

# **Extraordinary Strains in Food Supply Chains: A Literature Review on COVID-19 Induced Food Supply Chain Disruptions and Resilience**

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## **Abstract**

As a new agitator of Supply Chain disruptions, COVID-19 global pandemic has significantly triggered an extraordinary series of shocks on food supply chains worldwide including bottlenecks in farm labor, processing, transportation, and logistics, as well as the significant swings in customer demand. Many of these strains are the consequences of policies enacted to prevent spreading the virus. The food industry is one of the important sectors in each economy. While the consequences of COVID-19 are still being felt, past experience has shown the necessity of a well-organized and foreseeable global trade environment in ensuring that food reaches people in need. In order to avoid the impending global food crisis, it's critical to examine how COVID-19 has impacted food supply networks and to discover the potential remedies. Hence, the main objectives of this literature analysis are to examine the nature of COVID-19's induced food supply chain disruptions in worldwide and to highlight strategies needed to mitigate the adverse effects of pandemic on the food supply chains as well as to enhance the resilience of worldwide food supply chains. This scrutiny has been conducted using a comprehensive and systematic review of literature published in relation to the impact of COVID-19 on food supply chains and this study included the content of 30 articles which were selected as per the Prisma approach. In reviewing the selected literature, steps of thematic analysis are considered to derive the major findings. The COVID-19 pandemic necessitated the adoption of emergency-preparedness procedures and the development of food supply chain contractual transactions across the worldwide nations. Without reverting to the previous state of food supply chains, novel experience resultant from COVID-19 emphasized the importance of building a smart food value chain with the involvement of all value adding stakeholders in order to ensure the resilience amidst and beyond the crisis.

## **Keywords**

COVID-19 Pandemic, Supply Chain Disruption, Food Supply Chain, Resilience

## **1. Introduction**

As a new agitator of supply chain (SC) disruptions, the COVID-19 global pandemic has significantly triggered an extraordinary series of shocks on the supply chains worldwide (Ivanov & Dolgui, 2020). The global pandemic situation has tremendously impacted on each area of the society and economy leading to a series of utterly novel decisions and policy-making settings for SC scholars and experts. SCs were put to the test in terms of resilience, flexibility, and recovery throughout the pandemic, stressing the crucial importance of resilience in managing SCs in this unpredictable world (Ivanov & Dolgui, 2020). Supply chain disruptions are high-impact, low-frequency occurrences that alter the SC's structural design and have a substantial impact on performance (Ivanov et al., 2019). The effect of a disruption propagation on supply chain performance and the disruption-based scope of variations in

supply chain structural design and planning parameters is referred to as the ripple effect (Dolgui et al., (2018); Ivanov et al.(2015)). The ripple effect in the supply chain arises from the dissemination of disruption to the supply, manufacturing and distribution networks from the initial point of disruption.

COVID-19 Pandemic is considered as the main disruption which caused ripple effects in the supply chains recently due to its very lasting existence and its unpredictable scaling. The epidemic outbreak propagation can be identified as a novel complex setting with both forward and backward disruption propagations (ripple effects), since suppliers, facilities, and markets which are opening and closing simultaneously and sequentially during this crisis period (Li et al., 2021). The food industry is one of the important sectors in each economy. “Epidemic outbreak (COVID-19, SARS-CoV-2) is an exceptional scenario of agri-food supply chain (AFSC) risk at the globalized level which is characterized by logistics’ network breakdown (ripple effects), demand mismatch (uncertainty), and sustainable issues” (Yadav et al., 2021). Based on the food consumption patterns and other political, economic, and social factors, food supply chains of many countries have severely impacted due to the Covid-19 pandemic disruptions in different manners. Most of these disruptions occurred as an end result of policies implemented to limit the virus's spread. A wide range of safety precautions taken to certify the smooth flow of entire food supply chain can be divided into self-hygiene, worker health issues, usage of self-equipment such as gloves, masks, helmets, maintenance of social distance, sanitized surface and work area (Aday & Aday (2020); Barman et al. (2021)). Those actions have had a direct influence on the countries' food security as well. The impact of labour issues and lockdown policies on food supply chain operations have been mainly studied in most research studies. While the consequences of COVID-19 are still being felt, past experience has shown the necessity of a well-organized and foreseeable global trade environment in ensuring that food reaches people in need. In order to avoid the impending global food crisis, it's critical to examine how COVID-19 has impacted food supply networks and to discover potential remedies. Hence, the main objectives of this literature analysis are to examine the nature of COVID-19's induced food supply chain disruptions in worldwide and to highlight the strategies needed to mitigate the adverse effects of pandemic on the food supply chains as well as to enhance the resilience of worldwide food supply chains.

## **2. Methodology**

This scrutiny is based on a comprehensive and systematic review of literature published in relation to the impact of COVID-19 on food supply chains and this study included the content of 30 articles which were selected as per the Prisma approach. The main data sources used in this study are materials such as research papers, reports, letters, web content published during the COVID-19 pandemic period (2020-2022). Most of the papers that were assessed were taken from main research databases such as Scopus, Science Direct, Web of Science, PubMed and etc. The below-given keyword's strings have been entered as in title: 1. (“Agri food supply chain” OR “Food supply chain”) AND (“COVID-19” OR “Pandemic disruption”). 2. (“Agri food supply chain” OR “Food Supply Chain”) AND (“Supply chain disruption”) AND (“COVID-19”). Thus, this provides the first level all searched database having links between various scope of Supply chain disruption, Agri food supply chain, and COVID 19 Pandemic. The complete process of paper selection and exclusion is shown in below Figure 1.

In reviewing the selected literature, steps of thematic analysis are considered to derive the major findings of this study. The most widely accepted framework for conducting thematic analysis is considered in this study which consists of six steps: familiarizing with the data, generating initial codes, searching for themes, reviewing themes, defining, and naming themes and producing the report (Kiger & Varpio, 2020). Through an effective categorization and integrative analysis, this paper presents the impact of COVID-19 pandemic on food supply chains under the five main supply chain disruption categories (themes) such as Supply disruption, Production disruption, Transportation & Logistics Disruption, Demand disruption and Trade disruptions. After analyzing the risk management and resilience strategies (codes) against the COVID-19 pandemic induced food supply chain disruption of all reviewed articles, common and important strategies (themes) were developed. Since the researcher driven focus followed to identify the themes of interest, deductive approach of thematic analysis was followed in this study.

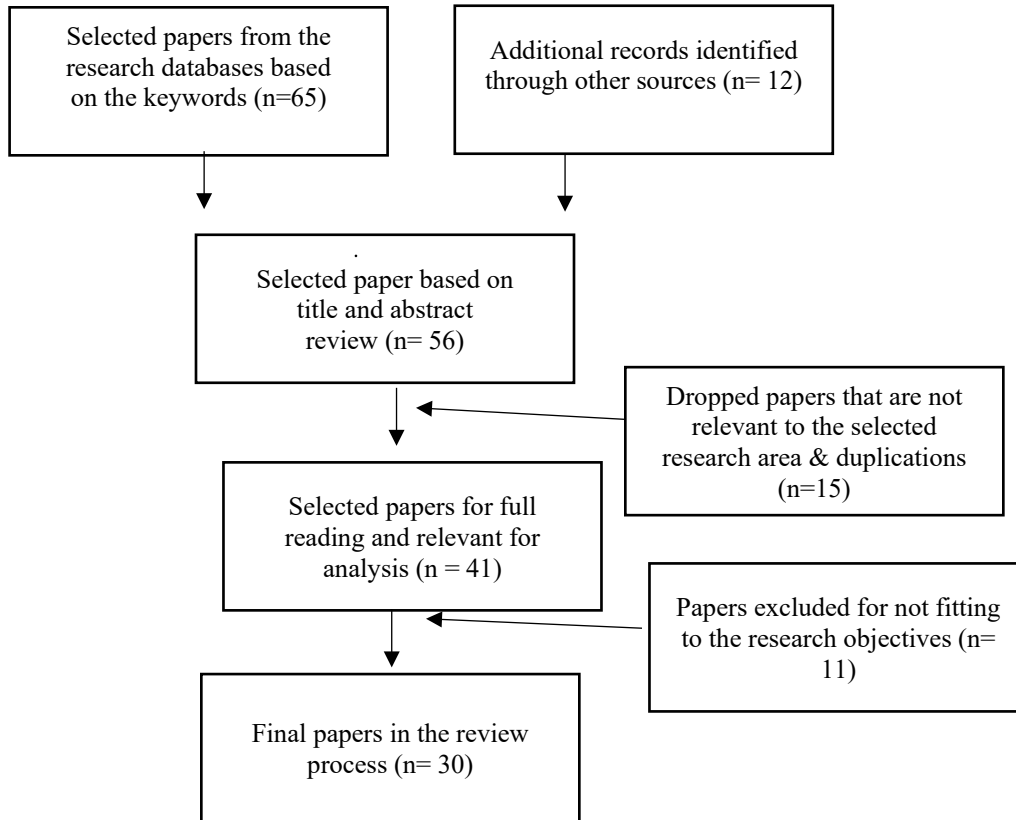


Figure 1. Article Searching, Selection and Exclusion Process

### 3. Literature Review

#### 3.1 Food Supply Chains

The food industry includes fruits, vegetables, meats, dairy products, ready-to-eat foods, and other consumable items. In terms of capital investment and labor, there are two basic categories in the food and agriculture supply chain. While the first category consists of the products such as corn, wheat, maize, soybeans, and oilseeds, the second category consists of high-value products such as fruits, vegetables, fisheries and etc. Large capital investments are required for staple items. The five primary steps of the food supply chain include agricultural production, postharvest management, processing, distribution/retail/service, and consumption (Aday & Aday, 2020). “A perishable products supply chain is not only a supply chain, but also a value-added chain, which takes the perishable products as the core, forming a supply chain network to meet the requirements of consumers” (Deng et al., 2019).

#### 3.2 COVID-19 Pandemic induced Disruption in Food Supply Chains

“Epidemic outbreak (COVID-19, SARS-CoV-2) is an exceptional scenario of agri-food supply chain (AFSC) risk at the globalized level which is characterized by logistics’ network breakdown (ripple effects), demand mismatch (uncertainty), and sustainable issues” (Yadav et al., 2021). Based on the food consumption patterns and other political, economic, and social factors, food supply chains of many countries have severely impacted due to the COVID-19 pandemic disruptions. A wide range of safety precautions taken to certify the smooth flow of entire food supply chain can be divided into self-hygiene, worker health issues, usage of self-equipment such as gloves, masks, helmets, maintenance of social distance, sanitized surface and work area (Aday & Aday (2020); Barman et al. (2021)). In general, all supply chain stakeholders, such as farmers moving to the farm or processing factories, merchants picking up products and transporting them into warehouses, and buyers and sellers heading to markets, rely substantially on physical movements. COVID-19 induced lockdown-style policies have inflicted chaos on the entire food supply chain including farm output and food processing, transportation and logistics, and customer demand (Deconinck et al. (2020); Michèle (2020)). Although the economic repercussions of COVID-19 disruptions on industrial and tourism sectors were noticeable to policy developers, the effects on the agri-food chains were less apparent (Boughton et al.,

2021). The pandemic disruption brought uncertainty for all parties associated with the food supply chains and they experienced both short-term and longer-term consequences (Arif Husain et al., 2020). However, different food products encountered interruptions at various points of the supply chain, and they have not been equally affected. Hence, this current study mostly focused on the ripple effect of COVID-19 on the food supply chain, and it is discussed under the five main disruption categories such as Supply Disruption, Production Disruption, Transportation and Logistics Disruption, Demand Disruption and finally Trade Disruption.

### **3.2.1 COVID-19 Pandemic Induced Supply Disruptions in Food Supply Chains**

Farm labors, seeds, pesticides, fertilizers, and energy are mainly considered as the inputs for farm production. During the epidemic, supplies to agricultural productions were disrupted to varying degrees. Out of them, labour shortage has mainly hampered farm production. While Some farm sectors such as vegetables and fruits are heavily reliant on labour, grains and oilseeds need less. The availability of seasonal workers for fruit and vegetable growing and harvesting has been limited in several countries due to limits on people's mobility (Deconinck et al. (2020); Michèle (2020)). During the crisis period, it was critical to safeguard and maintain the health of those who work in the food supply chain. This crisis threatened the possibility of agricultural firms and other farms to work due to the lack of workers caused by ill health as well as the physical distance that must be kept during production (Alsuwailem et al., 2021). The seeds are the main raw material used in the Agri-production. Seeds can be produced, processed, and packed in a variety of nations as the seed industry is well globalized. Seeds are often transported by air transportation which was significantly hampered during the lockdown period (Deconinck et al., 2020). While seed deficits had not been a strain during this period, farmers experienced some difficulties in getting the seeds due to some travel and import restrictions (Deconinck et al., 2020). China is considered as a significant supplier of pesticides, were also a source of concern at first. When China was lifted from its emergency state, these concerns seemed to vanish (Aday & Aday, 2020). Fertilizer and energy supplies have been essentially unaffected, and the prices of major fertilizers persisted low in several countries. Fertilizer availability was not a big issue on a global scale, yet local disruptions have happened due to travel restrictions (Aday & Aday, 2020). Although this agriculture sector may benefit from the price reduction of agrochemicals, the supply chain disruption may increase the scarcity of inputs leading to higher import prices (ICRA Lanka, 2020). Even though the majority of Agri- firms rely on their core inputs, they were more exposed to supply interruptions because they must get their supplies from domestic markets.

### **3.2.2 COVID-19 Pandemic Induced Production Disruptions in Food Supply Chains**

Some agricultural lands have remained uncultivated due to farmers' restricted access to agricultural supplies. However, as the agricultural firms were typically located in remote locations far from heavily populated areas, the pandemic had not much effect on the rural Agri- production. The supply chain affects all parties involved, including producers and distributors as well as labor-intensive food processing facilities. COVID-19 has inflicted chaos on the food processing industry, which has been harmed by social distance laws, sick leaves of workforce, and lockdown processes designed to prevention of virus spreading. In the food and agriculture industries, the meat and poultry processing industries are critical infrastructure. COVID-19 clusters were found around the worldwide meat processing plants, showing that meat processing was more susceptible than other types of food processing due to its labor-intensive processes and the cold and humid condition inside the facilities (Aday & Aday, (2020); Deconinck et al. (2020); Michèle, 2020)). The social distancing measures and adequate staff protections required in those fruit and vegetable packing plants or meat processing plants reduced operational efficiency (Aday & Aday, (2020); Deconinck et al. (2020); Michèle, 2020)). In wealthy countries, however, grain handling and processing is well automated and less labor-intensive., therefore it has not been impacted as hard as the meat processing industry. Although centralized food manufacturing assisted food processors in increasing production and cutting costs, it caused food chain disruption during the epidemic outbreak, as the entire factory was shut keeping high-capacity production lines at a low level of productivity (Aday & Aday, 2020). The shutdown of those food facilities reverberated all over the food supply chain, slowing the distribution of food products and agricultural inputs and causing issues in assuring a consistent supply of food to markets (Deconinck et al., (2020). COVID-19's long-term containment strategies in securing efficiency and effectiveness of food production, availability of staple foods and nutrition, and cross-national trade were all at risk.

### **3.2.3 COVID-19 Pandemic Induced Transportation & Logistics Disruptions in Food Supply Chains**

The food supply chain's most important problems were raw materials collection from suppliers and guaranteeing the smooth flow of food from producers to end customers, especially in times of global crises. While agricultural activities continued during the pandemic, logistics were significantly disrupted (World Bank, 2021). Transportation and logistical bottlenecks have impeded the movement of goods along supply networks. The primary modes of transport for agricultural and food items are bulk (ships and barges), containers (by boat, rail, or truck), and other road transport;

and air freight (Michèle, 2020). Oilseeds and cereals are routinely transported in the form of bulk; meat and dairy products are often transported using refrigerated containers and trucks; and perishable and high value food stuffs are frequently transported by air in passenger planes' "bellies" (Michèle, 2020). COVID-19 influenced these modes of transportation in a variety of ways. While Bulk shipments had not experienced any significant delays, the air freight system has been considerably affected. Transportation disruptions involving containers and trucks occurred in the middle of the spectrum (Michèle, 2020). Restrictions between cities, provinces, regions, and countries obstructed the delivery of staple foods. In comparison to basic products, obtaining high-value products necessitates a great amount of effort (Aday & Aday, 2020). The perishable high-value goods, such as vegetables and fruits, are the hardest hit by these logistics issues and border inspection delays that disrupt whole food supply networks. Furthermore, most of the fresh food items of restaurants and food processing facilities were destroyed in vain owing to transit complications occurred during the lockdown and shutdown of institutions. However, cereal supplies have been relatively undisturbed as the cereals can be loaded, distributed, and managed with minimum labour requirements (Michèle, 2020).

### **3.2.4 COVID-19 Pandemic Induced Demand Disruptions in Food Supply Chains**

Behavioral changes of customers caused a considerable impact on the food supply chain performance. When it considers the impact of COVID-19 pandemic on consumers' food demand, it's evident that demand differs based on food price, income level, socio-demographic status, consumption and shopping preferences, and time restrictions (Aday & Aday (2020); Godrich et al. (2022)). Changing demands brought changes to packing materials and their design, delivery services, and storage requirements (Godrich et al., 2022). While some customers paid more attention to reduce food waste in order to improve food security, consumers' overbuying has caused a greater levels of food waste. Due to the lockdowns, panic buying, and other supply disruptions, the COVID-19 epidemic resulted in a massive spike in food prices. In addition to food supply, food security is mostly determined by consumer access to food. Since the onset of this world-wide crisis, consumer demand for some food items had risen, and some shop shelves had been momentarily emptied, causing an excess sale of vital goods (Aday & Aday (2020); Godrich et al. (2022)). Demand for food is usually inelastic and a shortfall of purchasing power due to the crisis changed the food consumptions patterns of people and the demand shifting away from value-added foods items to basic cereals (Arif Husain et al., (2020); Barman et al.(2021); Godrich et al. (2022); World Food Programme (2020)). Consumers have placed a premium on foods with a lengthy shelf life, such as canned meals, pasta, milk and refrigerated foods, due to the ease in daily food preparation at homes. (Aday & Aday, 2020). As a result of their desire to eat better meals while staying within their budget, consumers have turned to natural food and beverage items that comprise ingredients that provide nutritious, such as vegetables, fruits, whole grains, olive oil and etc((Aday & Aday (2020); Siti Rubiah Lambert et al. (2021)). Due to panic buying and storing of food unnecessarily, demand for vital food products surged considerably as the epidemic spread, restraining access to essential food items for vulnerable segments of the population (Alsuwailem et al. (2021) Deconinck et al. (2020); Central Bank of Sri Lanka (2020); Institute of Policy Studies (2020)). Regardless of government guarantees, several retailers set up free deliveries on orders to prevent panic buying and established special shopping hours for vulnerable clients. To avoid overcrowding, supermarkets also regulated the maximum number of people allowed at any moment (Aday & Aday, 2020). COVID-19 has caused a dramatic shift in customer demand away from restaurants, food service, and other take away options, demanding considerable modifications in the food supply chain (Aday & Aday (2020); Deconinck et al. (2020); Michèle (2020)).

### **3.2.5 COVID-19 Pandemic Induced Trade Disruptions in Food Supply Chains**

As a result of the COVID-19 crisis, food trade policies of certain governments have been evolved, with exports being restricted and imports being made easier. This pandemic had a substantial impact on food trade due to export restrictions imposed by the authorities (WFP Nepal, 2020). Export restrictions drove up the price of stable agricultural commodities such as wheat, maize, and rice around the world, reducing the quantity and quality of food consumed (Aday & Aday (2020); M. R. Roshana & Nuskiya Hassan (2020). The main reason for countries which imposed export restrictions was to maintain a constant supply of items in the domestic market. Due to the COVID-19 outbreak, a total of 19 nations have taken measures to restrict exports of 27 food products. Although the export ban generally had this impact in short run, it may have certain adverse consequences, such as lower domestic pricing, which hurt farmers financially, causing in lesser farming productivity and reduced industry incentives. (Aday & Aday, 2020). On other hand, countries that rely heavily on imports were at risk of food instability during the lockdowns. During these periods, those countries saw a considerable decline in the importation of various food commodities (Alsuwailem et al., 2021). These import and export limitations will lead countries to experience some loses to their competitive and comparative advantages as a consequence of dropping their place in global market places, eroding faith in international trade and obliterating future import and export opportunities (Aday & Aday, (2020);Alsuwailem et al. (2021) Swinnen & McDermott ( 2020)).

### **3.3 Food Supply Chain Resilience against the COVID-19 Pandemic**

#### **3.3.1 Resilient Strategies against Supply and Production Disruptions**

As a result of transportation disruptions and quarantine measures, the supply side of the Agri value chain has been mainly harmed by labour shortages, which would limit food production and processing, and led to an increase in food wastage (Arif Husain et al. (2020); Barman et al. (2021); Hossain, (2020) Siti Rubiah Lambert et al. (2021); Siti Rubiah Lambert et al.(2020a); World Food Programme, (2020)). Countries must take steps to guarantee the safety of agricultural workers, such as onsite healthcare specialists keeping track of employees' disease status. It was critical to inform farmers about transmission channels and raise pandemic preparedness awareness. As a solution to the farmers' vulnerability and food insecurity, providing cash allowances and low-cost resources is more important to keep farmers in business (Galappattige, (2020); Mottaleb et al., (2020)). Safeguarding the lands, introducing digital farming technologies for smallholders, endorsing comprehensive agribusiness models, and enlightening the capabilities of farmers and other food chain actors to manage the risks can be identified as instruments for promoting smallholders' presence in agri-food supply chains (Vos & Cattaneo, 2021). Decentralization of food manufacturing could be used in the pandemic period to mitigate the challenges and risks related with the centralization approach, as decentralization allows the supply chain to be more flexible and customers to purchase fresh, organic foods (Aday & Aday, 2020). Agricultural transformation, which can be characterized as technological innovation and labor upskilling, may result from the timely-critical nature of agricultural processes, as well as the demand for greater output over time.

Diverse technology applications can be used to create a long-term supply chain to avoid food shortages during a pandemic (Abid & Jie, 2021). AFSCs' digitization not only aids their survival, but also allows them to handle their activities more efficiently in the case of an interruption (Joshi & Sharma, 2021). With the deployment of digital technologies, AFSCs will have access to real-time data that will help them make better decisions (Joshi & Sharma, 2021). Digital Technology enabled AFSC will be swift, adaptable, discernible and it brings resilience in AFSC (Joshi & Sharma, 2021). To grow more food in response to COVID-19, new strategies such as new thinking and investment in horticulture, crop diversification, indoor vertical farming, investments in enhancing the farming skills and providing trainings combined with an investment in digital automation, constructing a more evidence-based risk and resilience framework, and developing collaborative partnerships among the government, science, industries can be implemented (Garnett et al., 2020). Governments also can implement several strategies to keep small farmers with the agricultural production such as assigning healthcare professionals to ensure the safety of agricultural laborers, establishing food banks to create new markets for unsold products, deploying warehouse receipt systems, improving access for financial loans to restart production, getting the best price for food products and technology usage etc.

#### **3.3.2 Resilient Strategies against Transport & Logistics Disruptions**

Supply chain actors should increase their usage of innovative delivery methods such as "click and collect" services and electronic purchases and for example farmers have embraced digital platforms to offer their goods directly to consumers (Michèle, 2020). It is critical to make the maximum utilization of existing logistics facilities, particularly the logistics vehicles avoiding empty returning. By merging many deliveries into one or more vehicles, the concept of an 'Urban Distribution Center' can assist in getting maximum use of available capacities, improving the efficiency of the collection centers and transportation operation (Aday & Aday, 2020). Governments should establish agricultural products collection centers in reachable places so that small-scale farmers can reduce their unnecessary transportation expenses. Agricultural products collection facilities for high-capacity storage should be built, and innovative storage structures can also be used to reduce food waste across the food value chain (Aday & Aday, 2020). A public distribution system (PDS) is a revitalizing technique for assuring affordable food supply to more needy people, and the entire supply chain network of PDS is made up of the supplier (farmer), central warehouse, capital city warehouse, small city warehouse, and fair price shop (Barman et al., 2021). Food can be delivered at a reasonable price over fair price shops (FPS) in both urban and rural regions and it contributes to ensure the resilience of supply chain during a pandemic (Barman et al. (2021); Singh et al., (2021)).

#### **3.3.3 Resilient Strategies against Demand and Trade Disruptions**

Changes in demand resultant from the crisis also had an impact on food supply chain performance. Therefore, statistical approaches, predictions, and simulations can be utilized to forecast demand, particularly for perishable food items, which are more vulnerable to crisis like COVID-19 (Aday & Aday, 2020). Because the SARS-CoV-2 can be transferred easily through the air, people should always wash their hands. Retailers and other food preparation must adhere to high hygiene requirements when handling food including wearing suitable masks and gloves in cutting, slicing, or packaging foods. To avoid contamination, consumers were supposed to handle foods in stores that they

only intended to buy. Sophisticated technology applications can be used to prevent the transmission of microorganisms by humans in food facilities such as using robots to serve food to customers in the food service industry and using Cyber Physical Systems to monitor unsafe or low-quality products in the food supply chain. (Aday & Aday, 2020). Other methods such as route optimization, E-farm marketing, smart Agri product packaging, cold chain for perishables, and simulation of consumption patterns are also important in enhancing capability and flexibility of Agri firms to survive in a rapidly changing environment caused by the COVID-19 (Yadav et al., 2021).

Consumer access to food, not only food supply, posed the greatest danger to food security, as the lockdown measures and other COVID-19-related disruptions resulted in the loss of millions of jobs and a pay freeze for some employees (Godrich et al. (2022); WFP Nepal (2020)). To avoid a spike in starvation and food insecurity, social safety nets and food assistance programmes are essential including increasing consumers' access to markets and prioritizing the low-income consumers' needs and etc (Michèle, 2020). Establishing web-based food distribution systems will strengthen the relationship between buyer and seller by ensuring information flow between suppliers, facilities, collecting centers, and merchants. The largest e-commerce firms should enthusiastically cooperate with the government to digitize rural market services and inspire small-scale farmers to join the e-commerce industry. Consequently, Small farmers can sell their commodities at a greater price thanks to the digitization of procedures, which allows them to reach out to more customers in a direct and efficient manner, skipping intermediaries. In order to link retail chains with e-commerce through digital platforms, government can perform a prominent role by guaranteeing food security and regulating food prices (Abid & Jie, 2021). Furthermore, companies can buy directly from farmers, without the middlemen, removing barriers and preventing stockpiling and corruption (Abid & Jie, 2021). There are few measures which can be used to prevent worldwide food security crisis and to enhance the international trade such as avoiding protectionist policy, monitoring food prices and markets and ensuring the transparency of relevant information , implementing export restrictions to isolate domestic food markets from global market developments during the lockdown period, temporarily easing the strict requirements for food imports such as food labelling requirements, providing external assistance for poorer countries on favorable terms, such as concessional loans, grants, debt rescheduling, or debt swaps to quickly implement large-scale social safety net programmes (Arif Husain et al., (2020); Barman et al. (2021); Deconinck et al. (2020) Michèle, 2020) Siti Rubiah Lambert et al.(2021); World Food Programme,(2020)). Moreover, undertaking foreign agriculture investments through direct collaborations with other countries is ideal strategy to maintain sustainability of worldwide food supply chains (Alsuwailem et al., 2021). As a response to the COVID-19 pandemic, major exporters and importers of staple foods should agree to refrain from erecting trade obstacles. Worldwide trade routes should remain open so that international markets can help avert food shortages and mitigate the inevitable global economic crisis (Swinnen & McDermott, 2020).

#### **4. Results and Discussion**

Even prior to the COVID-19 disaster, food networks have been sensitive to climate and disease-related challenges, such as the oil crisis in the 1970s, the SARS and Ebola outbreaks, and the 2006–2008 food crisis, despite the fact that the recent situation appears to be extraordinary (Aday & Aday, 2020). Agriculture-based economies have been hit the worst by COVID-19, resulting in food security challenges such as inflation, price volatility, and lack of traceability (Barman et al. (2021); Joshi & Sharma (2021); Siti Rubiah Lambert et al. (2020)). The breakdown in the producer-end of the supply chain, triggered by workers shortages, transportation issues, and input shortages and delays, has largely collapsed the food supply chain during the lockdown period (Central Bank of Sri Lanka (2020); M. R. Roshana & Nuskiya Hassan, 2020)). Accordingly, all subsequent intermediary processes of food manufacturing, such as processing, packaging, storage, and distribution had been hampered during this period. Small farmers were susceptible to coronavirus because of their low income and advanced age. Economic access and physical food supply are both threatened by the economic instability resultant from pandemic. There was a risk of arising hunger and malnutrition issues as a result of this pandemic disruptions (Aday & Aday (2020); Godrich et al. (2022)).

COVID-19 has affected both high and low-income countries, but the aftershocks of COVID-19 could have serious adverse consequences for low-income developing countries (Mottaleb et al., 2020). While there have been obvious difficulties and issues in developing countries, food supply chains in the developed countries have exhibited extraordinary resilience and robustness being confronted with COVID-19 (Deconinck et al. (2020); Michèle (2020)). Countries fighting the pandemic ought to put up every effort to shift the concerns of the food supply chain. The intensity and mix of agricultural inputs, which varies by product and country, had a significant impact on farming practices. The main objective of this literature analysis is to examine the nature of COVID-19's induced food supply

chain disruptions in worldwide. Therefore, based on the findings of literature review, impact of COVID-19 pandemic on food supply chains can be summarized as shown in below Figure 1.

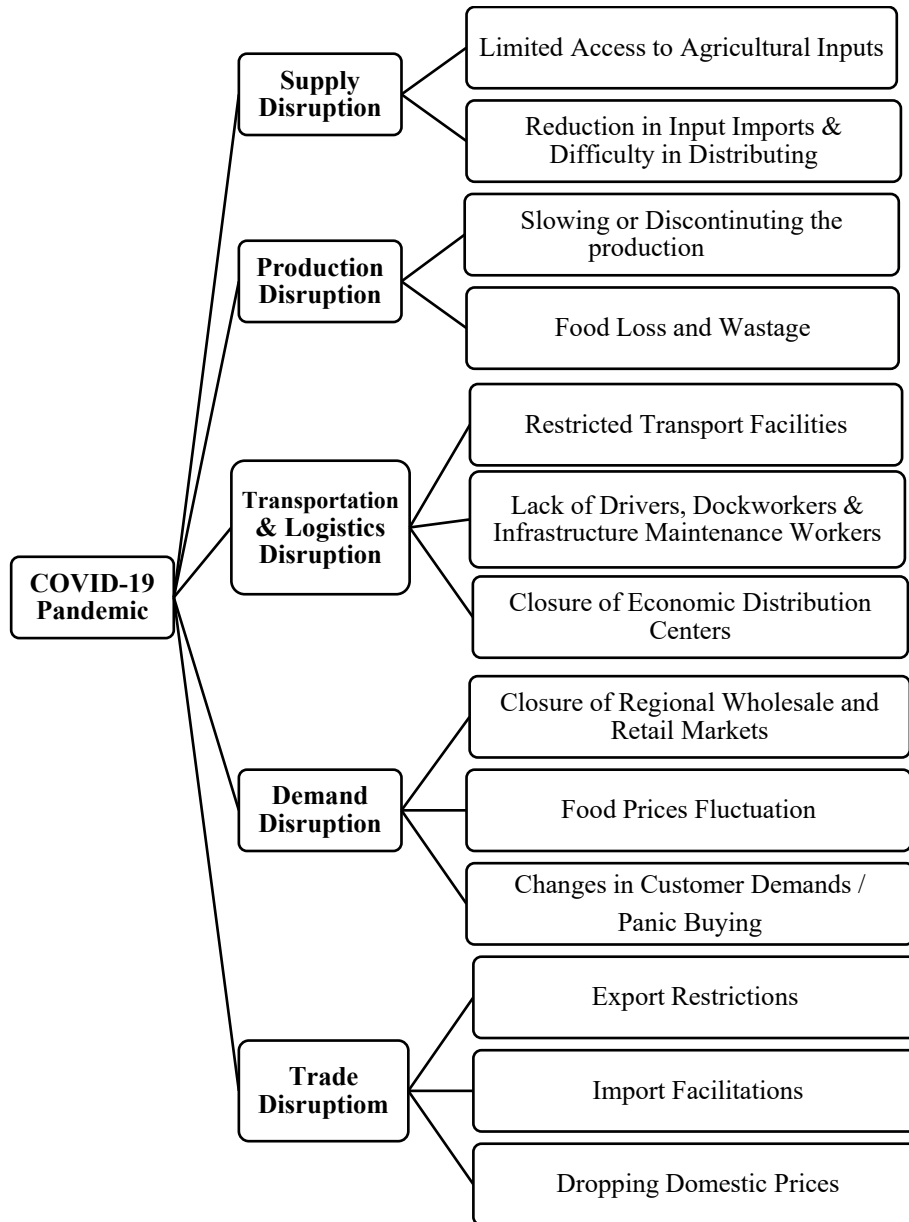


Figure 1. Impact of COVID-19 pandemic on food supply chains

The vulnerability of a food supply chain to the pandemic has been linked to its stage of development such as traditional, transitional, or modern and comparatively, modern food supply chains have more capabilities to cope with COVID-19 pandemic as they are more capital-intensive and see emerging contractual arrangements across the worldwide countries (Arif Husain et al., 2020). The COVID-19 pandemic necessitated the adoption of emergency-preparedness procedures and the development of food supply chain contractual transactions. Governments and private sectors can use Supply Chain Management (SCM) Data Science to ensure food security and the smooth operation of the country's food supply chain in a variety of ways, including improving the availability of reliable information and dissemination, accessing precise data at the real time to identify causes of probable disruptions(Alsuwailem et al., 2021). Those precise data also enable improved decision-making and increases the overall profitability of the supply chain. Governments should require continuous interaction with a wide range of industry leaders in all aspects of the Agri-



food chain in setting of priorities and recovery policies during the Covid-19 crisis (Mussell et al., 2020). The younger generation of low-income countries who are more likely to give up farming due to some shortcomings in agriculture sector such as low agricultural earnings and productivity, a larger risk of child labor, involuntary labor and other human rights abuses, and deforestation which could be aggravated as farmers seek more fruitful land to generate more incomes (Siti Rubiah Lambert et al., 2020). This raises questions about the agriculture sector's long-term survival in addition to the COVID-19 implications and governments should take some proactive approaches to enhance the attractiveness towards the farming among the young adults with the digitalization and globalization.

AFSC's multi-tiered sustainability may aid in the reduction of losses at various stages while minimizing deterioration of agri-food quality, contributing to the long-term viability (Yadav et al., 2021). With the COVID-19 epidemic, IoT-driven food security system has taken a significant place in ensuring the sustainability at the globalized level (Yadav et al., 2021). To avoid the bull-whip effect, enablers such as information dissemination, coordination and collaboration, IoT-based infrastructure, and the establishment of food quality standards are responsible for information processing inside an AFSC multi-tier system. In the wake of this pandemic, Voluntary Sustainability Standards (VSS) can be adopted into food systems, as a tool to enhance openness and traceability throughout the Agri-food supply chains (Siti Rubiah Lambert et al. (2021); Siti Rubiah Lambert et al. (2020)). All stakeholders should contribute to keep the flow of food and commodities across the supply chain (Aday & Aday, 2020). The second main objective of this literature analysis is to highlight the strategies needed to mitigate the adverse effects of pandemic on the food supply chains as well as to enhance the resilience of worldwide food supply chains. With special reference to the COVID-19 pandemic, the risk management and resilience strategies for food supply chains identified from the literature review have been summarized in below Table 01.

Table 1. supply chain resilience strategies against the COVID-19 pandemic

<b>Strategy</b>	<b>Actions</b>	<b>Reference</b>
<b>Finding alternative sources of supply and giving exemptions for food and agriculture sectors</b>	<ul style="list-style-type: none"> <li>- Finding alternative sources of supply when faced with disruptions to avoid the supply shortages (foreign labours, new seeds, organic fertilizers &amp; etc.)</li> <li>- Searching for temporary substitutes for real ingredients when obtaining them is challenging.</li> <li>- Exemptions of food and agriculture from lockdown restriction</li> <li>- Loosening visa restrictions to attract foreign seasonal workers, and administrative flexibility</li> </ul>	(Alsuwailem et al., 2021) (Deconinck et al., 2020)
<b>Capacity enhancement of farmers/food manufactures while ensuring their health and safety</b>	<ul style="list-style-type: none"> <li>- Assigning healthcare professionals to ensure the safety of agricultural labourers</li> <li>- Leveraging the potential of digital technology for smallholders</li> <li>- Expanding operating hours</li> <li>- Investment in enhancing farming skills and Providing trainings</li> <li>- Securing land tenure</li> <li>- Indoor vertical farming</li> <li>- Decentralization of food manufacturing to minimize the problems and hazards associated with the centralization paradigm</li> <li>- Improving access for financial loans to restart production</li> </ul>	(Aday & Aday, 2020) (Abid & Jie, 2021) (Garnett et al., 2020) (Vos & Cattaneo, 2021)
<b>Promoting partnerships among the stakeholders</b>	<ul style="list-style-type: none"> <li>- Developing collaborative partnerships among the government, science, industries</li> <li>- Promoting inclusive agribusiness models</li> <li>- Purchasing directly from farmers and removing the middleman to remove barriers and deter hoarding and corruption</li> </ul>	(Abid & Jie, 2021) (Garnett et al., 2020) (Godrich et al., 2022) (Mussell et al., 2020)

		(Vos & Cattaneo, 2021)
<b>Exploring new product development opportunities</b>	<ul style="list-style-type: none"> <li>- New thinking and Investment in Horticulture</li> <li>- Crop diversification</li> </ul>	(Garnett et al., 2020)
<b>Developing innovative delivery methods and distribution facilities</b>	<ul style="list-style-type: none"> <li>- Providing "Click and collect" services and online purchasing facilities for farmers to sell their goods directly to consumers</li> <li>- Establishing 'Urban Distribution Center'/ Public distribution system (PDS) to make better use of capacity by combining many deliveries into one or more vehicles</li> <li>- Creating agricultural production collecting centers in easily accessible areas for small-scale farmers.</li> <li>- Establishing cold chain for perishable products</li> <li>- Smart Agri product packaging</li> <li>- Establishing food banks to create new markets for unsold products</li> <li>- Deploying warehouse receipt systems</li> <li>- Usage of specialized private aircraft for freight expanded</li> </ul>	(Abid & Jie, 2021) (Aday & Aday, 2020) (Deconinck et al., 2020) (Godrich et al., 2022) (Michèle, 2020) (Yadav et al., 2021)
<b>Developing new market channels and enhancing customer satisfaction while ensuring their health and safety</b>	<ul style="list-style-type: none"> <li>- E-Farm Marketing: Establishing web-based food distribution systems to strengthen the relationship between buyer and seller by ensuring information flow</li> <li>- Utilizing statistical approaches, predictions, and simulations to forecast customer demand and consumption patterns, particularly for perishable food items, which are more vulnerable to COVID-19</li> <li>- Adhering to strict sanitary standards in handling the foods</li> <li>- Using the various robot systems to ensure food safety in food facilities by preventing the transmission of microorganisms by humans</li> <li>- Using a Cyber Physical System (CPS) to monitor unsafe or low-quality products in the food supply chain</li> <li>- Decentralized facilities give the supply chain more flexibility &amp; allows customers to acquire fresh, natural items</li> </ul>	(Aday & Aday, 2020) (Deconinck et al., 2020) (Yadav et al., 2021)
<b>Ensuring smooth flow of global trade and implementing large-scale social safety net programs</b>	<ul style="list-style-type: none"> <li>- Avoiding protectionist policy</li> <li>- Monitoring food prices and markets</li> <li>- Making sure that information is transparently</li> <li>- Implementing export restrictions to isolating domestic food markets from global market developments during the lockdown periods</li> <li>- Temporarily easing the strict requirements for food imports such as food labelling requirements</li> <li>- Reducing border waiting times</li> <li>- Streamlining the certification procedures</li> <li>- Providing external assistance for poorer countries on favorable terms, such as concessional loans, grants, debt rescheduling, or debt swaps to quickly implement large-scale social safety net programmes</li> </ul>	(Arif Husain et al., 2020) (Barman et al., 2021) (Deconinck et al., 2020) (Godrich et al., 2022) (Michèle, 2020) (Siti Rubiah Lambert et al., 2021) (World Food Programme, 2020)
<b>Deployment of digital technologies</b>	<ul style="list-style-type: none"> <li>- Using diverse technology applications to create a long-term supply chain to avoid food shortages during a pandemic</li> <li>- Deployment of digital technologies to have access to real-time data on Agri-Food Supply chain</li> <li>- Investment in digital automation</li> </ul>	(Abid & Jie, 2021) (Alsuwailem et al., 2021) (Joshi & Sharma, 2021)

	<ul style="list-style-type: none"> <li>- Developing IoT-driven food security system for ensuring sustainability at the globalized level</li> <li>- Using Supply Chain Management (SCM) Data Science to ensure food security and the smooth operation of the country's food supply chain</li> </ul>	<p>(Vos &amp; Cattaneo, 2021) (Yadav et al., 2021)</p>
<b>Constructing a more evidence-based risk and resilience framework</b>	<ul style="list-style-type: none"> <li>- Setting of priorities and recovery policies during the COVID-19 crisis with the continuous interaction with a wide range of industry leaders in all aspects of the food chain</li> </ul>	<p>(Mussell et al., 2020)</p>
<b>Adopting Sustainability Standards</b>	<ul style="list-style-type: none"> <li>- Adopting Voluntary Sustainability Standards (VSS) into food systems</li> <li>- Establishing Multi-tiered sustainability to reduce the losses at various stages</li> <li>- Establishment of food quality standards</li> </ul>	<p>(Siti Rubiah Lambert et al. (2021) (Siti Rubiah Lambert et al. (2020) (Yadav et al., 2021)</p>

## 5. Conclusion

COVID-19 had the possibility to worsen the poverty and malnutrition, particularly in developing countries with inadequate social safety nets. COVID-19 resulted in travel restrictions of laborers, consumer demand fluctuations, shutting down the food manufacturing facilities, restricted food trade legislation, and financial limits in the food supply chain. The COVID-19 pandemic highlights the significance of guaranteeing public food security during such extraordinary economic shocks, as well as the risk of exacerbating existing food insecurity issues in the countries which need to be addressed effectively. While there have been obvious difficulties and issues in developing countries, food supply chains in the developed countries have shown remarkable resilience and robustness in the face of COVID-19. While the consequences of COVID-19 are still being felt, past experience has exhibited the necessity of a well-organized and foreseeable global trade environment in ensuring that food reaches people in need. Exemptions from lockdown restrictions for food and agriculture, measures to ensure the health of agriculture and food workers, loosening visa restrictions to attract foreign seasonal workers, and administrative flexibility were among the policy measures taken to protect the functioning of food supply chains. The COVID-19 pandemic necessitated the adoption of emergency-preparedness procedures and the development of food supply chain contractual transactions across the worldwide nations. Immediate economic assistance initiatives required to avoid this health catastrophe from escalating into a food crisis, and governments should participate in better data collection in order to equip policymakers with the adequate information so that they can form policies that successfully develop comprehensive food value chains. Without reverting to the previous state of food supply chains, novel experience resultant from COVID-19 emphasized the importance of building a smart food value chain with the involvement of all value adding stakeholders in order to ensure the resilience amidst and beyond the crisis. These lessons learnt from the COVID-19 epidemic will be valuable in dealing with the impending food crisis and the further research on the ripple effects of disruptions in food supply systems is needed to enlighten the prospective solutions.

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