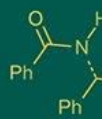


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Munish Kaundal
University Institute of
Agriculture Science,
Chandigarh University,
Mohali, Punjab, India

Kanishk Sood
University Institute of
Agriculture Science,
Chandigarh University,
Mohali, Punjab, India

Gurkaran Singh
University Institute of
Agriculture Science,
Chandigarh University,
Mohali, Punjab, India

Harshpreet Singh
University Institute of
Agriculture Science,
Chandigarh University,
Mohali, Punjab, India

Sheetal Kour
University Institute of
Agriculture Science,
Chandigarh University,
Mohali, Punjab, India

Corresponding Author:
Munish Kaundal
University Institute of
Agriculture Science,
Chandigarh University,
Mohali, Punjab, India

Transformation of the agri-food sector caused by COVID-19: A review of challenges and opportunities

Munish Kaundal, Kanishk Sood, Gurkaran Singh, Harshpreet Singh and Sheetal Kour

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Abstract

The COVID-19 pandemic has precipitated a paradigm shift in agri-food supply chains (AFSCs), exacerbating existing vulnerabilities and disrupting the entire value chain. This review paper provides a comprehensive analysis of the impact of COVID-19 on AFSCs, highlighting the critical loss points and opportunities for sustainable food production and circulation. The paper examines the effects of COVID-19 on the upstream and downstream segments of AFSCs, including production, processing, packaging, transportation, storage, and distribution, as well as the consequences for food security, economic stability, and environmental sustainability. The findings suggest that the pandemic has triggered a perfect storm of supply chain disruptions, including inventory management challenges and logistical bottlenecks, leading to food waste, economic losses, and environmental degradation. However, the crisis also presents opportunities for innovation, collaboration, and policy reforms to build more resilient and sustainable AFSCs, leveraging digital technologies, circular economy principles, and sustainable agriculture practices. This review paper emphasizes on the need for a coordinated response to address the challenges and opportunities arising from the COVID-19 pandemic and to develop more agile, adaptive, and resilient AFSCs.

Keywords: Agri-food supply chains, COVID-19, food security, economic losses, environmental degradation, sustainable agriculture

1. Introduction

The coronavirus (COVID-19) has caused a dramatic and unprecedented transformation of socioeconomic norms since it was first reported in Wuhan, China (Rowan and Laffey, 2020) [24]. The COVID-19 pandemic is impossible to predict because many countries are experiencing a second or consecutive wave of infection. Similar to the Black Swan event, there is a significant gap in published research on communications for businesses, most of which is neither prepared nor planned to be bypassed (Reid *et al.*, 2020) [22]. COVID-19 is impacting government and commercial healthcare systems like never before. Companies are experiencing market and financial shocks due to the COVID-19 outbreak, factory closings, labour shortages, cash flow strains, and supply chain disruptions. Global mitigation efforts are focused on public health strategies to contain, limit, and reduce the spread of the virus through hand hygiene, social distancing, closure (stay at home), and community protective face masks present in 50 countries. This reality has caused an uncommon techno-socio-economic seismic tremor that has cleared out numerous divisions looking for unemployment benefits due to COVID-19, and the food chain sector is no exception (Galanakis, 2020) [14]. There is an opportunity to move to resilient supply chains after COVID-19, which implies reassessing vulnerabilities due to excess time or ordinary business practices (Sarkis *et al.*, 2020) [25]. In 2020, environmental and health problems caused by the COVID-19 pandemic were highlighted, and monitoring and mitigation measures were recommended (Barcelo, 2020) [4]. The widespread COVID-19 has created emotional vulnerability and eccentricity, with the potential for socio-economic harm in numerous segments. Countries were reopening for business while there were economic issues, there were stimulus packages, and there was an unprecedented lack of critical information (such as marketing new consumer trends and behavioural changes to offset on-site protection and social distancing) to enable businesses to make priority decisions about key recovery needs after COVID-19 (Sarkis *et al.*, 2020) [25].

Due to the almost simultaneous shutdowns of countries caused by COVID-19, countries were exiting the COVID-19 bubble and were providing a useful lens to review and report recovery. This scenario helped to provide a real-time analysis of the situation and reveals the main challenges that the industrial political and socio-economic landscape is now facing internationally. Food insecurity means that countries depend on imports but may not earn enough foreign exchange to buy essential imported goods. The post-COVID-19 era also offers unparalleled opportunities to address climate change and develop green innovations for sustainable food production and security.

2. Agri-food supply chain

AFSC is a complex network connecting distribution channels from farm to table. AFSC administration is an organized approach that guides item stream from makers to customers (Bhatia and Janardhana, 2020) ^[5]. India is at a point where more brainstorming and restructuring are needed to streamline AFSCs to meet the unexpectedly growing demands of certain products. There are five important stages of FSC that must be managed immediately, namely production, processing and packaging, handling and storage, marketing and distribution, and consumption (Forsido *et al.*, 2020) ^[13]. The food industry is witnessing dramatic changes during this pandemic, including market modernization, reduced product shelf life, technological advances, and diversification of consumer demand. Companies participating in and collaborating with such FSC practices face several risks that must be effectively managed. Growing concerns about food nutrients, increased interest in their safe packaging and freshness, and demand for certain foods, including immune-active products, require more attention throughout the supply chain. Coherent action is also needed where the market can play a valuable role and improve private equity financing. As FSCs provide a link between primary producers and final consumers through intermediaries, effective supply chain analysis and green practices in their management can address this significant economic loss of FSCs (Yu *et al.*, 2021; Khan *et al.*, 2021) ^[34,15].

3. Impact of COVID-19 on AFCs

A comprehensive analysis of the impact of COVID-19 on agri-food supply chains is presented in the following subsections, along with remedial strategies.

3.1 Production

The production of raw products is the first stage of FSC, and the largest employer of rural labour in the country is less directly affected, but its indirect effects are the worst. Although about 70% of agricultural workers are available locally, limited mobility and social distancing have increased labour shortages at the production stage, leading to crop failure (Larue, 2020) ^[17]. Grape farmers in the western city of Pune were forced to help student volunteers with the harvest. That is why a prominent group of farmers in India demanded a relief package of 1.5 lakh crores from the relevant government agencies. Rural areas appear to be at risk of COVID-19 disruptions due to inadequate surveillance systems for returning workers. In addition, this workforce penetrates rural non-farm employment (RN-FE), where about 39% of rural women participate and account for 61% of income in rural India (Chand *et al.*, 2017) ^[7].

Because RN-FE is directly, not indirectly, involved in the agri-food sector, it also affects AFSCs. Moreover, the Indian economy consists of approximately 80% of grain-free foods that are fed primarily with perishable FSCs. Reduced demand and export instability of perishable products like milk, fish, chicken, and vegetables occur due to changing food purchasing and eating habits of consumers with limited income. Moreover, farmers may find it difficult to cultivate and preserve high-quality seeds for the upcoming season if they are unable to receive agricultural inputs at the appropriate times during this crisis. Concern about the availability of protective equipment and protective gloves also hinders animal productivity. Various low-cost harvesting techniques must be distributed across the country, along with other agricultural machinery. Regular power supplies and information on the use of agricultural machines are also necessary to make farmers aware of such machines and technologies (Chand *et al.*, 2017) ^[7]. This will assist them in handling similar circumstances in the future.

3.2 Distribution and marketing

Distribution and marketing agents that match supply and demand, are experiencing many ups and downs in AFSCs, and several AFSC players are exiting the food trade due to pressure on logistics services. Food shortages, rising demand and pricing, and unemployment are the results of such disturbances in the MSMEs' (Micro, Small, and Medium sized Enterprises) processing chain (Farias and Gomes, 2020; Singh *et al.*, 2021). ^[10,29]. Normally, the supplier plans for an expected increase in customer demand for special occasions, but unfortunately, the rapid and unpredictable increase in demand among critical categories caused a short-term depletion of the entire planned food distribution network, time development, and delivery systems (Mussell *et al.*, 2020) ^[20]. On the other hand, on the supply side, the slowdown in food supply and trade is liquid. Coffee farmers cannot sell it in India's largest coffee-producing province, Karnataka, due to a supply chain blockage, and USD 52 million worth of processed coffee tons are piling up in warehouses. Therefore, small FSCs must find more efficient distribution options for farmers for quick food delivery (Todorovic *et al.*, 2018) ^[31]. However, there are some such innovations we are practicing *viz.*, the state of Kerala uses mobile vegetable vans to deliver fruits and vegetables but this is a crude, temporary fix for immediate issues.

3.3 Storage

Studies show that handling and storage are a significant part of postharvest losses, accounting for a third of food losses in FSCs worldwide (Food and Agriculture Organization, 2019; Yahia *et al.*, 2019) ^[12,33]. Movement restrictions made all handling and storage even more difficult, leading to the waste of perishable food. A huge loss of vegetables is now seen as harvested peppers and cucumbers are left to rot in Haryana. In addition, Asia's largest onion store in Maharashtra also found it difficult to process the harvested onions as there was no transport across the country. In Delhi's Anandpur Mandi, the country's largest agri-food market, tons of vegetables and fruits rot (Abhishek *et al.*, 2020) ^[1]. Losses in horticulture and floriculture due to cancellation of orders also lead to financial imbalance. In the case of perishable grains, even significant losses are observed in the absence of rotation and inappropriate

storage techniques. In addition, low-cost techniques such as evaporative coolers, in-system boxes, and airtight bags must be adopted for proper storage and proper observance of first-in, first-out rules (FIFO) rules. There should be a focus on solar cold storage across the country to avoid such problems in the future (World Health Organization, 2020; Belhadi *et al.*, 2020) [32,28].

3.4 Consumption

AFSCs in India's food market and consumption are huge, with urban dwellers consuming about 60% of India's food. All the food eaten in these places is bought because almost all the townspeople are net food buyers. However, about 80% of the remaining 40% of food is purchased (Reardon *et al.*, 2020) [21]. This proportion of food purchased in bulk in the total food supply is decreasing day by day due to the deterioration of incomes and eating habits. About 85% and 53% of the rural workforce do not have paid work, and 53% of the labour force and 46% of white-collar workers do not receive paid vacation. More than 70% of workers work without a legal contract. Overall, almost 90% of all Indian families will experience a significant drop in income in the coming months (Abhishek *et al.*, 2020) [1]. As a result, restaurants are closed, and food and nutritional insecurity are increasing day by day. In addition, a problem emerging in society today is the transfer of shopping and consumption habits from local markets to supermarkets. Short FSCs and local products can be a possible solution to these problems (Cappelli and Cini, 2020; Mayurnikova *et al.*, 2020) [6,16]. In addition, the demand for green agricultural products should be encouraged. This study aims to strengthen the relationship between urban residents and agricultural suppliers through the development of a green agricultural supply chain. However, it is noteworthy that in such pandemic situations, the poor get free rice, pulses, cooking gas, etc. for at least three months under the Pradhan Mantri Garib Kalyan Yojana (PMGKY, India). The Defence Food Research Laboratory (DFRL) is working nonstop during COVID-19 to supply wholesome meals, particularly to healthcare professionals in India. With the help of a food delivery software created by young programmers, the Karnataka government is successfully feeding one million hungry underprivileged people in Bengaluru (Food and Agriculture Organization, 2020) [18].

3.5 Processing and packaging

Food processing and packaging, which are important links in the two pillars of the country's economy (agriculture and industry), are experiencing both positive and negative effects due to COVID-19. The demand for durable foods such as instant noodles, flour, cooking oils, crackers, snacks, etc. rose because these products were hoarded to survive the crisis. Due to the limited number of processed foods, multinational companies like ITC, Britannia, Parle, Nestle, and PepsiCo provide livelihoods to approximately 1.3 billion people (Forsido *et al.*, 2020) [13]. However, in the future, due to a lack of raw materials, packaging resources, and mobilized labour, almost all food industries may stop. The barriers between the different stages of FSC must be removed, and this opportunity must be used to increase sustainable food production and circulation. It further balances food security, the economic crisis, and job opportunities. However, some other ancillary sectors of food processing, including medium-sized enterprises, remain at

risk and are more vulnerable to labour shortages. Disturbances in the availability of labour and the risk of viral infection also disrupted the entire milk processing and circulation network. The egg, fish, meat, and chicken processing sectors are suffering heavy losses due to the zoonotic nature of COVID-19. There has been an estimated loss of INR 22.5 million as a result of misinformation about the meat and poultry sectors. An official memorandum was released to support these farmers with an INR 100 per bird (Food and Agriculture Organization, 2020) [18].

3.6 Transportation

Since the majority of farming activities depend on the weather and season, they must be scheduled and must accelerate when necessary. Since all supply chain cycles involve activities including the procurement of agricultural products, storage, packaging, stock management, and distribution, delays in one area can have an impact on yield and output throughout the entire production process. One of the main problems with the food supply chain resulting from COVID-19 is transportation delays. To operate a truck, one needs multiple truck drivers; however, the number of drivers was limited due to pandemic. Furthermore, it can be difficult for trucks to service particular routes in an efficient manner. In order to protect truck drivers from COVID-19 while transporting goods, the governments of several nations have raised the maximum service hours for truck drivers (Tabak, 2020) [30]. Furthermore, food waste levels were higher as a result of transportation issues during lockdowns or overspending on perishables due to panic shopping (Fleetwood, 2020) [11]. Delivery choices, storage conditions, and packaging materials and designs will all alter in response to shifting demands (Reynold, 2020) [23]. There were additional problems with food loss and waste related to transportation difficulties for both air and sea goods.

Table 1: Transportation of bulk-packaged fruits and vegetables and the resultant post-harvest losses

Crops	Loss in sacks (%)	Loss in plastic crates (%)	Age of loss reduction (%)
Tomatoes	16.7	2.2	87
Bananas	5.4	2.1	61
Cauliflower	11.0	4.5	60
Mandarins	7.2	4.1	43
Snap beans	18.0	7.3	60

3.7 Food supply

The causes of food waste in the retail trade are related to the limited life span of perishable foods, the private quality standards of buyers, and fluctuations in demand, especially for fresh products. The actions and decisions of retailers regarding food quality and quantity are dictated by their suppliers. Storage conditions, packaging quality, and handling greatly affect food quality, shelf life, and acceptability. The food supply network connects an agricultural system to consumers who handle the capacity, bundling, transportation, and production processes (Chen *et al.*, 2020) [8]. The COVID-19 pandemic does not directly affect food production in the same way as other illnesses like listeria, E. coli, bird flu, and mouth soreness. Due to limitations, farmers were forced to destroy critical food items in the field. For instance, dairy farmers often dump several litters of milk into the clogged supply chain.

Damage was done to tea plants as a result of logistical issues. During a worldwide emergency, maintaining logistical coherence is crucial for the food business. Getting resources from suppliers and ensuring the flow of food from producers to purchasers is the biggest problem in the food supply chain (Alonso *et al.*, 2007) ^[2]. Pandemic concerns' impact on horticultural frameworks often varies according to the type and quantity of agricultural inputs used, as well as the commodity being delivered.

3.8 Consumer behaviour

Examining the question of how the COVID-19 pandemic influences consumers' food demand, it becomes clear that demand fluctuates based on a number of factors, including consumption, shopping habits, income level, sociodemographic status, and food prices. Furthermore, there was a shift in the frequency of grocery store trips and the amount of money spent there each time (Bakalis *et al.*, 2020; Cranfield, 2020) ^[3,9]. The COVID-19 pandemic disrupted everyday routines and led to boredom, which is characterized by a high calorie intake from high fat, carbohydrate, and protein consumption. Furthermore, the quarantine induced tension in individuals, leading them to seek solace in sugary foods, as foods high in carbohydrates can serve as a kind of self-medication by stimulating the release of serotonin. These poor eating habits may have a role in the development of obesity, which is connected to COVID-19-related chronic inflammation and major consequences (Muscogiuri *et al.*, 2020) ^[19].

There was an unexpected change in demand from food service to retail as a result of the closure of restaurants and limited-service eateries, which had an impact on consumers' eating and spending habits. Prior to the epidemic, reports indicated that the ratio between using food services and buying food from supermarkets was 50%; for supermarkets, it was about 100%. The frequency of trips to the grocery shop dropped, but the average amount spent on food increased. A few food categories were harder to get by for consumers during the COVID-19 blackout. Fascinatingly, baked goods and bread continued to be found on store shelves. Because of ease and frequent home cooking, consumers have concentrated on long-lasting products, such as pasta, dried or canned goods, milk or milk alternatives, and frozen foods. Home baking and the tendency to believe rumors or receive misleading information led to people stockpiling these foods in their kitchens. The closing of restaurants and social distance made consumers prefer takeout and home delivery choices (Shahidi, 2020) ^[27].

Given the crucial role that consumers play in the food supply chain, shifts in consumer behaviour have a significant impact on it. Food prices increased significantly as a result of the COVID-19 epidemic due to supply chain interruptions, lockdown limitations, and panic buying. In order to improve food security, some consumers may focus more on reducing food waste (Shafiee-Jood and Cai, 2016) ^[26]. The reverse is also conceivable, too, as a large number of perishable items were thrown out or disposed of as a result of restaurants, processing facilities, and schools closing.

4. Conclusion

The COVID-19 pandemic has brought to the forefront the vulnerabilities and complexities of agri-food supply chains (AFSCs), highlighting the need for a paradigm shift towards

more resilient, sustainable, and adaptive systems. This review paper has provided a comprehensive analysis of the impact of COVID-19 on AFSCs, identifying critical loss points, remedial strategies, and opportunities for innovation and growth. The findings suggest that the pandemic has accelerated the need for digital transformation, circular economy principles, and sustainable agriculture practices in AFSCs. To build more resilient AFSCs, it is essential to adopt a holistic approach that integrates technological innovations, policy reforms, and stakeholder collaboration. This includes leveraging digital technologies such as blockchain, IoT, and AI to enhance supply chain visibility, traceability, and transparency; promoting circular economy principles to reduce food waste and environmental degradation; and adopting sustainable agriculture practices to ensure long-term food security and environmental sustainability. Furthermore, the pandemic has highlighted the need for more agile and adaptive AFSCs that can respond quickly to disruptions and changes in demand. This requires a shift towards more decentralized, localized, and diversified food systems that can reduce reliance on global supply chains and promote food sovereignty. Ultimately, the COVID-19 pandemic presents an opportunity for AFSCs to transform and evolve, embracing new technologies, business models, and practices that prioritize sustainability, resilience, and social equity. By working together, stakeholders across the food system can build a more robust, responsive, and sustainable food future that benefits all.

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