

Perishable Food Supply Chain Management: Challenges and the Way Forward

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Abstract

Perishable food supply chains (PFSCs) have been associated with a number of concerns, including an increase in food safety and quality challenges, increased food waste and loss, and poor profitability. Given the perishability and limited shelf life of such items, risk management in PFSCs has become crucial. Although several studies on perishable food supply chain have been conducted, challenges and mitigation measures have not gotten the essential priority. Consequently, the purpose of this study was to identify challenges in the perishable food supply chain system (PFSCS) and to provide ways to address such challenges. A complete evaluation of peer-reviewed papers published between 2005 and 2020 was undertaken from Scopus, Google Scholar, ScienceDirect, and MDPI. Eight key challenges were identified, and implied explanations were provided by exploring from the viewpoint of related published research. To address the identified issues, the authors proposed a number of possible risk mitigation measures.

Keywords

Perishable Food, Food Supply Chain, Challenges, Mitigating Strategies

1. Introduction

As the world strives toward sustainability in all spheres of life, major sustainability concerns continue to hit industries. Recent increase in food waste and poor food quality has necessitated adoption of effective food supply chain management (FSCM). Food is a fundamental requirement for human's survival on earth, and as such, the food industry assumes a critical function in guaranteeing this demand/requirement through the implementation of dynamic and efficient managerial strategies that consider aspects such as warehousing, manufacturing, transportation, and sustainability, all of which have a significant impact on our

economic situation, the environment, and the society as a whole. Furthermore, numerous business organizations have over the years encountered significant challenges with their supply chain operations, causing failure in most of their activities. Therefore, it is essential to acknowledge the significant impact that identifying and managing risk has on the overall resilience and stability of supply chain systems.

The perishable food supply chain industry has a variety of challenges, including poor infrastructure, a lack of technology, and insufficient logistics, among others. These issues contribute to food waste and losses, which impair industry profitability, contribute to food insecurity, and have negative environmental consequences. The United Nations' Department of Economic and Social Affairs, following its 2017 World Population Prospects Revision, reported that the global population is expected to reach 9.8 billion by the year 2050 (UN Department of Economic and Social Affairs, 2017). To be capable of feeding close to 10 billion people by 2050 as reported by the UN, perishable food supply chains are a crucial component of the food industry that requires careful management to ensure food safety, quality, and sustainability.

Food losses and waste account for one-third of worldwide food production (FAO, 2023). Furthermore, this estimate of food waste equates to 1.3 billion tons of food lost due to deficiencies and limitations in the current FSCM strategy (Zhong et al., 2017). In 2011, the world wasted 492 million fruits and vegetables owing to an ineffective food supply chain system. About 300 million barrels of oil and 230 cubic kilometers of water would be needed to produce the food that is wasted every year around the world (Gardas et al., 2018).

These statistics are saddening, raising the moral question of unfairness to the concerned countries or industries as many people die of hunger; meanwhile, such foods could have been donated to charity to help the less privileged survive. When perishable food products are disposed of improperly, significant amounts of natural resources are lost, and considerably more are lost during the production, shipping, and marketing of these commodities (Sgarbossa & Russo, 2017). The challenges that the food industry faces as a whole must be addressed in order to prevent the negative impact of potential supply chain interruptions on their operations.

As reported by (Joshi & Visvanathan, 2019), the difficulty of reducing food waste has not been given sufficient attention. Given that the global population is as reported by the UN is expected to reach nearly 10 billion by 2050 (United Nations Department of Economic and Social Affairs, 2017), it is of the utmost importance to effectively manage the PFSC challenges in order to reduce food waste and guarantee adequate food supplies. The goal of this study is to identify some challenges in the perishable food supply chain system (PFSCS) and suggest strategies that can be implemented to reduce and mitigate risk in the PFSCs.

Perishable Food

Perishable food is defined by (Shukla & Jharkharia, 2013) as eatable agricultural

products that deteriorates or decays over time, such as meat, milk, eggs, fruits, flowers, and vegetables, as well as their processed products. According to (Hunt Ashby, 2008), perishable foods are characterized as products with a restricted shelf life, which are prone to spoilage or pose a risk to health if not stored appropriately or consumed within a specific timeframe. According to (Rijpkema et al., 2014) perishable commodities have a limited shelf life after harvest or production. The length of time before food products become unmarketable or inedible depends on the food product and a number of environmental factors. These environmental factors consist of the storage temperature, pressure, and relative humidity, as well as the gas's composition and velocity. (Hertog et al., 2014) found that temperature has the most significant effect on the shelf life of perishable food. A high temperature increases respiration and the growth of germs, which can destroy some foods in a matter of hours or days (Giannakourou & Taoukis, 2003; Gwanpua et al., 2015). Low temperatures can cause cold-related injuries and make food products unmarketable (Aghdam and Bodbodak, 2014). However, perishable foods stored at the correct temperature can typically maintain their quality for several days or weeks, or even months or years in the case of frozen foods (Mercier et al., 2017). Hence, refrigeration or cold chain assumes a pivotal role in mitigating food loss. This phenomenon holds particular significance in the present era of globalization, wherein perishable agricultural products are consistently transported over long distances across nations and continents to fulfill consumers' demand for a diverse selection of fresh produce throughout the year.

2. Overview of Supply Chain

2.1. Supply Chain

Supply chain consists of all the steps that must be taken to satisfy a client's order. The term "supply chain" is used to describe the comprehensive process through which raw materials are transformed into completed products and distributed to consumers. As such, the supply chain includes not only the producers and suppliers of commodities but also the storage facilities, distributors, wholesalers, retailers, truck drivers, and consumers who purchase the products. Consumers are the first step in the customer's product supply chain, which continues to the inventory and warehouse where the goods are housed. A customer may order the product through its only distributor or pick it up at the warehouse. The product is obtained by the distributor from the manufacturer. The producer sells to the distributor, who then supplies the goods to the end user. The manufacturer also places orders with vendors for the materials it needs. The process continues in this manner until the product is offered for purchase. This requires extensive coordination among those involved in the supply chain to ensure that the right goods reach the right customers at the right time, from production to distribution to retail. The following **Figure 1** illustrates the interconnections between

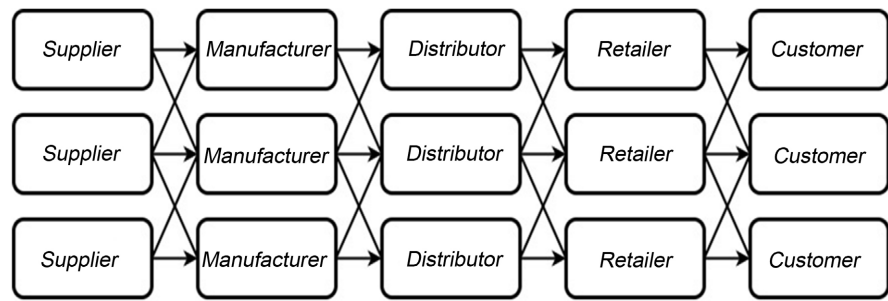


Figure 1. Relationships among supply and demand networks (Chopra & Meindl, 2019).

various supply and demand chain networks.

2.2. Food Supply Chain (FSC)

The FSC concept is a new area of SC associated with risks and uncertainties in the production and inventory systems of food products because of the perishability involved. In developed countries like Hong Kong, food losses and waste are high at the post-harvest stage of the SC system, and there is a need to address such challenges to increase profits for the drivers in the chain and also add value to members of the SC. The food industry plays a vital role in making the existence of human life possible because, without food, no man can survive.

FSC starts with farming and passes through transport, processing, and distribution before reaching the final consumers. Nonetheless, apart from the social problem created as a result of food wastage, it also poses a threat to the environment because of poor disposal methods adopted by most companies, such as the release of methane gas from the spoiled product, which could lead to ozone layer depletion. The economic impact appears as an increase in operating costs and a decrease in the productivity of a national GDP as a result of massive losses experienced in waste. In many inventory systems, the assumption is that inventory shelf life is definite; meanwhile, perishable goods are susceptible to specific environmental and weather conditions that guarantee a shorter life span. Models in inventory are classified as having a random life span, a fixed lifetime, or a proportion decay life span (Lemma et al., 2014).

Many researchers in recent times have proposed a simulation-optimization approach to perishable inventory models, but the limitation of the simulation model is that it provides more performance indicators for evaluating the behavior of the system than optimizing the system. The result that emerged from simulation analysis is imperative in analyzing and interpreting the functioning of the whole system, but there is no guarantee of an optimal solution to the model developed (Chan & Chan, 2010).

Risk in Food Supply Chain (FSC)

FSC is prone to many risks and uncertainties as a result of its short and unpredictable shelf life. There are various classifications of risks in SC (Heckmann et al., 2015; Ho et al., 2015). The commonly used classification of risks in the SC

comes from (Tang, 2006) which divides the SC risks into disruption and operational risk. The disruption risk is caused by human-made and natural disasters such as earthquakes, floods, hurricanes, terrorist attacks, and economic crises (Nakandala et al., 2017). Operational risks arise when performing business processes or SC activities (Wang, 2016). (Heckmann et al., 2015) reported that the uncertainties inherent in supply, demand, market prices, and prices such as failure of machinery, equipment, supply, or management give rise to operational risk. Such risk factors disrupt SC and require an appropriate assessment to develop a risk mitigation strategy. These risks, such as damage, power outages, and damage to machinery or equipment, disrupt the SC and require an appropriate assessment to develop a risk mitigation strategy.

As a result of human and natural causes, SC is turning out to be more at risk (Ali et al., 2018; Govindan, 2018). FSC seems more complex because food products are not durable goods (Ali & Nakade, 2017; Singh et al., 2018). Food is an essential prerequisite for human existence. Over time, the FSC has encountered several factors, including the volatility of food prices, the inconsistency of climate, governance issues, food security, and the distribution of FSC values (Fredriksson & Liljestrand, 2015; Gokarn & Kuthambalayan, 2017). Accepting risks for the FSC can improve its resilience, equity, and effectiveness (Govindan, 2018). To ensure safe and reliable products, each driver of the SC needs to be aware of the risks inside and outside the network. Numerous studies show that organizations must adhere to formal structures for identifying and assessing risks in the SC and, ultimately, implement risk reduction plans to minimize food waste (Khan & Burnes, 2007).

2.3. Supply Chain Management (SCM)

In this modern era, concentrating on the efficiency and effectiveness of distinct business functions in understanding the strategic importance of planning, managing, and designing the entire SC is a relatively new practice in today's global market (Min & Zhou, 2002; Saengsathien, 2015). Organizations no longer compete as a separate division with an explicit trademark but as an integral part of the SC since the performance of all parties affects the overall performance of the SC. Therefore, SCM models and practices need to be incorporated into business processes to facilitate the timely fulfillment of customer requirements.

The concept of SC has been developed since the beginning of problems with material flows (Forrester, 1961) and has continued to scale up since the 1990s, as supported by a significant increase in related research published in highly ranked journals by both practitioners and academics (Saengsathien, 2015). In addition to integrated materials and logistics management, (Chen & Paulraj, 2004) recognized quality innovation, increased interest in the market and industrial networks, and influential industry research as the first sources of inspiration for the SC concept.

Though supply chain (SC) or supply chain management (SCM) does not have

a unique definition, an SC can still be seen as a network of joint ventures that are connected from the ultimate source to the final destination (Chan & Chan, 2010). An SC is a network of people, companies, job functions, technology, and data involved in transforming raw materials into finished goods that are later transported to the final consumers (Miranbeigi et al., 2015). SC is complex because it involves various activities and procedures that are divided into functions (inventory, production planning, purchasing and shipping, logistics, internal and organizational relationships, and implementation steps) and long-term horizons of the organization (Arshinder et al., 2008).

SC also refers to a logistics network consisting of stocks of raw materials and finished products moving between suppliers, production centers, warehouses, distribution centers, and retail stores and facilities (Ritha & Sutha, 2016). SC is viewed as integrating entities like manufacturers, distributors, suppliers, retailers, third-party logistics dealers, and other middlemen working together either directly or indirectly to perform some specific functions (Saengsathien, 2015), such as: 1) purchasing raw materials; 2) transforming these materials into finished or semi-finished products; 3) increasing the worth of these products; 4) the distribution of this product in retail stores, which will subsequently provide the product to end-users and customers; and 5) the exchange of information between its SC members to maximize the total value created for consumers.

More so, (Stock & Boyer, 2009) reviewed 173 SCM definitions in a series of journals and books, combining suggestions from practitioners, scientists, and hybrid sources to give them a broader meaning. They defined SCM as managing a network of relationships between interdependent organizations and enterprises comprising procurement, marketing, raw material suppliers, processing, logistics, and other related entities to accelerate the flow of resources, data, and services from the origin to the final consumers, thereby minimizing costs and maximizing profits. Modern SC, also termed green logistics, is dynamic in nature and somewhat difficult to model using mathematical methods (Alharbi et al., 2015; Gan & Cheng, 2015; He et al., 2015). Therefore, their efficient and productive management becomes a daunting task, which most often requires a lot of information, large amounts of data, and in-depth human knowledge to be accomplished.

SC can be divided into three types: agile SC, lean SC, and hybrid SC (Wang et al., 2004). A lean SC makes an effort to remove waste and other non-value-added services across the chain through the application of continuous improvement techniques. More so, to ensure cost efficiency when required, the customer might not be considered by this SC. Agile SC strives to introduce new methods and technologies, respond to uncertain market changes, and benefit from them, for example, by using information systems or technologies, integrating all business processes, and introducing innovations throughout the company.

An intermediary chain known as hybrid SC has been proposed (Saengsathien, 2015). Hybrid SC strives to defer product differentiation to final assembly to

achieve mass customization using special assembly rules.

Sustainable Supply Chain Management (SSCM)

In the present 21st century, companies and industries must now get a license to be approved for “production and delivery”, that is, the way the product is manufactured and delivered must be accepted by the public (van der Vorst et al., 2013). In a bid to achieve this, if questionable methods are employed by any of the SC stakeholders, their products will not be allowed to reach the final consumers. Today, consumers around the world require more from food than just nutritional characteristics. These requirements include safety, quality, integrity, variety, and sustainability (Van Der Vorst et al., 2009). The word “sustainable” is described as an action aimed at satisfying current needs without compromising the ability to meet the needs of a future generation (Baldwin, 2012). For sustainability to occur, three elements of sustainable development have to be reconciled.

SSCM differs by definition but represents an attempt to integrate the three underlying principles of sustainable development (e.g., social, environmental, and economic goals) into governance (Roy et al., 2018). For example, (Seuring & Müller, 2008) discussed this concept in detail, defining SSCM as a collaboration between companies in the areas of materials, information, and capital management and the supply chain, taking a three-dimensional dimension of sustainable development, that is, economic, environmental, and social considerations about the needs of customers and stakeholders.

According to (Saengsathien, 2015), sustainability has become an apt topic in science and industry. This follows from the understanding that SC results must be measured in terms of economic benefits, environmental impacts, and social values (Pagell & Wu, 2009). SSCM allows us to understand and identify complex trade-offs, which is why many company leaders need practical structures and tools to prioritize and make financially stable and sustainable decisions (Gupta & Palsule-Desai, 2011).

A review of related research on SCM shows that many studies have been carried out concerning social, economic, and environmental sustainability (Saengsathien, 2015) using various approaches such as linear programming, integer programming, dynamic programming, mixed integer programming, analytical approaches, simulation approaches, evolutionary algorithms, artificial neural networks, fuzzy logic, etc. However, limited research has been conducted on how to tackle the inherent challenges of risks and uncertainties associated with perishable food products.

3. Research Methodology

The study undertook a literature review employing diverse keywords, including “supply chain challenges and risks”, “perishable food supply chain barriers/challenges”, “perishable supply risks”, and “food supply chain risk/challenges”. Forty-five (45) peer-reviewed papers published between 2005-2020 were ex-

plored from Scopus, Goggle scholar, Science Direct and MDPI. Twenty of the articles (20) were considered valid from which yielded 8 primary challenges that are pertinent to PFSCs, as reported in multiple papers. The challenges were delineated in CH1 through CH8 for the purpose of facilitating the identification of their corresponding recommended mitigating strategies.

4. Perishable Food Supply Chain Challenges

Numerous studies have concentrated on PFSCs. After evaluating the literature that covered the perishability in planning and distribution concerns, (Amorim et al., 2013) came to the conclusion that the perishability component in food production needed to be addressed comprehensively. In their review of the literature on agri-fresh product supply chains, (Shukla & Jharkharia, 2013) identified the three main challenges in PFSCs as minimizing post-harvest loss (PHL), maximizing revenue, and the satisfaction of customers.

Numerous studies have also emphasized on various PFSC risks, challenges, and barriers. According to (Raut & Gardas, 2018), the main cause of PHL in India is an absence of connections among institutions, the government and other businesses. Food characteristics such as Perishability, bulkiness, changing seasons, quality variances, rules and regulations, and infrastructure were identified by (Gokarn & Kuthambalayan, 2017) as important challenges impeding waste reduction in FSCs. The failure of incorporating food features and quality in supply chain planning and design poses a significant barrier to the sustainable future of PFSCs (Deng et al., 2019). According to (Ali et al., 2018), precise control and management of temperature is necessary to decrease food waste.

Significant contributors to PHL in the supply chains for vegetables and agri-cultural products are the absence of ripening rooms, inadequate cold storage, and other supportive facilities at the cultivation/farming stage (Murthy et al., 2009; Raut & Gardas, 2018). Scholarly articles that center on developing nations have placed significant emphasis on infrastructure-related challenges, including but not limited to and market accessibility, power supply, road networks (Gligor et al., 2018; Naik & Suresh, 2018). Literature also places significant emphasis on matters pertaining to information dissemination, transparency, and traceability in PFSCs, as evidenced by the works of (Aung & Chang, 2014; Balaji & Arshinder, 2016). (Ganeshkumar et al., 2017) reported a significant issue of substantial agricultural produce wastage, primarily perishables, ranging from 30% to 60% in India. This was attributed to the inefficiency of existing warehousing and storing facilities.

The enhancement of PFSCs' efficiency can be achieved through the implementation of information sharing and traceability practices, which have been shown to decrease both demand and supply uncertainty (Lusiantoro et al., 2018; Sharma et al., 2019). Concerns about farmers' lack of knowledge were brought to light by (Zhong et al., 2015), who further highlighted the importance of connecting farmers with suppliers and consumers.

Food waste in food supply chains is significantly attributed to ineffective demand management (Balaji & Arshinder, 2016). Supply management and demand management both aid in determining the needs for infrastructure (NCCD, 2015). Additional literature sources, including (Prakash et al., 2017), have similarly identified PFS sustainability challenges such as higher operational expenses, insufficient pre-harvest management, and lack of governmental assistance.

4.1. Identified Key Challenges of Perishable Food Supply Chain

1) Insufficient incorporation of product attributes and perishability factors in supply chain planning. The temperature ranges, product handling procedures, storage requirements, and logistical capabilities of food products varies, the facilities within the PFSCs most often lack product specific design considerations. This challenge is further reported by (Aung & Chang, 2014; Gokarn & Kuthambalayan, 2017; Rahbari et al., 2019). (CH1)

2) Poor logistical planning: Vehicles with refrigerator, which are needed to transport perishable goods, use a lot more energy than non-refrigerated vehicles. Logistics performance is a significant problem because of poor infrastructure, subpar services, and a failure to take environmental impact into account when designing networks (Gokarn & Kuthambalayan, 2017; Song & Ko, 2016). (CH2)

3) Poor management of demand for perishable food items: The lack of demand-driven production often leads to either excessive inventory of insufficient stock, which result in spoilage and wastage (Langroodi & Amiri, 2016; Sel et al., 2017; Taylor & Fearn, 2009). (CH3)

4) Poor control and management of temperature: Poor management of temperature restricts the product's geographic reach and increases the risk of product spoilage, which has an unsustainable impact on the economy and the environment (Ali & Nakade, 2017; Keivan Zokaei & Simons, 2006). (CH4)

5) Poor Pre-Harvest Management: Conditions before harvest, such as irrigation methods, high-quality seeds, and the time of harvest, have a significant implication on the quality and holding of the life of PFSC (Gokarn & Kuthambalayan, 2017). (CH5)

6) Lack of supply chain visibility and traceability: This is one major problem that leads to various challenges in the management of goods and services, especially perishables including increasing risk in the event of returns, recalls, spoilage, and incorrect detection of batch. The consumer might also receive false information about products, such as information about their production location and shelf life (Faisal & Talib, 2016; Ringsberg, 2014; Xiao et al., 2017). (CH6)

7) Inadequate infrastructure: Factors such as power outages, insufficient farm connectivity, and inadequate transportation infrastructure often leads to unanticipated delivery delays, decreased shelf life, and poses negative impacts on economic activities all through the PFSC (Joshi et al., 2009; NCCD, 2015; Raut & Gardas, 2018). (CH7)

8) Inadequate Cold Chain Support: In PFSCs, cold chain support is very cru-

cial. Insufficient cold chain support leads to compromised product quality and safety. Post-harvest loss (PHL) and supply chain sustainability challenges in PFSC are also caused primarily by the unavailability and inadequate cold chain support (Joshi et al., 2009; NCCD, 2015; Raut & Gardas, 2018). (CH8)

4.2. Recommendations for Managing the Challenges

1) Insufficient incorporation of product attributes and perishability factors in supply chain planning: Identifying facility gaps and developing pack houses, ripening chambers, and food processing hubs at appropriate supply chain locations. (CH1)

2) Poor logistical planning: Cold logistics investment and collaborative green transportation solutions. (CH2)

3) Poor management of demand for perishable food items: Contract farming, information sharing with farmers, a storage facility for surplus produce, and co-operative demand forecasting. (CH3)

4) Poor control and management of temperature: Invest in the cold chain. Construction of multi-product compatible facilities. (CH4)

5) Poor Pre-Harvest Management: Investment in innovative farming practices, harvesting technologies, and farmer training. (CH5)

6) Lack of supply chain visibility and traceability: Vertical integration of farm produce and mandatory traceability implementation across the supply chain. Eco-labeling of farm produce allows for product environmental footprint tracking. (CH6)

7) Inadequate infrastructure: Development of local markets, aggregation hubs, and processing centres, as well as investments in rural infrastructure. (CH7)

8) Inadequate Cold Chain Support: Infrastructure Integrated cold chain solutions, including the development of auxiliary infrastructure such as packhouses, ripening units, and reefer vehicles. (CH8)

5. Limitations and Research Gap

This work has some limitations, which present an opportunity for future research. The study is based on a review of literature. The majority of the articles considered were broadly localized and based on the author's organizational experience. As a result, they may not necessarily represent the broader pan-industry and cross-national perspective.

The majority of the examined articles in this research were undertaken in the context of an Asian developing country: India, Vietnam, Thailand; thus, there is scope to compare these results with other developed and developing countries across the globe, particularly in Africa. The heterogeneity of PFSC, with varied products, stakeholders, and geographic regions, makes developing generalizable insights and standards for PFSC management difficult. More research is required to develop context-specific solutions capable of addressing the particular issues faced by various stakeholders in various regions. Additionally, it was discovered

from the study that PFSC faces significant regulatory challenges such as rules regulating food safety, trade restrictions, and labeling requirements. The SCM process becomes more difficult as a result of the differences in regulations from country to region. More research is required in order to fully understand how these rules affect the PFSC and to build compliance approaches that preserve effective supply chain operations. Addressing these limitations can help enhance the effectiveness, sustainability, and resiliency of the supply chain for perishable food, as well as ensure that customers in every region of the world have access to food that is both safe and nutritious.

6. Conclusion

The supply chain is turning out to encounter more challenges as a result of human and natural factors. FSC seems more complex because food products are not durable goods. Food is an essential prerequisite for human existence. It is therefore important to consider issues that affect PFSCS in our societies to decide the right action to take next. Some of the issues that pose a challenge to the perishable food supply chain are described in this paper, namely: lack of perishability-related SC design; poor pre-harvest management; a lack of product attributes and concern for perishability during SC planning; difficulties with tracking and monitoring in the supply chain, etc. There are other issues found outside the food supply chain that also pose challenges to PFSC. But in this paper, we aim to ensure an improved comprehension of the issues and challenges and identify some ways forward or make some recommendations on how to resolve them. There is a need for further research on the inventory of food products aimed at maximizing the overall profitability of the supply chain, including risk reduction factors and assessments of sustainability.

Conflicts of Interest

The authors declare no conflicts of interest in the publication of this research.

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