

# Food Production Impacted by COVID-19 Pandemic

Journal of Nutrition Food Science and Technology

Review Article

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Submitted : 6 Feb 2021 ; Published : 13 Apr 2021

## Abstract

The consumers' food demand varies depending on income level of consumers, consumption, the price of foodstuffs, sociodemographic situation, time constraints, and shopping preferences, in addition to spending money on food in per visit changed and number of visits to food store. Interruption of the daily-routine life by COVID-19 pandemic resulted in boredom with high consumption of carbohydrate, fat, and protein, in addition to quarantine-caused stress that pushed the people to sugary food consumption for feeling positive. Due to ability of carbohydrate-rich foods to encourage serotonin production, they can be used as self-medicating components. These unhealthy eating habits may lead to obesity-associated-COVID-19 serious complications and chronic inflammation. An unusual demand shift from food service to retail due to the closure of restaurants and limited service eating places that affected the eating or purchasing habits. Using food service and purchasing food from supermarkets had the same ratio as 50% before the COVID-19 outbreak, nevertheless, it is almost 100% for supermarkets. During the COVID-19 lockdown, consumers experienced decreased availability of certain types of foods. The spending money on food was raised per visit, whereas the number of visits to food store was decreased.

In conclusion, movement restrictions both national and international contributed to challenges, including consumers' changes in demand. These restrictions caused consumers prepared cooking at their home, in addition to preventing them from getting COVID-19 infection at the stores, restaurants, markets, and supermarket.

**Keywords:** COVID-19; SARS-CoV-2; Impact; Food Production; Food Supply Chain

## Food Supply Chain Impacted by COVID-19 Pandemic

Five stages of food supply chain include agricultural production, postharvest handling, processing, distribution/retail/service, and consumption [1]. The two used-food-supply-chain systems include system-based on regulations and laws that use mandatory standards which are under the state agency inspection and voluntary standards which are under the market laws or international associations [2]. The World Health Organization (WHO) the strategic preparedness and response plan that includes the health measures with eight priority steps and actions :

1. Coordination, planning, and monitoring at the country level,
2. Risk communication and community participation,
3. Surveillance, rapid response teams, and case investigation,
4. Entry points,
5. National laboratories,
6. Prevention and control of infection,
7. Situation management, and
8. Operational support and logistics [3].

Currently, online meeting and flexible work from home have become standard practices [4-5]. The United States Centers for Disease Control and Prevention (US CDC) developed response

plans to provide guidance for continuity of operations in the food processing facilities and manage COVID-19 in the food industry, particularly, meat and poultry processing industries [6]. COVID-19 pandemic might contribute to a US \$80 billion loss in tourism sector and US \$113 billion loss in aviation [7, 8].

The European Food Safety Authority stated that there is no evidence of association between risk of COVID-19 and food consumption [9], whereas the Norwegian officials stated that there is no association between the transmission of SARS-CoV-2 (COVID-19) via imported food and the origin of the salmon outbreak is still unclear [10, 11]. Nevertheless, some eating and cooking habits may contribute to the emergence of the coronavirus from animals to humans [9]. During the COVID-19 pandemic era, four major issues involving the food supply chain and the food industry have been raised, 1) People tend to have follow a healthy diet for protecting their immune system [12], therefore , the demand in bioactive-ingredient-containing functional food is increased, 2) Producers, retailers, and consumers has payed more attention on food safety, 3) Due to people on lockdown restrictions, food security concerns have been arisen, and 4) During the COVID-19 pandemic

era, the food sustainability problems have emerged [13]. In Germany and France, some of the markets limited the number of items, such as pork and beef products that a customer can buy and some restaurants stopped serving beef hamburgers. Close-down of the food plants contributed to the ripple effect in the food supply chain [14-17].

Governments are facing financial pressures because of the economic shrinkage and reallocating their resources focusing on financial incentives and social assistance programs [18, 19]. Seasonal or temporary employment, particularly for planting, sorting, harvesting, processing, or transporting crops to markets is common in the developing and developed countries that significantly affects the food supply chain as a result of the shortage of local or migrant workers because of travel restrictions imposed by city lockdown or sickness [20]. The objective of "Pick for Britain" campaign in Britain was to identify 70,000 British to work during the harvest and in the field, whereas a call has been performed to the unemployed individuals to work in fields in France [21]. In India, tea plants were being lost due to logistical challenges, whereas the British chair of dairy farmers demonstrated that around 5 million liters of milk are at risk in one week [22].

#### **Impact of COVID-19 Pandemic on Consumer Behavior**

The consumers' food demand varies depending on income level of consumers, consumption, the price of foodstuffs, sociodemographic situation, time constraints, and shopping preferences, in addition to spending money on food in per visit changed and number of visits to food store [23, 24]. Interruption of the daily-routine life by COVID-19 pandemic resulted in boredom with high consumption of carbohydrate, fat, and protein, in addition to quarantine-caused stress that pushed the people to sugary food consumption for feeling positive [25]. Due to ability of carbohydrate-rich foods to encourage serotonin production, they can be used as self-medicating components [25]. These unhealthy eating habits may lead to obesity-associated-COVID-19 serious complications and chronic inflammation [25]. An unusual demand shift from food service to retail due to the closure of restaurants and limited service eating places that affected the eating or purchasing habits [23, 26]. Using food service and purchasing food from supermarkets had the same ratio as 50 % before the COVID-19 outbreak, nevertheless, it is almost 100% for supermarkets [23, 26]. During the COVID-19 lockdown, consumers experienced decreased availability of certain types of foods [23, 26]. The spending money on food was raised per visit, whereas the number of visits to food store was decreased [23, 26]. Flour, a staple product was not found on food store shelves because of the more interest in home-baking, as a family activity in European countries [23, 26]. Individuals have focused on the products with long shelf life, such as canned or dried foods, milk, milk substitutes, pasta, and frozen foods because of convenience and daily cooking at home [23, 26]. Interestingly, the shortage of eggs was not only due to lack of packing for retail but also increased demand [27, 28].

In the United States, sales for eggs rose by 44% compared

to last year (2019), whereas household egg consumption increased 40% since march 20, 2020 in Argentina [4, 27, 28]. During COVID-19 pandemic, the flexibility associated with the packing and labelling of eggs because of the insufficient availability of suitably labelled retail packages to facilitate the egg distribution and fulfill the demand was provided by the United States Food and Drug Administration (US FDA) [4, 27, 28]. In the European countries, the demand for frozen vegetables increased by 52% and fresh bread by 76% in the week when the COVID-19 pandemic was announced, whereas the demand for alcoholic beverages increased twice, one month after pandemic announcement [29]. A study on 18 countries revealed that food buying behavior has changed due to willingness of healthy food consumption without exceeding normal budget. Most customers adopted a basic approach of returning to ingredient-containing beverage products, such as olive oil, whole grains, legumes, fruit, and vegetables and natural food. They are also looking for food products that improve their COVID-19-related mood [25, 30].

The behavior of the Italian population on food choices and behavior was assessed under COVID-19 quarantine in a recent poll performed by the Italy's the Council of Agricultural Research and Economics (CREA) among approximately responded 2,900 individuals from all regions of Italy demonstrated that healthy food and beverage consumption increased for 33% of vegetables, 29% of fruit, 26.5% of legumes, and 21.5% of extra-virgin olive oil. Nevertheless, 44.5% and 16% of them consumed more sweet food and drank more wine, respectively, whereas 44% and 37% of them reported body weight gain because of low-level physical activity and intake of higher calories and needed weight loss by adjusting their diet, respectively [31].

During COVID-19 pandemic in the United States, a survey of 630 consumers in May 2020 revealed that 70% of consumers decreased the frequency of food shopping and preferred online shopping, 56% of them were worried about not finding particular foods they would like to buy in the store or forgetting to buy something, 70% of them consumed more food while staying at home, 43% of them consumed more fruits, 42% of them consumed more vegetables, 30% of them consumed more protein-containing foods (fish, chicken, or meat), 39% of them made their breakfast more balanced, 47% of them consumed more sweet foods, 24% of them consumed less vegetables, 21% of them consumed less fruits, and 19% of them consumed less protein-containing foods [32].

A survey on 1,005 over-18-year-old-male and -female French people demonstrated that during the 8-week quarantine, they changed their views on the ecological, economic, and social value of food production [33]. They would only buy "essential" foods, spend more time cooking, and pay more attention to food spending when they return to "normal" after COVID-19 pandemic measures have been relieved [33]. Approximately, one-third of them wasted less food, 29% of them bought more local food, and 20% of them went online shopping [33]. Another survey in France conducted on April 6th and 7th,

2020 among 1,000 above-18-year-old adults revealed that 82% of them believed in safety of foods they bought, 7% of them believed in unsafety of foods they bought, 42% of them preferred the packaged foods more than normal, 42% of them stated that the COVID-19 pandemic did not change their attitudes towards packaged foods, 77% of them believed in enough food production to meet the consumers' needs, and 16% of them did not believe in enough food production [34].

### Impact of COVID-19 Pandemic on Global Food Trade

Before COVID-19 crisis, the vulnerability of food systems to problems associated with diseases and climate has been confronted long, including the SARS and Ebola outbreaks, the oil crisis in the 1970s, and the food crisis in 2006-2008 [35]. Due to current COVID-19 crisis, some governments changed the food trade policies by moving towards facilitating imports and restricting exports for ensuring the maintenance of the number of products in the domestic markets. The export restriction has some negative effects as the following: 1) Countries will lose their competitive advantage by losing their place in international markets, 2) Dropping domestic prices that will decrease crop production and incentives in the industry, and 3) Undermining exporters' reputation and decreasing importers' confidence in the international markets that contribute to destroying future business opportunities and trust for exporters [36, 37]. Due to COVID-19 pandemic, a total of 19 countries have taken to export restrictions for 27 food products. Currently, a total of 8 countries are going on their measures on 11 food products. For considering the assessment of the effects of the import restrictions in term of kilocalorie unit, Tajikistan, Uzbekistan, Afghanistan, and Azerbaijan were negatively affected by 79%, 70%, 61%, and 54%, respectively [38]. The world prices of staple food commodities, such as rice, wheat, and maize were pushed up by export-restricted policies and contributed to decreasing the quantity and quality of food products [39]. Due to export restrictive policies and negative effects of the capacity utilization of food-manufacturing plants to respond demand, foods that are not locally grown but needed for processing were not available, including inability of local sellers to find buyers that resulted in excess supply and waste accompanying economic losses and transportation challenges for air and sea cargo [40-43].

### Minimizing The Impact of COVID-19 Pandemic

COVID-19 disruptions may contribute to hunger, malnutrition, and increasing number of individuals facing extreme hunger to 265 million in 2020 [44, 45]. Among children who are younger than 5 years old, COVID-19 pandemic contributed to 14.3% increase in prevalence of malnutrition wasting or health and social-protection interruption in low- and middle-income countries [46].

### Food Supply Chain Strategies

At the household level, COVID-19 pandemic resulted in 12% of increase in food waste [47]. Approximately, one-third of all food productions was wasted across the food supply chain stages (production, postharvest handling, processing, distribution, and consumption). Some bioactive compounds

can be gained from food wastes to re-utilize them in food chain, such as carotenoids, essential oils, flavonoids, glucosinolates, isothiocyanates, phenols, and whey protein by conventional or innovative techniques (extraction, fractionation, and isolation stages) [13, 48, 49]. Robot systems assist individuals to serve the foods to consumers in food-serving industry, in addition to monitoring the unsafe or low-quality food products in food supply chain by the Cyber Physical System (CPS) [50, 51]. Approximately, 25% increase of productivity by automation to complete the work more efficiently than humans, indicating an important role by making data-driven autonomous decision in production in the fourth industrial revolution [50, 51]. The COVID-19 pandemic resulted in challenges that include adopting new workplace policies, actions to decrease human contact, and change of working conditions [52].

To respond to these challenges, organizations should establish some measures as the following:

1. Monitoring COVID-19 symptoms of the workers, suppliers, contractors, and visitors before entering the facilities, monitoring all staff to wear face protection equipment and gloves, and performing body temperature screening of all staff at the entrance of the facilities;
2. Should consider employees' work rotation, working hour reduction, dividing number of workers in each work shift into 3 or 4 groups, and adjusting their break time to avoid overcrowding; and
3. Should redesign warehouses and processing to allow social (physical) distancing, build barriers or dividers that cover the upper part of the body of the workers to maintain social distance, and use diagonal arrangement in case of using two side engagement in food processing [53].

All countries should maintain the balance between workers' safety and food product quantity [54]. Decentralization of the food manufacture provides reduction of the transportation and storage costs, minimizing the environmental impacts, shortening the food supply chain, reduction of the emission and energy consumption during storage and transportation, flexibility in food supply chain, and simplifying the administrative procedures [55-57]. During COVID-19 pandemic, changes in food demands should be determined by using simulations, statistical models and forecasts, particularly, the daily-life products, such as food items and sanitizers to propose optimal decision for demand disruptions and tackling supply by the manufacturers [58]. Storage centers should be invested by the government or private centers. Web-based-food-distribution system should be established to strengthen the relationship between buyer and seller [20, 54, 59-60]. Digital commerce services, an important role in interaction and trading activities among the actors of the food supply chain allow small farmers to reach more consumers in a direct effective way and collaboration between the largest e-commerce companies and government to encourage rural markets to be part of e-commerce economy and offer mostly organic fertilizers at a reasonable cost [61], in addition to "Supply Chain Management (SCM) Data Science" [62].

Agricultural production collection centers with high capacity



storage at the location comfortably reached by small-scale farmers should be built by countries [63]. Maintaining the activities of small- and medium-size agricultural enterprises requiring additional capital injection by using the capital injections from donor or government through improved technologies or modern facilities that entail higher production costs [64]. Contractual agricultural arrangement can be made by the horizontal and vertical coordination mechanisms between food banks and farmer associations as the following : 1) Assist farmers to create new markets [65], 2) Countries can deploy warehouse receipt systems that allow small-scale food producers to easily access to financial loans and receive the best price for their agricultural products [66], 3) Countries should develop e-commerce for small shareholders to commercialize agricultural products to wider scale of consumers [67], and 4) Small-scale agricultural producers should have easy access to credit for involving the financial problems [63]. Additionally, confidence in financial organizations can be promoted by the temporary liquidity guarantee program (TIGP) that allows a limited term guarantee for newly issued debt of financial companies and affiliates and non-interest bearing transaction accounts [54, 68-70].

### Recommendations for Government

To focus on the impact of COVID-19 pandemic on agricultural products and food supply cuts by observation of the progress and recommended actions without waiting too long for the implementation of certain interventional strategies, a COVID-19 crisis committee should be appointed during food value chain in collaboration with the private sectors [20]. An Agriculture Response Program was designed by the government of Canada for 50-70% funding assistance without paying back regarding health protocol, strategic projects, product distribution, product movement, marketing, development, and abattoir efficiency [71]. The government of Canada also implemented a US \$50 million financial aid program for small farmers who hired temporary foreign employees through the COVID-19 outbreak by allowing employers to get US \$ 1,500 per foreign worker with 14-day-self-isolation upon entry into Canada [72]. Additionally, The government of Canada and Belgium allowed postponing the recruitment or offer long-term contracts for employers [73]. The Logistic Sub-Group of the United Kingdom developed crisis management, shore base logistics and freight management, accommodation and transportation, and safe passage programs to provide safe passage (health issue) and assurance to health personnel and their families, including guidelines and raising awareness to logistic sector [74]. The “green lanes” for vehicles carrying agri-food products for ensuring the fast and free movement on the borders was implemented by the Commission of the European Union (EU), in addition to highlighting the free movement of seasonal workers and agri-foods for easy reaching their workplaces. Common Agricultural Policy (CAP) payments and temporary framework for state aid measures were also introduced by the Commission of the EU to extend the farmers’ application deadline to get income support and supported farmers and agri-food business for ensuring liquidity [75]. To facilitate connections between the

local residents and agriculture sectors, online platforms should be implemented [68]. The best way to solve the labor shortage over the medium to longer term during COVID-19 pandemic is “labor-replacing mechanization policy” [76]. Additionally, the employed agricultural-production individuals were importantly considered as “critical infrastructure workers” by the United States government [77, 78]. To take the recommendations and measures in food and agriculture during the COVID-19 pandemic, the COVID-19 Commission that consisted of two members of from the Ministry of Agriculture and Forestry and seven academicians in Turkey was established [79].

### Discussion

Review of personnel occupational health and safety practices, human resource planning in the face of absenteeism or increasing demand, travel limitations, business continuity planning, progressive investment and resource plans of the next 3 years, alternative input source channels, establishing COVID-19 positive-reporting system, and promoting understanding COVID-19 transmission are important to change the business models of the agricultural firms [80, 81]. More organized by using the COVID-19 crisis as a driving force are needed by the small companies [82]. COVID-19 pandemic, panic buying, food- supply-chain disruptions, and city-lockdown restrictions caused a significant risen-food price [83], whereas some consumers will pay more attention to decrease food waste for improving food security [84].

### Conclusion

Movement restrictions both national and international contributed to challenges, including consumers’ changes in demand. These restrictions caused consumers prepared cooking at their home, in addition to preventing them from getting COVID-19 infection at the stores, restaurants, markets, and supermarkets.

### Abbreviations

CAP	: Common Agricultural Policy
CPS	: Cyber Physical System
CREA	: The Council for Agricultural Research and Economics of Italy
EU	: European Union
SCM	: Supply Chain Management
US CDC	: United States Centers for Disease Control and Prevention
US FDA	: United States Food and Drug Administration
WHO	: World Health Organization

### References

1. Aday S and Aday MS (2020). Impact of COVID-19 on the food supply chain. *Food Quality and Safety* 2020, 4(4), 167-180. doi: 10.1093/fqsafe/fyaa024
2. Bendekovic J, Naletina D, Nola I (2015). Food safety and food quality in the supply chain. *Trade Perspectives*, 151-163.
3. World Health Organization. 2019 Novel Coronavirus (2019-nCoV): Strategic preparedness and response

- plan (online). Available at: [https://www.who.int/docs/default-source/coronaviruses/srp-04022020.pdf?sfvrsn=7ff55ec0\\_4&download=true](https://www.who.int/docs/default-source/coronaviruses/srp-04022020.pdf?sfvrsn=7ff55ec0_4&download=true) (accessed on January 5, 2021).
4. Food and Agriculture Organization of the United Nations, World Health Organization. 2020. COVID-19 and Food Safety: Guidance for food businesses : Interim guidance (online). Available at: <https://www.fao.org/3/ca8660en//CA8660EN.pdf> (accessed on January 5, 2021).
  5. Nicola M, Alsafi Z, Sohrabi C, et al (2020). The socio-economic implications of the coronavirus pandemic (COVID-19: A review. *Interventional Journal of Surgery*, 78, 185-193.
  6. United States Centers for Disease Control and Prevention. COVID-19 critical infrastructure sector response planning (Online). Available at: <https://www.cdc.gov/coronavirus/2019-ncov/community/organizations/meat-poultry-processing-workers-employers.html> (accessed on January 5, 2021).
  7. International Air Transport Association (IATA). IATA Updates COVID-19 financial impacts-relief measures needed (online). Available at: <https://www.iata.org/en/pressroom/pr/2020-03-05-01/> (accessed on January 5, 2021).
  8. World Tourism Organization. International Tourism Numbers could fall 60-80 % in 2020 (online). Available at: <https://www.unwto.org/news/covid-19-international-tourist-numbers-could-fall-60-80-in-2020> (accessed on January 5, 2021).
  9. Rizou M, Galanakis IM, Aldawoud TMS, et al (2020). Safety of foods, food supply chain and environment within the COVID-19 pandemic. *Trends in Food Science and Technology*, 102, 293-299.
  10. Arellano N. Norway denies seafood link to new COVID-19 infections in China. *Rastech Magazine* (online). Available at: <https://www.rastechmagazine.com/Norway-denies-seafood-link-to-new-covid-19-infections-in-china/> (accessed on January 5, 2021).
  11. Dalton J. Coronavirus: Fears of second wave in China as dozens test positive in the outbreak at Beijing food market. *Independent* (online). Available at: <https://www.independent.co.uk/news/world/asia/coronavirus-beijing-china-outbreak-xinfandi-food-meat-market-a9564816.html> (accessed on January 5, 2021).
  12. Rodríguez-Pérez C, Molina-Momtes E, Verardo V, et al (2020). Changes in dietary behaviors during the COVID-19 outbreak confinement in the Spanish COVIDiet Study. *Nutrients*, 12(6), 1730.
  13. Galanakis CM (2012). Recovery of high added-value components from food wastes: Conventional, emerging technologies and commercialized applications. *Trends in Food Science and Technology*, 26(2), 68-87.
  14. Levany S. US producers “in tears” at having to cull livestock on their farms. *The Guardian* (online). Available at: <https://www.theguardian.com/environment/2020/jun/10/us-producers-in-tears-at-having-to-cull-livestock-on-their-farms> (accessed on January 5, 2021).
  15. Murphy C. Costco to temporarily limit meat purchases to 3 items person. *USA Today* (online). Available at: <https://www.usatoday.com/story/money/2020/05/04/costco-limits-meat-purchases-3-items-per-person/3078198001/> (accessed on January 5, 2021).
  16. Rude J (2020). COVID-19 and the Canadian cattle/beef sector: Some preliminary analysis. *Canadian Journal of Agricultural Economic/Revue Canadienne d'agroeconomie*, 68(2), 207-213.
  17. Valinsky J. One in five Wendy's is out of beef, analyst says. *Cable News Network* (online). Available at: <https://edition.cnn.com/2020/05/05/business/wendys-beef-shortage/index.html> (accessed on January 5, 2021).
  18. Food and Agricultural Organization of the United Nations. Extension and advisory services: At the frontline of the response to COVID-19 to ensure food security (online). Available at: <http://www.fao.org/3/ca8710en/CA8710EN.pdf> (accessed on January 5, 2021).
  19. Food and Agricultural Organization of the United Nations. Interim guidance: Sustaining FAO's commitment to Environmental and Social Standards during the COVID-19 pandemic (online). Available at: <http://www.fao.org/3/ca9290en/CA9290EN.pdf> (accessed on January 5, 2021).
  20. Food and Agricultural Organization of the United Nations. Responding to the impact of the COVID-19 outbreak on food value chains through efficient logistics (online). Available at: <http://www.fao.org/3/ca8466en/CA8466EN.pdf> (accessed on January 5, 2021).
  21. Nature Plants. Food in a time of COVID-19. *Nat Plants* 2020; 6: 429.
  22. British Broadcasting Corporation. Coronavirus: Five ways of the outbreak is hitting global food industry (online). Available at: <https://www.bbc.com/news/world-52267943> (accessed on January 5, 2021).
  23. Bakalis S, Valdramidis VP, Argyropoulos D, et al (2020). Perspectives from CO+RE: How COVID-19 changed our food systems and food security paradigms. *Current Research in Food Science*, 3, 166-172.
  24. Cranfield JAL (2020). Framing consumer food demand responses in a viral pandemic. *Canadian Journal of Agricultural Economics*, 68, 151-156.
  25. Muscogiuri G, Barrea I, Savastano S, et al (2020). Nutritional recommendations for COVID-19 quarantine. *European Journal of Clinical Nutrition*, 74(6), 850-851.
  26. Shahidi F (2020). Does COVID-19 affect food safety and security?: A summary report on the Extraordinary Scientific Roundtable of IUFOST-CIFST on March 21, 2020. *Journal of Food Bioactives*, 9, 1-3. doi: <https://doi.org/10.31665/JFB.2020.9212>
  27. Mazili SR. How producers keep the egg supply chain going amid COVID-19; 2020 (online). Available at: <https://ew-nutrition.com/how-producers-keep-the-egg-supply-chain-going-amid-covid-19/> (accessed on January 5, 2021).
  28. Reiley L. Stress-baking and hoarding have led to a retail egg shortage. There are eggs in the pipeline, but may be not enough. *The Washington Post* (online). Available at: <https://www.washingtonpost.com/business/2020/03/26/shortage-eggs-stress-baking/> (accessed on January 5, 2021).

29. Crisp. Get a LIVE view into COVID-19 effects on in-store purchases; 2020 (online). Available at: <https://www.gocrisp.com/demandwatch> (accessed on January 5, 2021).
30. Hughes M. Evolving eating habits as a result of COVID-19; 2020 (online). Available at: <https://www.newfoodmagazine.com/article/109890/evolving-eating-habits-as-a-result-of-covid-19/> (accessed on January 5, 2021).
31. The Council for Agricultural Research and Economics. How did Italian eating habits change during lockdown? 2020 (online). Available at: <https://www.foodnavigator.com/Article/2020/06/05/Coronavirus-lockdown-found-toworsen-childhood-obesity> (accessed on January 5, 2021).
32. DeBroff S. How COVID-19 has impacted consumers food habits. 2020 (online). Available at: <https://www.foodmanufacturing.com/consumer-trends/blog/21133823/how-covid19-has-impacted-consumer-food-habits>. (accessed on January 5, 2021).
33. Askew K. Life in lockdown: Coronavirus prompts half of French consumers to reappraise “value” of food. 2020 (online). Available at: <https://www.foodnavigator.com/Article/2020/05/29/Life-in-lockdown-Coronavirus-prompts-half-of-French-consumers-to-reappraise-value-of-food> (accessed on January 5, 2021).
34. International Food Information Council. COVID-19 impact on food purchasing, eating behaviors, and perceptions of food safety. 2020 (online). Available at: <https://foodsight.org/consumer-survey-covid-19s-impact-on-food-purchasing/> (accessed on January 5, 2021).
35. Agrilinks. Preventing global food security crisis under COVID-19. 2020 (online). Available at: <https://www.agrilinks.org/post/preventing-global--food-security-crisis-under-covid-19-emergency> (accessed on January 5, 2021).
36. Espitia A, Rocha N, Ruta M. COVID-19 and food protectionism: The impact of the pandemic and export restrictions on world food markets. *Policy Research Working Paper*, No. 9253, World Bank. pp. 1-30.
37. Food and Agriculture Organization of the United Nations. Why export restrictions should not be a response to COVID-19: Learning lessons from experience with rice in Asia and the Pacific. 2020 (online). Available at: <http://www.fao.org/3/ca9362en/CA9362EN.pdf> (accessed on January 5, 2021).
38. International Food Policy Research Institute. COVID-19 food trade policy tracker. 2020 (online). Available at: <https://www.ifpri.org/project/covid-19-food-trade-policy-tracker> (accessed on January 5, 2021).
39. Fyles H, Madramootoo C (2016). Key drivers of food insecurity. In : *Emerging Technologies for Promoting Food Security*. Woodhead Publishing, 1-19.
40. Arianina K, Morris P. COVID-19 restrictions threaten global food supply. 2020 (online). Available at: <https://www.squirepattonboggs.com/-/media/files/insights/publications/2020/05/covid-19-export-restrictions-threaten-global-food-supply/w360covid19exportrestrictionsthreatenglobalfoodsupply.pdf> (accessed on January 5, 2021).
41. Ndemezo E, Ndikubwimana JB, Dukunde A (2018). Determinants of capacity utilization of food and beverage manufacturing firms in Rwanda: Do tax incentives matter?, 1-21. Available at SSRN: <https://ssrn.com/abstract=3217757>
42. Reddy VR, Singh SK, Anbumozhi V. Food supply chain disruption due to natural disasters: Entities, risks, and strategies for resilience. *Economic Research Institute for ASEAN and East Asia*, 1-36.
43. The Organization for Economic Co-operation and Development. COVID-19 and international trade : issues and actions. 2020 (online). Available at: <http://www.oecd.org/coronavirus/policy-responses/covid-19-and-international-trade-issues-and-actions-494da2fa/> (accessed on January 5, 2021).
44. Food and Agriculture Organization of the United Nations. Impacts of coronavirus on food security and nutrition in Asia and the Pacific: Building more resilient food system. 2020 (online). Available at: <http://www.fao.org/3/ca9473en/CA9473EN.pdf> (accessed on January 5, 2021).
45. World Food Program. COVID-19 will double number of people facing food crises unless swift action is taken. 2020 (online). Available at: <https://www.wfp.org/news/covid-19-will-double-number-people-facing-food-crises-unless-swift-action-taken> (accessed on January 5, 2021).
46. Headey D, Heidkamp R, Osendarp S, et al (2020). Impacts of COVID-19 on childhood malnutrition and nutrition-related mortality. *The Lancet*, 396(10250), 519-521.
47. Aldaco R, Hoehn D, Laso J, et al (2020). Food waste management during the COVID-19 outbreak : a holistic climate, economic and nutritional approach. *The Science of the Total Environment*, 742, 140524.
48. Deng Q, Zinoviadou KG, Galanakis CM, et al (2015). The effects of conventional and non-conventional processing on glucosinolates and its derived forms, isothiocyanates : Extraction, degradation, and applications. *Food Engineering Reviews*, 7, 357-381.
49. Galanakis CM (2013). Emerging technologies for the production of nutraceuticals from agricultural by-products : a viewpoint of opportunities and challenges. *Food and Bioproducts Processing*, 91(4), 575-579.
50. Iqbal J, Khan ZH, Khalid A (2017). Prospects of robotics in food industry. *Food Science and Technology*, 37(2), 159-165.
51. Bowler AL, Bakalis S, Watson NJ (2020). A review of in-line and on-line measurement techniques to monitor industrial mixing processes. *Chemical Engineering Research and Design*, 153, 463-495.
52. Carnevale JB, Hatak I (2020). Employee adjustment and well-being in the era of COVID-19: Implications for human resource management. *Journal of Business Research and Design*, 116, 183-187.
53. Shahbaz M, Bilal M, Akhlaq M, et al. (2020). Strategic measures for food processing and manufacturing facilities to combat coronavirus pandemic (COVID-19). *Journal of Pure and Applied Microbiology*, 14(2), 1087-1094.
54. Food and Agriculture Organization of the United Nations.



- Policy responses to keep input markets flowing in times of COVID-19. 2020 (online). Available at: <http://www.fao.org/3/ca8979en/CA8979EN.pdf> (accessed on January 5, 2021).
55. Almena A, Fryer PJ, Bakalis S, et al. (2019). Centralized and distributed food manufacture : a modeling platform for technological, environmental and economic assessment at different production scales. *Sustainable Production and Consumption*, 19, 181-193.
  56. Almena A, Lopez-Quiroga E, Pryer PJ, et al. (2019). Towards the decentralization of food manufacture: Effect of scale production on economics, carbon footprint and energy demand. *Energy Procedia* 2019, 161, 182-189.
  57. Food and Agriculture Organization of the United Nations. Decentralized development in agriculture. 2005 (online). Available at: [http://www.fao.org/docs/up/easypol/342/decen\\_dev\\_in\\_agri\\_012en.pdf](http://www.fao.org/docs/up/easypol/342/decen_dev_in_agri_012en.pdf) (accessed on January 5, 2021).
  58. Paul SK, Chowdhury P (2020). A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19. *International Journal of Physical Distribution and Logistics Management*. doi: 10.1108/ijpdlm-04-2020-0127
  59. Morganti E, Gonzalez-Feliu J (2015). City logistics for perishable products : the case of the Parma's Food Hub. *Case Studies on Transport Policy*, 3(2), 120-128.
  60. Ngai EWT, Chen TCF, Ho SSM (2004). Critical success factors of web-based supply-chain management systems: An exploratory study. *Production Planning and Control*, 15(6), 622-630.
  61. Zeng Y, Jia F, Wan L, et al. (2017). E-commerce in agri-food sector: A systematic literature review. *International Food and Agribusiness Management Review*, 20(4), 439-460.
  62. Waller MA, Fawcett SE (2013). Data science, predictive analytics, and big data: A revolution that will transform supply chain design and management. *Journal of Business Logistics*, 34(2), 77-84.
  63. Food and Agriculture Organization of the United Nations. COVID-19 and the risk to food supply chains: How to respond? 2020 (online). Available at: <http://www.fao.org/3/ca8388en/CA8388EN.pdf> (accessed on January 5, 2021).
  64. Tetteh AB, Sipiläinen TAI, Bäckman S, Kola J (2015). Factors influencing smallholder farmers' access to agricultural microcredit in Northern Ghana. *African Journal of Agricultural Research*, 10(24), 2460-2469. doi: 10.5897/AJAR2015.9536
  65. Jackson A, Yurkevich V. Farmers are throwing out food that could go to food banks. American Farm Bureau and Feeding America want to change that, CNN. 2020 (online). Available at: <https://edition.cnn.com/2020/04/13/business/farmers-food-supply-food-banks-donations-trnd/index.html> (accessed on January 5, 2021).
  66. Miranda MJ, Mulangu FM, Kemeze FH (2019). Warehouse receipt financing for smallholders in developing countries: Challenges and limitations. *Agricultural Economics* 2019, 50(5), 629-641.
  67. Khanal AR, Mishra AK (2016). Financial performance of small farm business households : the role of internet. *China Agricultural Economic Review*, 8, 553-571.
  68. Food and Agriculture Organization of the United Nations. COVID-19 and smallholder producers' access to markets. 2020 (online). Available at: <http://www.fao.org/3/ca8657en/CA8657EN.pdf> (accessed on January 5, 2021).
  69. Dodson C (2014). Bank size, lending paradigms, and usage of Farm Service Agency's guaranteed loan programs. *Agricultural Finance Review*, 74(1), 133-152.
  70. Davison L (2019). The temporary liquidity guarantee program: A systemwide systemic risk exception. *Journal of Financial Crises*, 1(2), 1-39.
  71. Novascotia. COVID-19 : Agriculture Response Program. 2020 (online). Available at: <https://novascotia.ca/coronavirus/agriculture-response-program/> (accessed on January 5, 2021).
  72. Ker AP (2020). Risk management in Canada's agricultural sector in light of COVID-19. *Canadian Journal of Agricultural Economics*, 68(2), 251-258.
  73. The Organization for Economic Co-operation and Development. Managing international migration under COVID-19. 2020 (online). Available at: <http://www.oecd.org/coronavirus/policy-responses/managing-international-migration-under-covid-19-6e914d57/> (accessed on January 5, 2021).
  74. The United Kingdom Oil and Gas Industry Association Limited. COVID-19 Logistics Best Practice Guidelines. 2020 (online). Available at: <https://oilandgasuk.co.uk/wp-content/uploads/2020/05/OGUK-Guideline-COVID-19-Logistics-Best-Practice-May-2020.pdf> (accessed on January 5, 2021).
  75. Rossi R. Protecting the EU agri-food supply chain in the face of COVID-19. European Parliamentary Research Service. 2020 (online). Available at: [https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/649360/EPRS\\_BRI\(2020\)649360\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/649360/EPRS_BRI(2020)649360_EN.pdf) (accessed on January 5, 2021).
  76. Troskie DP. Impact of COVID-19 on agriculture and food in the Western Cape. Western Cape Department of Agriculture. 2020 (online). Available at: <https://www.hortgro.co.za/wp-content/uploads/docs/2020/03/agricultural-scenariosc.pdf> (accessed on January 5, 2021).
  77. Food and Agriculture Organization of the United Nations. 2020 (online). Food systems and COVID-19 in Latin America and the Caribbean: Impact and risks in the labor market. Available at: <http://www.fao.org/3/ca9237en/CA9237EN.pdf> (accessed on January 5, 2021).
  78. United States Centers for Disease Control and Prevention. Agriculture workers and employers. 2020 (online). Available at: <https://www.cdc.gov/coronavirus/2019-ncov/community/guidance-agricultural-workers.html> (accessed on January 5, 2021).
  79. Ministry of Agriculture and Forestry of Turkey. COVID-19 precautions. 2020 (online). Available at: <https://www.tarimorman.gov.tr> (accessed on January 5, 2021).
  80. Clift K, Court A. How are companies responding to the coronavirus crisis ? World Economic Forum. 2020 (online). Available at: <https://www.weforum.org/>

- agenda/2020/03/how-are-companies-responding-to-the-coronavirus-crisis-d15bed6137/ (accessed on January 5, 2021).
81. International Chamber of Commerce (ICC), World Health Organization (WHO). ICC-WHO Joint Statement : an unprecedented private sector call to action to tackle COVID-19. 2020 (online). Available at: <https://www.who.int/news-room/detail/16-03-2020-icc-who-joint-statement-an-unprecedented-private-sector-call-to-action-to-tackle-covid-19> (accessed on January 5, 2021).
  82. Food and Agriculture Organization of the United Nations. Adjusting business models to sustain agri-food enterprises during COVID-19. 2020 (online). Available at: <http://www.fao.org/3/ca8996en/CA8996EN.pdf> (accessed on January 5, 2021).
  83. European Data Portal. Shedding light on changing consumer behaviour with economic data. 2020 (online). Available at: <https://www.europeandataportal.eu/en/covid-19/stories/shedding-light-changing-consumer-behaviour-economic-data>. (accessed on January 5, 2021).
  84. Shafiee-Jood M, Cai X (2016). Reducing food loss and waste to enhance food security and environmental sustainability. *Environmental Science and Technology*, 50(16), 8432-8443.

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