert some IoT components like microprocessors, sensors, and antennas in food products to ensure food safety and quality (Verdouw et al., 2019 [42]). Designing and managing a strong IoT hardware infrastructure that can support FSC procedures and activities remains a significant problem in FSCM given the delicate and unique nature of food products.

Because of the complexity of FSCM and its network structures, network structure is another technical key challenge. Companies that want to use IoT face a huge challenge in keeping the FSC's complex networked structures running smoothly. The complex nature of food supply chain management and its network structures enhances the complexity of internet applications. This could explain why there have only been a few large-scale internet applications in food supply chain management implemented (Hong et al., 2011 [43]).

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Interoperability and integration with current information technology are hard since IoT technology cannot always be compatible with the FSCM. Complete integration with disparate technologies and data services across multiple supply chains is required (Haddud et al., 2017 [44]). The most obvious problem in this area is making sure that all the sensors, devices, and system parts in the FSC network can work together well enough to do what is intended (Ben-Daya et al., 2019 [45]). The collected data would be less significant and valuable if there was no interoperability across the entire FSC (Astill et al., 2019 [32]).

IoT applications create huge amounts of data that needs to be stored and processed. This makes it hard to manage and analyse big data (Lee and Lee, 2015 [46]). Big data management and analytics are hard because applications create a lot of data that needs to be stored and looked at (Lee and Lee, 2015 [46]).

The vast amount of data generated by multiple connected sources becomes problematic when it is not properly managed (Alonso et al., 2020 [47]). Even with IoT, obtaining, storing, accessing, and using data from the field is significantly more difficult in the food industry because it labour intensive and human generated (Astill et al., 2019 [32]).

Internet availability and reliability are huge difficulties in the FSCM, especially since most rural areas don't have the right infrastructure and have poor Internet connectivity and reliability (Astill et al., 2019 [32]). This makes it hard to put sensors on food packaging (Mustafa and Andreescu, 2018 [48]).

E. Financial difficulties

High capital investment is still one of the most important reasons why FSCM doesn't use and adopt IoT technology (Aryal et al., 2018 [49]). The IoT adoption options are not very attractive, particularly for small-scale food companies, due to the high cost of capital investments. Aside from the acquisition, the incentives for setting up the necessary infrastructure and architecture that traverses organisational boundaries along the entire supply chain are seen as problematic. Even when IoT technology is used in a small way, like when biosensors are used in food packaging, the expenses are fairly high.

Because of the numerous uncertainties, such as weather conditions, health conditions, food qualities, perishability of food products, harvest and production yield, and demand fluctuation, operations and maintenance cost challenges are numerous (Verdouw et al., 2019 [42]). Monthly service fees, frequent tag renewal, regular risk costs for implementation that can increase overall operating costs, and additional monitoring costs to meet time-temperature criteria and delivery under varying conditions are included in the operation and maintenance expenses (Ndraha et al., 2018 [50]).

F. Social difficulties

Cooperation among supply chain players such as producers, farmers, retailers, collectors, and customers is a significant challenge in facilitating harmonised and synchronised information sharing for stakeholders who do not share the same ownership. Also, a big obstacle is optimising available resources to manage the demand for a particular food treatment along the supply chain (Ndraha et al., 2018 [50]).

G. Operational difficulties

Because of the complexity of the FSC-generated data, new technologies, and the difficulty of its supply chain networks, it is very hard to manage the supply chain and IoT networks (Aryal et al., 2018 [49]). Data security and trust among supply chain participants is another operational key challenge for FSCM IoT adoption (Abdel-Basset et al., 2018 [34]).

H. Educational difficulties

Because IoT technology is still in its early stages of development, knowledge about its applications is limited. Different stakeholder perceptions of IoT may result in the prevention and failure of IoT adoption. Multiple food products, especially in FSCM, will require different stakeholders to fully understand IoT technology in order to use it most effectively all along the supply chain (Astill et al., 2019 [32]). IoT is a relatively new field, so it comes with a lot of risk when it comes to IoT elements or related things like economic, social, and legal issues (Brad and Murar, 2014 [51]).

IoT technologies are still very difficult to use in FSCM because there is a lot of uncertainty about them. Given that IoT is a new technology, technical IoT skills are a significant challenge. As a result, IoT adoption in the FSCM would be heavily reliant on the technical knowledge of its users. One of the major barriers to successful IoT implementation in agricultural FSCM is a lack of skilled personnel expertise to operate the technology.

Another factor influencing this phenomenon is a company's lack of financial resources and skills to invest in technical expertise (Verdouw et al., 2019 [42]).

I. Governmental difficulties

In order to manage FSC integrity, social impact, environmental issues, economic risk, and sustainability, the regulatory authorities must come up with government rules and policies for IoT. (Ndraha et al., 2018 [50]). Poor IoT regulation could lead to low standards for food safety and traceability, which could lead to uncontrolled chemical use, pollution, and not enough capacity to track food, especially in developing countries (Aung and Chang, 2014 [26]). Because of this, the right laws regulating the use of IoT in FSCM may affect how people choose to buy food (Bouzembrak et al., 2019 [52]).

Thus, the adoption of technology for FSCM is influenced by considerations such as potential benefit, accessibility of hardware and infrastructure, cost of implementation, security and privacy issues, readiness to adopt, degree of data complexity, peer and government assistance, access to technical knowledge - based resources, and compatibility with current FSCM should be taken into account (Affia, Yani, and Aamer, 2019 [24]).

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VII. OVERCOMING IMPLEMENTATION DIFFICULTIES

A. Training

In the Indian context, despite the fact that the FSSAI has mandated codex-based standards, not all participants in the fruit and vegetable supply chain have a comprehensive understanding of quality control guidelines and procedures. Some training for the stakeholders may remedy this challenge.

Through the integration between government and NGOs, the farmers and middlemen could receive training on the GAP of postharvest technologies, for example, shading the agricultural products during trans- port to and from the marketplace, grading, usage of cold storages, and improvised solar-drying techniques (Ali, et al., 2021 [53]).

Increasing the awareness and education regarding proper food preparation, food storage, date labeling and the redistribution of excess food can reduce the impact of the wasted food (Fadhel, 2021 [35]).

B. Policy Framework

It is important to achieve integration of agriculture, health and environment policies, implying that policy integration is a political process in itself. Multilevel governance is key in the consolidation of new policy frameworks through bottom-up approaches and broad participation of relevant stakeholders (Galli et al., 2020 [54])

Policymakers in the agriculture, energy, education, and food sectors must collaborate to promote the use of cold chain technology, enhance logistics, maintenance, services, infrastructure, education, and management skills, and develop sustainable markets for the design, use, and funding of cold chains in order to reduce perishable food losses (Kitinoja, 2013 [55]).

Well-established guidelines can influence supply chain outcomes. Imposing certification requirements and regulations that address quality and safety concerns will help to reduce food wastage.

Farmers, storage facilities, food processing companies, retailers, and logistics service providers will all benefit from a policy-backed push to build more cold storage facilities.

The Indian government's proposal to encourage 100% FDI in the food-processing sector with a five-year tax break will help enhance the efficiency of the FSC as in addition to finance, global firms will contribute modern food processing equipment, new information technology for tracking products in storage and transportation, and management expertise (MOFPI, 2014 [56]).

C. Infrastructure Development

Post-harvest loss can be cut down by putting money toward storage and logistics technologies and making it easier for farmers to get their goods to markets (World Food Programme, 2015 [57]).

Policymakers can provide incentives to encourage investment in cold chain transportation and storage infrastructures through private-public partnerships. NGOs could help small stakeholders access and benefit from these services by providing it at a low cost in the beginning (Moraes, Costa, Pereira, & Silva, 2021 [58]). Small farmers and intermediates cannot adopt the improved refrigerated cold chain because it is very expensive without access to microfinance. The role of the public-private partnerships is to fill this gap by investing in the cold chain transportation and storage for the perishable products (Ali, et al., 2021 [53]).

The public sector needs to provide funds for investments in fundamental infrastructure to enable cold chain expansion (i.e. energy, roads) in order to increase the value of high-quality, nutritious food production, handling, and consumption. Governments should restrict disincentives and participate in infrastructure components that are currently lacking in their cold chain development efforts (Kitinoja, 2013[55]).

D. Research and Development

Supporting research and development of cutting-edge innovations like better stock management tracking systems can contribute to more efficiency in the FSC in the future (Thyberg and Tonjes, 2016 [59]).

VIII. CONCLUSION

This study provides an in-depth review of the existing literature on the FSC, technology applications in improving FSCM, key challenges associated with technology adoption, and interventions that may help overcome these challenges.

Food loss and waste are exacerbated by a lack of adequate and effective FSCM. Such losses have been discovered to be primarily caused by elements in the food supply chain (FSC), such as a lack of transportation and distribution systems, insufficient processing and packaging, and insufficient storage facilities and techniques (Chauhan et al., 2018 [5]).

By improving FSC performance, information technology can have a significant impact on reducing food waste and loss. According to Kaipia et al. (2013)[6], an effective information exchange system and on-time deliveries can increase FCC performance, while van Donselaar et al. (2006)[7] illustrated how supermarkets can reduce food perishability by enhancing the intelligence of automated shop ordering systems.

Using data-driven decision technology for FSCM, such as Cloud Computing, Big Data Analytics, and IoT, can result in enhancements that render the food supply chain more resilient and sustainable (Zhong et al., 2017 [9]).

IoT can enhance FSCM by reshaping and upgrading it to become smarter and add more value. RFID has also been shown to be a crucial technology in FSCM giving the advantages of traceability and control in temperature fluctuations.

However, in spite of the advantages, developing countries face various barriers to widespread adoption of IoT technology in the FSCM, which are technical, financial, social, operational, educational, and governmental.

These challenges can be overcome by various initiatives in the areas of training and development, policy development, infrastructure and research.

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This paper adds to the current literature on food supply chain management, especially the stream on use of technology in FSCM, and is a useful resource for students, researchers and food supply chain professionals.

Future research could focus on the feasibility of constructing IoT with RFID in the areas of linking firm resources to big data analytics skills and innovative thinking, as well as extracting valuable data and insights for strategic decision-making (Shashi, Centobelli, Cerchione, & Ertz, 2021 [14]).

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Authors Contributions	I am the sole author of the article.

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