

## Review

# Impact of COVID-19 on the food supply chain

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## Abstract

A pandemic is not a new event encountered in the history of humanity because mankind has faced various pandemics in history. The common point of pandemics is their serious negative effects on the global economy. Considering the food supply chain, one of the most important sectors of the economy, it has been seen that COVID-19 has an impact on the whole process from the field to the consumer. In the light of recent challenges in food supply chain, there is now considerable concern about food production, processing, distribution, and demand. COVID-19 resulted in the movement restrictions of workers, changes in demand of consumers, closure of food production facilities, restricted food trade policies, and financial pressures in food supply chain. Therefore, governments should facilitate the movement of workers and agri-food products. In addition, small farmers or vulnerable people should be supported financially. Facilities should change the working conditions and maintain the health and safety of employees by altering safety measures. Food protectionist policies should be avoided to prevent an increase in food prices. In conclusion, each country must realize the severity of the situation and sometimes should tighten or loosen the measures according to the spread of the pandemic. The supply chain also should be flexible enough to respond to the challenges in the food supply chain. The purpose of this review is to evaluate the impact of COVID-19 on the agriculture and food sector and to summarize the recommendations required to reduce and control the effect of the pandemic.

**Key words:** pandemic; COVID-19; agriculture; food; supply chain.

## Introduction

As the COVID-19 disease spread rapidly to six continents by the novel coronavirus SARS-nCoV-2, many countries around the world have declared state of health emergency. On 11 March 2020, the World Health Organization (WHO) declared the rapidly spreading disease as a pandemic and called on countries to plan preparatory and response actions in line with the Global Strategic Preparedness and Response Plan (WHO, 2020a; Vasavada, 2020). WHO explained that a pandemic caused by a coronavirus has not been seen before, and this disease is the first pandemic caused by the coronavirus. COVID-19 is the fifth pandemic, following 1918 influenza virus (H1N1), 1957 influenza virus (H2N2), 1968 influenza virus

(H3N2), and 2009 Pandemic flu (H1N1), that resulted in the human deaths of around 50 million, 1.5 million, 1 million, and 300 000, respectively (Liu *et al.*, 2020). WHO indicated that this outbreak is not just a public health crisis, but it is a crisis that will touch every sector. Therefore, every sector and every individual should be involved in this struggle (WHO, 2020c). As of 5 August 2020, the number of cases per 1 million population is given for different regions as follows: 9 613.03 in Americas, 3 694.43 in Europe, 1 136.41 in South-East Asia, 2 167.25 in Eastern Mediterranean, 742.75 in Africa, and 176.36 in Western Pacific region. The global total of confirmed cases has reached to 17 528. 223 per 1 million population and 687.64 per 1 million population for corresponding deaths (WHO, 2020b).

The 'Strategic preparedness and response plan' by WHO includes the health measures that all countries had to prepare for and respond to this pandemic. This plan covers what we have learned about the virus so far and aims to transform this information into strategic action that can guide all national and international partners while developing national and regional operational plans. According to this plan, priority steps and actions are outlined in eight main topics:

- Coordination, planning, and monitoring at the country level;
- Risk communication and community participation;
- Surveillance, quick response teams, and case investigation;
- Entry points;
- National laboratories;
- Prevention and control of infection;
- Situation management;
- Operational support and logistics (WHO, 2020a).

The implementation of these measures caused the closure of workplaces and educational institutions, and temporary restrictions in travels and social meetings. Flexible working from home and online meetings have become standard practices nowadays. However, people who work in the food industry do not have work from home option hence they need to keep their typical office routines (Nicola *et al.*, 2020; FAO and WHO, 2020).

As a consequence of the COVID-19 crisis, response plans for food workers were developed to provide guidance for continuity of operations in the food processing facilities and manage coronavirus in the food industry. Especially meat and poultry processing industries can be defined as the critical infrastructure in food and agriculture. The plan includes a hierarchy of control requirements for cleaning, sanitation, disinfection of facilities, screening, and monitoring of workers for COVID-19, managing the sick employees and education programs for workers and supervisors to prevent the spread of coronavirus (CDC, 2020b).

Every industry in the world expects to see how the COVID-19 outbreak will affect the manufacturing industry, and the food industry is no different from other industries. However, the difference in the food industry from other industries is to produce products that are essential for daily life. Everybody knows that if one factory closes, a certain number of people who works at these factories have the potential to starve, but if processors and distributors are infected, all people are at risk (Staniforth, 2020). In addition, the food industry is a very important sector in regard to economy. However, food sector faces different sets of challenges compared with other sectors that are not critical for daily life such as tourism and aviation during a pandemic. Pandemic might lead to a US\$113 billion loss in aviation and US\$80 billion in tourism sector (IATA, 2020; UNTWO, 2020). Some food companies face various challenges due to a drop in income, whereas others are working hard to meet the growing demand of retailers. During the current COVID-19 outbreak, some difficult decisions had to be made, including temporarily shut down of the various businesses. The fact is that this pandemic clearly demonstrated different companies from different industries are closely connected to each other all over the world (Sebastian, 2020; Shahidi, 2020).

A major concern shared by all food companies is preserving the employee's health and the provision of sufficient workforce due to those who do not want to work because of sickness or coronavirus fear. It is very important to protect and maintain the health of people working in the food supply chain during this time of crisis (FAO and WHO, 2020). However, keeping the distribution chain alive by

the supply management strategies is also important to meet the consumer demands (De Sousa Jabbour *et al.*, 2020). Maintaining the flow of food and commodities throughout the supply chain should be ensured with the contribution of all stakeholders. Ensuring the confidence of consumers is also essential for food safety and security (FAO and WHO, 2020). At this time of crisis, food security is associated with consumers' access to food rather than food availability (OECD, 2020b).

Consumers generally do not think much about how the food on their tables is produced. However, concerns about food safety in the midst of the global pandemic have drawn attention to the enormous infrastructure and workforce responsible for creating a safe and reliable food supply worldwide. Especially at the beginning of this global crisis, consumer demand for food has increased and some store shelves have been temporarily emptied and resulted in excess purchases of essential products. However, despite this unprecedented demand, the food supply chain remained strong, since many supply chain actors, including farmers, producers, distributors, and retailers, have worked hard to renew shelves (Nicola *et al.*, 2020; Watts, 2020).

Despite the large scale of the pandemic, there is no report that COVID-19 has been transmitted through food consumption to date. Therefore, as stated by the European Food Safety Authority, there is no evidence that food poses a risk to public health in relation to COVID-19. However, after the latest infections have been seen in Xinfandi market due to salmon processing, it can be concluded that the risk of the virus that transmitted through foods is lower than the perceived risk. Considering the survival time of SARS-CoV-2 in different environments such as plastic, steel, or cardboard, it is possible that animal tissues (meat, fish, or poultry) might be a serious source for foodborne transmission. Hygiene controls by food business operators are designed to prevent contamination of food by any pathogen and will therefore aim to prevent contamination of foods by the virus responsible for COVID-19 too (Arellano, 2020; Dalton, 2020; EC, 2020; Pressman *et al.*, 2020). It was reported that foods were not a source of spread of coronaviruses including MERS and SARS-CoV due to the acidic environments of the stomach (pH < 3.5) in previous outbreaks. However, some cooking and eating habits may lead to the reappearance of the coronavirus from animals to humans (Rizou *et al.*, 2020).

To summarize, four major issues have been raised in the food industry and the food supply chain during the COVID-19 outbreak. Firstly, people tend to have follow a healthy diet for protecting themselves and their immune systems (Rodríguez-Pérez *et al.*, 2020). Therefore, the demand for the functional foods which contain bio-active ingredients increased. Secondly, food safety has gained more attention to prevent the transmission of coronavirus among producers, retailers, and consumers. Thirdly, food security concerns have arisen because of the people on lockdown restrictions. Lastly, food sustainability problems have emerged in the era of pandemic (Galanakis, 2020).

In the light of recent challenges in food supply chain, there is now considerable concern about the food supply chain. Therefore, the purpose of this article is to provide information about the effects of the COVID-19 outbreak in the food supply chain and to summarize the measures taken to minimize these effects. Formal and informal sources were used to obtain information about the food supply chain during COVID-19 outbreak. The contents which were not reviewed by news editor, journal/magazine editor, or scientific editor before they are published online were not used as a supplementary source of information. Most of the content was based on

the well-known organizations such as Centres for Disease Control and Prevention (CDC), European Commission (EC), Food and Agriculture Organization (FAO), International Food Information Council (IFIC), International Food Policy Research Institute (IFPRI), International Labour Organization (ILO), International Trade Centre (ITC), The Organization for Economic Co-operation and Development (OECD), and World Health Organization (WHO).

### Effects of pandemic on food supply chain

The Food supply chain can be divided into five stages, including agricultural production, postharvest handling, processing, distribution/retail/service, and consumption. Two systems are being used in the food supply chain regarding food quality and safety. The First one is based on regulations and laws that use mandatory standards which are inspected by state agencies. The Second one is relying on voluntary standards which are defined by market laws or international associations (Bendekovic *et al.*, 2015). Safety measures to ensure the continuity of food flow in each stage can be grouped as food employee's health issues, personal hygiene, using personal protective equipments such as helmets and glove, sanitization of surfaces and working environments, safe handling/preparation/delivery of food, and maintenance of social distance. Protective measures in the last stages of the food supply chain are critical since more people can be potentially affected as moved towards the last stages (Rizou *et al.*, 2020).

Unlike foot and mouth disease, bird flu, *Escherichia coli* (*E. coli*), or Listeria, the COVID-19 pandemic does not directly affect production, as it does not spread directly through livestock or agricultural products (FAO, 2020a). However, due to the pandemic, governments around the world have made significant restrictions in the transportation (land, water, and air transport) of goods, as well as in the migration of labour. Reports showed that using the trucks for food distribution was declined to 60% since the restrictions in France which was 30% before the pandemic (FAO, 2020j; Bakalis *et al.*, 2020).

In developing and underdeveloped countries, temporary or seasonal employment is common, especially for planting, sorting, harvesting, processing, or transporting crops to markets. Therefore, the supply chain is significantly affected as a result of the absence of local or migrant workers due to sickness or travel restrictions imposed by lockdown. It also weakens not only production abilities for others, but also their own food safety, in cases where the disease directly affects their health or movement (FAO, 2020k). Especially, labour shortage due to COVID-19 crisis caused severe disruptions in some sectors such as livestock production, horticulture, planting, harvesting, and crop processing which are relatively labour intensive (Stephens *et al.*, 2020). However, shortage of farmworkers was a major issue well before the COVID-19 outbreak, too (Richards and Rickard, 2020).

Due to the fact that many skilled workers in the harvest could not access various countries because of the border controls, a call has been made to the unemployed persons to work in the fields in France. In Britain, 'Pick for Britain' campaign was aimed to find 70 000 British to work in the field and during the harvest (Nature Plants, 2020). However, due to the shortage of workforce as a result of illness and physical distance to be maintained during production, the crisis undermines the ability of farms and agricultural businesses to work. These conditions retarded the delivery of food and agricultural inputs and created problems in providing continuous food supply to markets (ILO, 2020). Although many manufacturers rely on their core inputs, most are more susceptible to disruptions, as they must obtain their requirements from domestic markets.

Logistics barriers that disrupt food supply chains further weaken high-value goods due to their short shelf life (Shahidi, 2020; FAO, 2020j; FAO, 2020k).

Most agricultural activities depend on the season and weather, and therefore, activities need to follow a fine-tuned schedule with flexibility so that immediate actions can be performed when needed. Since all processes and stages in a supply chain are strongly connected to each other, a slight delay or glitch can trigger a butterfly effect resulting in a big loss in the yield and output (FAO, 2020k). Actually, there are many reports that farmers were forced to destroy their products by burning or leaving them to spoil because of the restrictions. Dairy Farmers in America Co-operative consider 14 million litres of milk are being dumped every day due to interrupted supply chain. In England, chair of dairy farmers reported that approximately 5 million litres of milk are at risk in one week. Also, It was reported that tea plants were being lost because of the logistical challenges in India (BBC, 2020a). Therefore, maintaining logistical efficiency is a key factor for the food industry, especially in global crisis. The biggest issues in the food supply chain are obtaining raw materials from suppliers and ensuring the continuity of food flow from manufacturers to end users (Alonso *et al.*, 2007). The problems are jeopardizing the ability of agricultural businesses to continue their business as usual, and may have negative effects on food quality, freshness, and food safety, and hinder access to markets and affordability (FAO, 2020k). As countries struggle with that pandemic, they must make every effort to move the gears of the food supply chains. The impact of pandemic problems on agricultural systems largely depends on the intensity and composition of agricultural inputs and varies depending on the product produced and the country. Capital-intensive techniques are usually used in high-income countries for agricultural production, whereas production is mostly labour dependent in low-income countries. Thus, the supply chain should be kept running with a particular focus on the basics of logistic challenges (FAO, 2020j).

Food sector contains many diverse products such as meat, fruit, vegetable, dairy, ready-to-eat foods, and other edible products (Hueston and McLeod, 2012). However, the food and agriculture chain can be broadly classified into two categories regarding capital investment and labour. The First one can be defined as staple products such as wheat, corn, maize, soybeans, and oilseeds. The Second one contains high-value products such as fruit, vegetables, and fisheries. Staple products require large amounts of capital investments. Restriction between cities, provinces, regions, and countries has a negative impact on the distribution of staple products (FAO, 2020c). In contrast to staple products, a great deal of labour is required to obtain high-value products. However, time-sensitive nature of the agricultural operations (O'Brien *et al.*, 2014) and needs for higher productivity over time might lead to the agricultural transformation which can be defined as technological advancement and up-skilling of the labour force (Jeon, 2011; Martin, 2016).

The challenges that have been driven by movement restriction (national or international border closures) and the changes in demand of consumers are important. Because of the restrictions, consumers cannot go to restaurants and they prepare their meals at home. In addition, consumers do not want to go to markets and supermarkets due to catching the COVID-19 at the stores (FAO, 2020g).

The supply chain affects not only producers, distributors, and consumers, but also food-processing plants that are labour intensive. Production was reduced, suspended, or temporarily discontinued in many plants due to the workers who were found to be COVID-19 positive and who were reluctant to go to work, thinking

that they would get sick at work, mostly in meat-processing food companies at the time of the outbreak. For these reasons, it was thought that the production capacity of pork facilities decreased by approximately 25% in late April (Devereux *et al.*, 2020; Flynn, 2020).

In this context, there were at least 462 meat packaging and 257 food-processing plants and 93 farm and production facilities were affected by COVID-19 cases in the USA. At least 54,036 workers (39,905 meat packaging workers, 8,343 food-processing workers, and 5,788 farmers) have been identified as COVID-19 positive and at least 232 workers (184 meat packaging workers, 34 food-processing workers, and 14 farm workers) have lost their lives (Douglas, 2020). In Brazil, 2,400 meat plant workers were identified as COVID-19 positive from 24 slaughterhouses in 18 municipalities. Several meat factories suspended their operations after 246 positive cases in England and Wales. In Gana, 534 staff tested positive for the virus at a fish-processing factory. In Germany, 1,553 cases of COVID-19 were found at meat-processing plants, and in France, more than 100 coronavirus infections were recorded at slaughterhouses (BBC, 2020b; Gulland, 2020; Kaur, 2020; Ziady *et al.*, 2020). Close-down of the food plants created the ripple effect in food supply chain. Producers have been forced to cull the farm animals since they could not find any plant to sell their livestock. Greater consumer demand resulted in empty shelves and a decrease in supply caused an increase in the price of meat products. Some of the markets limited the number of items such as beef and pork products that a single customer could buy. Food services were also affected, and some restaurants stopped serving beef hamburgers (Hobbs, 2020; Levany, 2020; Murphy, 2020; Rude, 2020; Valinsky, 2020). Despite government reassurances, some of the stores started free delivery services on orders to prevent panic-buying. In addition, supermarkets determined the number of people allowed at any given time to stop overcrowding. Stores also adjusted special shopping hours for vulnerable customers (Nicola *et al.*, 2020).

There are several reasons at play that make food-processing facilities potential hotbeds for outbreak. Keeping social distance inside the food plants is difficult because workers stand side by side during long shifts on production lines. In addition, talking loudly or shouting, due to noisy environments, results in the release of more droplets to the air (Stewart *et al.*, 2020). Employees also travel on the same buses or use car-sharing systems allowing the virus to spread further. Moreover, the majority of workers have lower income and mostly do not have insurance coverage or paid sick leave. Therefore, food-processing workers are taking risk to go work even if they feel sick which increase the risk of infection. Cold and humid environment inside the food-processing facilities is another factor that facilitates the spread of the COVID-19. It is possible that cold and dark environments without any ultraviolet light can keep coronavirus alive and might result in an increase in the rates of transmission (Artiga and Rae, 2020; Gulland, 2020). The stability tests of the virus under five different temperatures (4, 22, 37, 56, and 70 °C) and five different surfaces (paper, tissue paper, wood, and cloth) showed that SARS-CoV-2 is highly stable at 4 °C, but sensitive to heat. In addition, it was found that the virus is stable on smooth surfaces, however susceptible to standard disinfectants (Chin *et al.*, 2020). Another study by Van Doremalen *et al.* (2020) suggested that SARS-CoV-2 remains stable in aerosols for 3 h. The same study revealed that virus was viable for 4, 24, 48, and 72 h on copper, cardboard, stainless steel, and plastic, respectively. These outcomes indicated that the cooking temperatures above 70 °C are enough to kill the SARS-CoV-2, but sanitary recommendations (washing

hands, separating raw and cooked meat, etc.) should be followed while preparing and storing the foods (Rizou *et al.*, 2020; Shahidi, 2020).

Centralized food manufacturing is another factor that caused disruption of food chains during COVID-19 outbreak. This paradigm helped the food processors to increase production and reduce the costs. However, centralization has some drawbacks such as rigid and lengthy supply chain issues. In addition, using the small number of very large production facilities to meet the demands might create problems (Almena *et al.*, 2019a) such as closure of the entire facility in case of an outbreak leaving high capacity production lines with less alternatives.

Governments are also facing financial pressures due to the economic shrinkage and reallocating their resources focusing on financial incentives and social assistance programs. Therefore, it may be difficult to support programs aimed to improve productivity at the farm levels. It is possible that inadequate funding may reduce the demand for agricultural production and productivity over the medium term. The drop in demand will particularly harm the emerging private sector in developing countries (FAO, 2020e, 2020h).

The information provided by WHO indicated that coronavirus is transmitted through direct contact or respiratory droplets, however, the latest infections encountered in Xinfandi market raised questions over spread of coronavirus through food. Xinfandi market is the Beijing's largest wholesale food market with more than 10,000 workers and capacity of 18,000 tonnes of vegetables, 20,000 tonnes of fruit, and 1,500 tonnes of seafood, everyday (Hua and Cadell, 2020). Officials have detected more than 100 infected people, mostly serving at seafood, beef, and mutton sections. The coronavirus was detected on the board used for cutting up salmon at market. Officials point out that high humidity and low temperature conditions in Beijing might be the reason for transmission of coronavirus. In addition, officials stated that the surfaces of equipment's used for preparation of seafood and meat products contaminated by infected people could be another factor of transmission (Feng and Cheng, 2020; Reuters, 2020). The government blocked the entrances by police and temporarily closed the market due to the fears of a second wave of pandemic on June 13. The news has resulted in halted importation of salmon from European countries in China and salmon was taken off from some supermarkets' shelves in reaction. Norwegian officials stated 'there is no link between the transmission of coronavirus via imported food and the origin of the salmon outbreak is still unclear' (Arellano, 2020; Dalton, 2020). Negotiations between Norwegian and Chinese authorities are currently in progress to clear up the backlog. However, not only the supply of seafoods was affected, but also meat, fruit, and vegetables supply were damaged with the closure of the entire Xinfandi market. Authorities are trying to establish special trading places in the near future to maintain the supply chain of vegetables and fruits. In addition, government is considering to take actions to increase the hygienic standards in food markets (Globaltimes, 2020; Reuters, 2020). Authorities tested around 30,000 foods including meat, seafood, fruit, and vegetable between 11 and 17 June and results were negative for all samples. Food exporters to China were asked to sign official declarations in which they give a guarantee for their products that it is not contaminated by coronavirus. However, some of the exporters such as Brazilian grain exporters did not agree to sign the declaration (Good, 2020; Patton, 2020).

As a result, the COVID-19 pandemic ensured the use of mechanisms designed for emergency and affected contractual transactions in the food supply chains. At the same time, it resulted in the changes in



the supply–demand balance and left small producers and operators in a difficult situation (FAO, 2020i).

### Effects of pandemic on consumer behaviour

When the issue of how the COVID-19 pandemic affects consumers' food demand is examined, it is seen that the demand varies depending on the price of foodstuffs, income level of consumers, socio-demographic situation, consumption, and shopping preferences and time constraints. In addition, the number of visits to food store and spending money on food in per visit changed (Bakalis *et al.*, 2020; Cranfield, 2020).

COVID-19 outbreak interrupted the daily routine and resulted in boredom which can be defined as high energy intake by the consumption of high amount of fat, carbohydrate, and proteins. In addition, quarantine caused stress in people and pushed them toward sugary foods for feeling positive, because carbohydrate-rich foods can be used as self-medicating components due to their ability to encourage serotonin production. However, these unhealthy eating habits may contribute to the development of obesity linked to the chronic inflammation and serious complications of COVID-19 (Muscogiuri *et al.*, 2020).

The closure of restaurants and limited service eating places affected the eating/purchasing habits and resulted in an unusual demand shift from food service to retail. Reports showed that purchasing food from supermarkets and using food services had the same ratio as 50% before the outbreak; however, it is almost 100% for supermarkets. The number of visits to food store was decreased whilst spending money on food was raised per visit. Consumers experienced reduced availability of certain types of foods during the COVID-19 lockdown. In European countries, flour which is a staple product received more attention and not found on food store shelves due to the interest in home-baking as a family activity. Interestingly, bread and baked products kept their place on the supermarket shelves. Consumers have focused on the products with long shelf life such as dried or canned foods, pasta, milk, or milk substitutes, and frozen foods due to convenience and daily cooking at home. People stocked these foods at home because of the turn to home baking and believing rumours or getting false information. Consumers preferred takeaway and home delivery options as a result of social distance and closure of restaurants (Bakalis *et al.*, 2020; Shahidi, 2020). Indeed, it was interesting to note that the shortage of eggs was not only due to increased demand but also lack of packaging for retail. Household egg consumption increased 40% since March 20 in Argentina and sales of eggs rose by 44% compared to last year in the USA. The U.S. Food and Drug Administration provided flexibility related to the packaging and labelling of eggs due to the insufficient availability of appropriately labelled retail packages to fulfill the demand and facilitate the distribution of eggs during COVID-19 pandemic (FDA, 2020; Mazili, 2020; Reiley, 2020).

Global events such as COVID-19 increase the demand for food worldwide. In a study, demand data in European countries due to COVID-19 were evaluated. Accordingly, although the demand for fresh bread increased by 76% and frozen vegetables by 52% in the week when the pandemic was announced, the demand for alcoholic beverages did not increase. However, the demand for alcoholic beverages increased about twice, one month after pandemic announcement (Crisp, 2020).

Concerns about COVID-19 are far-reaching and they cover both health and financial issues. In a study on 18 countries, it was shown that food buying behaviour of the consumers has changed because of their will to consume healthy foods, but at the same time to achieve

this without exceeding normal budget. Consumers adopted a basic approach of returning to natural food and beverage products which contain ingredients that provide nutritional supplements such as fruits and vegetables, legumes, whole grains, or olive oil. At the same time, most consumers are concerned about the effect of COVID-19 on their mental effects; therefore, many consumers are looking for food products to improve this mood (Hughes, 2020; Muscogiuri *et al.*, 2020).

In a recent poll by Italy's Agricultural Research and Economic Council (CREA), the behaviour of the Italian population on food choices and behaviour was monitored under COVID-19 quarantine. Approximately 2,900 people from all regions of Italy responded. According to the results, healthy food and beverage consumption increased for vegetables (33%), fruit (29%), legumes (26.5%), and extra virgin olive oil (21.5%). However, it was determined that 44.5% of them had more sweet consumption and 16% of them drank more wine. Forty-four percent of respondents reported weight gain due to intake of higher calories and low levels of physical activity. Thirty-seven percent of respondents expressed that they need to lose weight by adjusting their diet (CREA, 2020).

According to the survey of 630 consumers in May, 70% of consumers reduced the frequency of food shopping and preferred online shopping during COVID-19 outbreak in the USA. Fifty-six percent of consumers are worried about not finding particular foods they want to buy in the store or forgetting to buy something. Seventy percent of consumers said that they consumed more food while at home. When examined in terms of healthy consumption, 43% of consumers emphasized that they consume more fruits, 42% more vegetables, and 30% more protein-containing foods (meat, chicken, or fish). In addition, 39% of consumers stated that they made their breakfast more balanced. When examined in terms of unhealthy consumption, 47% of consumers said that they consumed more sweets, 24% consumed less vegetables, 21% consumed less fruit, and 19% consumed less protein (DeBroff, 2020).

In another study, a survey on 1,005 men and women who are over 18 years old showed that more than half of the French people changed their views on the social, economic, and ecological value of food production, during the 8-week quarantine. The results showed that French consumers would only buy 'necessary' 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. Changing attitudes also seem to have had an impact on food waste, and one in three respondents stated that they now waste less food. This includes 29% of those who reported buying more local food and 20% went online shopping (Askew, 2020).

Another study conducted on the 6th and 7th of April, among 1,000 adults who are above 18, showed that 42% of consumers preferred the packaged foods more than normal, whereas another portion of the same ratio said that the pandemic did not change their attitudes towards packaged food. Eighty-two percent of consumers think that the food they buy during the pandemic is safe to consume. However, a portion of 7% thinks that the food that they buy is not safe. A total of 77% think that food producers can provide enough food to meet consumer needs, whereas 16% think that it cannot be provided (IFIC, 2020).

As consumers play a key role in food supply chain, changes in consumer behaviour strongly affected the food supply chain. COVID-19 outbreak caused a significant rise in food price related to lockdown restrictions accompanied by panic buying, as well as supply chain disruptions (EDP, 2020). Some of the consumers will pay more attention to reduce food waste for improving food security

(Shafiee-Jood and Cai, 2016). However, the opposite is also possible since lots of the perishable foods were discarded or dumped due to the closure of schools, restaurants, or processing plants. In addition, transportation problems during lockdown or overbuying of perishable items because of panic buying resulted in higher food waste levels (Fleetwood, 2020; Sharma *et al.*, 2020). Changing demands also will bring changes to packaging materials/design, delivery options, and storage conditions (Reynold, 2020).

### Effects of pandemic on global food trade

Although the current conditions seem exceptional, the vulnerability of food systems to problems related to climate and diseases has been experienced long before the COVID-19 crisis. Food systems have been unstable from various events and shocks previously such as the oil crisis in the 1970s, the SARS and Ebola outbreaks, and the 2006–2008 food crisis. Africa Swine Fever disease made the global commodity markets upset just a year ago and became a progressive epidemic in Eastern Europe and Asia. The world's largest swine producer (has 1/3 of the global market) and biggest exporter, China, lost 37% of its pigs by the end of 2019 (IPES, 2020). Ebola had a great negative impact on agricultural production, marketing, and trade economies of some African countries. On the production side, due to road constraints, farmers had limited access to inputs such as seeds, fertilizers, and pesticides, and most regions faced labour shortages. For this reason, more than 40% of agricultural land has not been cultivated. However, pandemic did not severely affect the production because agricultural areas were often in the geographic areas which are far away from urban densities (Agrilinks, 2020; Shahidi, 2020).

The current COVID-19 crisis has changed the food trade policies of some governments, moving towards restricting exports and facilitating imports. The main reason that countries impose export restrictions is to ensure the maintenance of the number of products in the domestic market. Although the export restriction typically produces this result in the short term, it also has some negative effects. First, export restrictions cause domestic prices to drop, which will hurt farmers financially resulting in the decrease in crop production and reduced incentives in the industry. Second, countries will lose their competitive advantage by losing their place in international markets. Third, export restrictions undermine exporter's reputation and encourage importers to reduce confidence in the world market, thereby reducing trust in international trade and destroying future business opportunities for exporters (Espitia *et al.*, 2020; FAO, 2020l).

In 2008 food crisis, although domestic food prices increased greatly, some big countries that could isolate themselves from world markets were not affected. Compared with 2004, rice prices increased by 224%, wheat prices by 108%, and corn prices by 89% (FAO, 2011). In general, prices increased due to trade constraints, risks, and uncertainties in international markets leading to an increase in prices in the import-dependent countries higher than they should be. Because of the export restrictions enforced by major exporting countries, panic-buying behaviour has been observed in importing countries and prices have been elevated due to more demand for products (DOS, 2011).

Although world food stocks are currently high, a prolonged pandemic crisis can cause problems in the food supply chain, as well as export-restricted policies, which can trigger the domino effect. According to the FAO 2019 grain production estimates, it was reported that there had been around 2.721 billion tonnes of production consisting of 1.44 billion tonnes for coarse grains, 763 million tonnes for wheat, and 512 million tonnes for rice. According to

FAO's 2020 estimates, wheat and coarse grain production is expected to be similar to 2019. For this reason, global grain markets are expected to follow a balanced situation despite the concern of COVID-19 (FAO, 2020b).

A total of 19 countries have taken measures to restrict exports, which are related to 27 food products due to COVID-19 outbreak. Some of these restrictions are inactive and currently a total of 8 countries are continuing their measures on 11 food. When the effects of restrictions on importing countries are evaluated (expressed as Kcal unit), it is seen that Tajikistan, Uzbekistan, Afghanistan, and Azerbaijan were negatively affected by 79%, 70%, 61%, and 54%, respectively (IFPRI, 2020).

To summarize, trading provides to move the products from surplus to deficit areas, preventing the shortages and food insecurity related to reliance only on domestic production (Baldos and Hertel, 2015; Fitton *et al.*, 2019). However, COVID-19 pandemic caused a significant impact on food trade and led to disruption in food supply chain due to the export restrictions. Export-restricted policies pushed up world prices of stable food commodities such as wheat, maize, and rice and resulted in reduction of the quantity and quality of food eaten (Fyles and Madramootoo, 2016). Customers also could not find the product which is not grown or produced nationally. Producers were also weakened by the restrictions because international market contains endless number of buyers and helps the producers to select the best one. When the export restrictive policies were applied, local sellers could not find buyers and resulted in excess supply and waste along with economic losses. Foods that are not grown locally but needed for processing were not available due to the restrictions and capacity utilization of food-manufacturing plants to respond demand was also negatively affected (Arianina and Morris, 2020; Ndemezo *et al.*, 2018; Reddy *et al.*, 2016). Transportation challenges for air and sea cargo were also further issues in association with food loss and waste (OECD, 2020a).

### Recommendations to minimize the effect of Covid-19

The COVID-19 outbreak seriously threatens food safety, security, and nutrition. The economic chaos due to the pandemic threatens economic access and physical availability of food. Disruptions and possible problems in marketing, logistics, and trade systems may restrict access to food in some places and times, therefore, hunger and malnutrition problems may appear (FAO, 2020g). Report from World Food Program showed that the number of people facing extreme hunger can increase to 265 million in 2020 as a result of COVID-19 (WFP, 2020a). Another study performed by Headey *et al.* (2020) indicated that COVID-19 leads to 14.3% increase in the prevalence of wasting among children who are younger than 5 years old due to malnutrition or interruption of health and social protection in low and middle-income countries.

### Strategies for food supply chain

Before the pandemic, one-third of all food produced for human consumption was lost or wasted across the food supply chain stages including production, postharvest handling, processing, distribution, and consumption. Therefore, food waste has gained more attention than ever before in the era of coronavirus. A study performed by Aldaco *et al.* (2020) indicated that COVID-19 had a minor impact on the overall food loss and waste generation but resulted in 12% higher creation of food waste on the household level.

Valuable bioactive components such as phenols, carotenoids, pectins, flavonoids, essential oils, glucosinolates, isothiocyanates, and whey protein isolate can be derived from food wastes to re-utilize them in food chain. These functional compounds can be used as preservatives, gelling agents, food, or nutritional supplements. Conventional or innovative techniques can be applied in the extraction, fractionation, and isolation stages of bioactive components from food wastes (Deng *et al.*, 2015; Galanakis, 2012; Galanakis, 2013). However, additional collection and processing centres are required to recover food wastes generated during production, processing, or consumption stages.

The European Food Safety Authority indicated that food is not a source of coronavirus and virus cannot be transmitted through the consumption of food. Environmental surfaces such as doorknobs, light switches, or foods contaminated with COVID-19 virus remain a potential risk of becoming infected (EC, 2020). However, the latest work performed by Richard *et al.* (2020) showed that SARS-CoV-2 can be efficiently transmitted via air. Therefore, people should always care about handwashing. In addition, retailers must follow the hygiene requirements when handling food. Food preparation workers must wear mask and gloves and change them frequently when cutting, slicing, or packaging of foods. Consumers are also responsible to prevent contamination by not touching the foods other than what they are willing to purchase in the stores (Morawska and Cao, 2020).

Various robot systems can be used to ensure food safety in food facilities by preventing the transmission of microorganism by humans. The fourth industrial revolution now plays an important role by making data-driven autonomous decision in production. Automation opens up new opportunity to increase productivity by 25% and to complete the task such as loading/unloading, placing, and packaging more efficiently than human being. Robots can also help us to serve the foods to consumers in food-serving industry. In addition, Cyber Physical System (CPS) can monitor the unsafe or low-quality products in food supply chain (Iqbal *et al.*, 2017; Bowler *et al.*, 2020).

The COVID-19 outbreak also resulted in difficult requirements for human resource management. These challenges include the change of working conditions, adopting new workplace policies and actions to reduce human contact (Carnevale and Hatak, 2020). Therefore, organizations must respond to the challenges by some measures. Firstly, COVID-19 symptoms of the workers, visitors, suppliers, and contractors should be monitored before entering the facility. The food safety or HACCP teams can perform temperature screening of all staff at the entrance of plant. Monitoring workers to wear face protection equipments and gloves is important, too. Secondly, facilities should consider reducing working hours and rotating employees. The overall number of workers in each shift should be divided into three or four groups and their break time should be adjusted to avoid overcrowding. Lastly, warehouses and processing facilities should be redesigned to allow employees to implement social distances. Building dividers or barriers which cover the upper part of the body of workers can be used to maintain social distance. Diagonal arrangement should be used if employees use two-side engagement in food processing (Shahbaz *et al.*, 2020). Robotic machines also can be used to lower the risk associated with COVID-19-infected workers during the coronavirus outbreak. Furthermore, robots can replace humans in food-processing operations to maintain social distancing by reducing the number of food workers. These precautions against the COVID-19 will result in more stable international market mechanism. Countries should

maintain the balance between the production quantity and safety of workers (FAO, 2020j).

Decentralization of food manufacture might also be used to avoid drawbacks and risks associated with centralization paradigm in the era of COVID-19. Low-scale facilities located near the consumers reduce the storage and transportation costs and minimize the environmental impacts. Building the production facilities closer to consumers help shorten the supply chain and decrease the emission and energy consumption during transportation and storage. Decentralization provides flexibility in supply chain and allows customers to get fresh and natural products. It also helps us to simplify the administration procedures in order to reach poor and disadvantaged people (Almena *et al.*, 2019a; Almena *et al.*, 2019b; FAO, 2005).

Industry also should determine which transportation routes are blocked (potential alternatives should be sought) and how many workers cannot work due to restrictions. The local labour force should be trained and activated in the event of cross-border restrictions. It would be an opportunity to ensure reliable and long-term workforce for future by training and increasing the skills of local employees. Agricultural workers now identified as essential people, and this ensured them to work under better conditions with higher wages (Petetin, 2020). At the same time, agricultural inputs should be considered as essential products to ensure food production. Collection centres should be selected and planned considering their distance to the manufacturer. Integration of small producers closer to collection centre with high capacity can also decrease mobility (Galanakis, 2020).

Changes in demands are another factor that affects supply chain performance. Therefore, the demands should be determined using forecasts and simulations. Especially, the products which are essential for daily life, such as sanitizers and food items, gained more demand at the beginning of crisis. However, the perishable nature of food products makes them more prone to impacts of COVID-19 on the supply chain. Therefore, statistical models can be applied by manufacturer to propose optimal decision for tackling supply and demand disruptions due to COVID-19 outbreak. Using those results, production, processing, and distribution can be adapted accordingly (Paul and Chowdhury, 2020).

In addition, it is necessary to use the logistics facilities in the most optimum way, especially the logistics vehicles should not return empty to the starting point. The concept of 'Urban Distribution Center' can allow us to use better capacity with consolidating number of deliveries by one or more vehicles. It also improves the effectiveness of the collection or transportation process. In addition, food protection should be ensured by coordinating the members of the supply chain. Private or government institutions need to invest in storage centres. Consumers should have access to markets, and attention should be paid to the needs of low-income consumers. The relationship between buyer and seller should be strengthened by establishing web-based food distribution systems. Web-based supply chain management system can be referred as an internet-enabled system and allows the information flow among suppliers, facilities, collection centres, and retailers. This system allows faster and flexible collaboration between company and customer (Morganti and Gonzalez-Feliu, 2015; FAO, 2020j, 2020k; Ngai *et al.*, 2004).

Digital commerce services play an important role in the interaction and trading activities among food supply chain actors. E-commerce provides opportunities to reduce the costs and increase the demand. In addition, small farmers are considered disadvantaged in food supply chain related to many challenges they

face in market access. Higher transaction charges in all deals do not allow small holders to be in better positions due to their small scale. Therefore, digitization of procedures allows small farmers to sell their crops at higher price and helps them to reach more customers in a direct and effective way bypassing intermediaries. The largest e-commerce companies collaborate with the government to digitize the services of rural markets and encourage them to be part of the e-commerce economy. These platforms offer mostly organic fertilizers to the market at a reasonable cost (Zeng *et al.*, 2017; FAO, 2020j, 2020e).

'Supply Chain Management (SCM) Data Science' can be used by governments and private sectors to solve SCM problems and forecast the outcomes by performing quantitative and qualitative methods bearing in mind the data quality and data availability (Waller and Fawcett, 2013). Therefore, data availability and dissemination should be improved. Access to correct data at the right time is important for the efficient functioning of the supply chain. The availability of reliable information reduces uncertainties in the market and allows private and public organizations to determine sources of potential disruptions and risks. Correct data also provide better decision making and enhanced profitability. In addition, collaboration between government agency and private sector can be more effective by easily accessible data. Sharing of data and information across the food supply chain can reduce the negative impacts and may strengthen the flexibility in the long run (FAO, 2020j).

### Recommendations for small farmers

Countries should take measures to ensure the safety of agricultural workers. Onsite healthcare professionals should track the illness status of employees. Countries should build agricultural production collection centres at locations easily reached by small-scale farmers relating to mobility reduction. Agricultural production collection centres should be designed to provide high capacity storage (FAO, 2020c). Improved and advanced storage structures also can be used to minimize the loss of foods throughout the food value chain. However, modern facilities or improved technologies entail higher production costs as it requires additional capital injection. Therefore, small- and medium-sized agricultural enterprises can maintain their activities using the capital injections from government or donors (Tetteh Anang *et al.*, 2015).

Food banks can play an important role considering the horizontal and vertical coordination mechanisms with farmer associations that make contractual agriculture arrangement. Primarily, It would be a way to help farmers to create new markets by selling their unsold produces to food banks and make connection between farmers and vulnerable people during COVID-19 outbreak (Jackson and Yurkevich, 2020). Second, whenever possible, countries can deploy warehouse receipt systems, allowing small-scale producers to improve access for financial loans and get the best price for their product. This receipt helps small farmers to store crops safely in a modern storage facility and allows them to sell their product later when the prices are higher. It also can be used as possessory collateral for a loan (Miranda *et al.*, 2019). Third, countries should participate in growth and rapid development of e-commerce for small shareholders. Communication through the internet ensures that commercializing produces to wider range of consumers and enables farmers to find cheaper inputs (Khanal and Mishra, 2016). Fourth, small-scale producers should have easy and unhindered access to credit for dealing with financial problems to continue production. Some countries offer incentive packages for small-scale farmers (FAO, 2020c). Access to credits is related to the ability of

small farmers to take risks and cope with high risk situations. It also enables making efficient investment decisions which results in rise in agricultural capacity and profitability (Iyanda *et al.*, 2014). Temporary liquidity guarantee program (TLGP) can promote confidence in financial organizations. Firstly, the TLGP allows a limited term guarantee for newly issued debt of financial companies and affiliates. Secondly, the TLGP fully insured non-interest bearing transaction accounts. Governments can provide interest-free loans or cash grants or arrange their pay periods to needy farmers to restart production. Guaranteed loans are essential sources of credits given to small farmers that are assisted by commercial creditors and protect them against loss by governments (FAO, 2020j, 2020d; Dodson, 2014; Davison, 2019). Trade restrictions and bureaucratic barriers should be lifted to ensure the accessibility of small-scale farmers and producers to markets. Governmental agencies must meet the energy requirements of small-scale producers in rural areas (FAO, 2020h).

As a result, the COVID-19 outbreak highlighted the connection between farmers and consumers. Low-income levels and older ages of small farmers make them vulnerable to coronavirus (Johr, 2012; Gneiting and Sonenshine, 2018). Therefore, it is important to educate the farmers about the transmission routes and increase the awareness of pandemic prevention (Wang and Wang, 2020). Crop diversification strategy which can be defined as an option to increase the diversity of food by crop rotation or intercropping for creating new marketing channels and enabling the harvesting throughout the year can be used to adapt the challenges easily (Hufnagel *et al.*, 2020). Buyer, investors, and bankers should pay the small farmers upfront for their produces to ensure liquidity for next season. Growing organic foods can also scale up the sales due to consumer interest and confidence. In addition, partnerships between small farmers and companies or government is another way to help the small farmers to increase productivity and incomes by adaptive technology investment (Winter and Davis, 2006; ITC, 2020).

### Suggestions for government and business

First of all, a crisis committee should be established to focus on the effect of COVID-19 during food value chain without waiting too long for the implementation of certain strategies and interventions. This committee should become a key actor to observe the progress and recommend actions to reduce the effects of COVID-19 on agricultural production and food supply cuts. In order to ensure adequate and full implementation of the strategies, it is important that the committee should collaborate with the private sector (FAO, 2020k). In Turkey, the Ministry of Agriculture and Forestry has formed the COVID-19 Commission consisting of seven academicians and two members from the Ministry of Agriculture and Forestry for measures and recommendations to be taken in the field of agriculture and food within the scope of the pandemic (MAF, 2020).

In the aftermath of the pandemic, governments around the world announced response plans to help the agriculture industry for reducing the effect of COVID-19 outbreak. In Turkey, Ministry of Agriculture and Forestry announced the precautions and funding assistance programs for farmers and manufacturing facilities/stores such as slaughterhouses, greenhouses, and bakery stores. In addition, Ministry of Internal Affairs issued the lockdown guidelines that allow the farmers and food production plants to continue their operations during lockdown (MAF, 2020; MIA, 2020). In Canada, Agriculture Response Program was designed for 50–75% funding assistance which do not have to be paid back regarding health protocol, marketing and product movement, distribution, strategic projects, abattoir efficiency, and development (Novascatia, 2020).



In the USA, Department of Agriculture committed programs and flexibilities such as food assistance, dumped milk, crop insurance, farm loan, commodity loan, crop acreage, animal mortality, pay-check protection, and economic injury disaster loan to help agricultural producers are related to the COVID-19 outbreak (USDA, 2020).

Governments also should establish and operate emergency provisioning strategies to support production. The regions most affected by the outbreak should be protected by temporary input subsidies programs. Timely support is essential for planting season for the next spring (FAO, 2020d). Data collection and assessment programs for migrants should be used to determine when and where the migrants are needed (Martin, 2016). Facilitating the cross-border movement of migrant workers is important because movement restrictions and border closures have a strong negative influence on agricultural labour supply. In Canada, government announced a US\$50 million financial aid program for small farmers who hired temporary foreign employees through the COVID-19 outbreak. Program allowed employers to receive US\$1,500 per foreign worker who has to self-isolate for 14 days upon their entry into Canada (Ker, 2020). The resulting shortage of labour can be reduced by policies that classify agricultural workers as critical persons and exempt them from travel limitations. In the USA, government highlighted the importance of people employed in agricultural production and considered them as 'critical infrastructure worker' (FAO, 2020f; CDC, 2020a). It should also be focused on giving longer stay permits by changing the visa and residence regulations for seasonal workers in the country. In some countries such as Canada and Belgium, governments allowed employers to postpone the recruitment or offer long-term contracts (OECD, 2020c). Commission of European Union (EU) introduced 'the green lanes' for vehicles carrying agri-food products to ensure free and fast movement on borders. EU measures also highlighted the free movement of agri-food and seasonal workers for enabling them to reach their workplace and exercise their activities. In addition, the commission extended the farmers' application deadline to receive income support known as Common Agricultural Policy (CAP) payments. Temporary framework for state aid measures was approved to support farmers and agri-food business to ensure liquidity (Rossi, 2020). However, it is necessary to encourage the local population to become agricultural workers. Local populations and unemployed people can be trained to work in farming practices like sowing, weeding, or harvesting to minimize the effect of the restriction on migrant workers. Online platforms should be used to facilitate connections between local residents and agriculture sector (FAO, 2020d). Unemployed people or local worker should be encouraged for being agricultural labour by adding premiums to wages since local workers do not want to work in farming due to the possibilities to find better non-agricultural alternatives (Martin, 2016). COVID-19 outbreak showed that labour-replacing mechanization policy is the best way to solve the labour shortage over the medium to longer term (Troskie, 2020).

Employment contracts that made between the actors in the food value chain should be fair to all parties and should be clear about the rights and responsibilities of the parties since public and private standards are used to define the minimum requirements in food safety and quality. However, private standards involve more stringent regulations than public standards and affect the prices that producers receive and the quantity of produces they sell. In addition, these standards make significant impacts on their income and market access (Mohan, 2020). In addition, the rights of producers

and vulnerable groups affected by changes in supply and demand and the need to adapt in accordance with these changes can be regulated by legal frameworks. Regulations to be enacted in emergencies such as the COVID-19 outbreak can contribute to the safe and problem-free operation of transactions. Moreover, it is necessary to strengthen the capacities of legal regulations, including ensuring the proportionality and necessity of restrictive measures and providing flexibility in the implementation of certain administrative requirements to face the challenges posed by the new situation. Providing flexibility in licensing requirements for direct selling, e-commerce, and food transport can also help small producers and agricultural businesses to find alternative market opportunities (FAO, 2020i) since flexibility is relatively associated with weak/strong position of farmers and presence of long/short food supply chains. Customers sometimes believe that food choice is imposed by supply chain challenges (Petetin, 2020).

Logistic operations are also critical to maintain the delivery of the foods, and, therefore, some efforts are needed to maintain operations. Therefore, more infrastructure investment should be required to allow more supervision services, upgraded sanitation systems, increased use of digital documentation, and operations. Countries should follow rigid hygienic control in the distribution sector to prevent transmission of the virus. The health and safety of the logistic employees who carry tradable products should be maintained (FAO, 2020j). In UK, Logistic Sub-Group developed three work streams named 'safe passage programs', 'crisis management, accommodation & transportation', and 'shore base logistics & freight management', respectively. These work streams were intended to provide safe passage (health issues) and assurance to personnel and their families. It also ensures the movement of stuff in an effective and consistent manner. Lastly, it provides guidelines and raises awareness to logistic sector (OGUK, 2020).

Rapid yield prediction and determination of national food stocks need to be made to define shortages or surpluses that may occur, particularly because of import prohibition or export restrictions. Better management of food stocks in different regions should be considered and non-food uses of farm products (e.g., for biofuel) should be reduced (FAO, 2020k). Crop yield information models can be used to help the governments to make decisions about food security or grain marketing. Local models can be defined as data intensive models and appropriate for small areas, whereas regionally models use data extensive techniques and cover large areas. Therefore, proper modelling method should be selected to understand the impacts of policy decisions (Donohue *et al.*, 2018).

To summarize, given that the duration of the COVID-19 outbreak is uncertain, agricultural firms have begun to change their business models. For example, issues such as promoting understanding of the transmission, creating reporting system for positive cases, progressive investment and resource plans covering the next 3 years, business continuity planning, alternative input source channels, increased focus on stock management, review of personnel occupational health and safety practices, travel limitations, and human resource planning in the face of increasing demand or absenteeism are important (Clift and Court, 2020; ICC and WHO, 2020). However, companies also need to cooperate with competing companies on some issues e.g. raw material supply. Small companies need to be more organized, using the crisis as a driving force. Firms should care about developing the information and communication technology infrastructure that can be used for the agriculture and food sector. It is also necessary to benefit from financial incentive packages according to the needs of the enterprises (FAO, 2020a).

## Actions on global trade

Continuing the flow of agricultural inputs between countries, even in quarantine restrictions or closing borders, is vital. Therefore, measures to facilitate the trade of farming inputs such as equipments and fertilizers should be taken in the short run because these requirements are crucial for planting activities to continue smoothly (FAO, 2020j).

Understanding the COVID-19 impact behind restriction policies is also important since food availability levels are high and the forecast of key staple production is good. Despite these favourable conditions, governments are working to ensure the food security due to high consumer demand and protect vulnerable people from price increases. However, lessons from past experiences have indicated that avoiding trade restriction policies can be as effective to protect consumers and farm incomes as direct support activities (Martin and Glauber, 2020). Therefore, agricultural trade options and strategies should be modified to minimize the effect of outbreak in medium term. Each country should determine its own policy to identify the consequences and importance of changing certain aspects of trade strategy like import taxes for farming inputs. It is more vital if the capacity of the national agricultural production is limited and prices show rising trend for some foods. The actions to be taken in the field of trade strategy are influenced by the production quantity and input use. This outbreak offers the opportunity to optimize trade options and to develop some procedures and policies (FAO, 2020j).

It is necessary to address trade and tax policies to keep global trade open. Some of the major exporting countries followed 'beggar thy neighbour' policy which force importer countries to cover the costs or risks of limited supplies at the beginning of the COVID-19 outbreak. Distributional effects of 'beggar thy neighbour' also include the increase in food prices and decline in food security (Barichello, 2020). Therefore, countries should take immediate actions regarding trade and tax policy options and their possible effects to develop a favourable condition for food trade. During the 2006–2008 food crisis, the lack of information about market conditions (production, stocks, consumption, trade, prices) and inefficient policy of countries led to disruptions and resulted in an increase in food prices. If one country starts to take the same restrictions as they did in 2006–2008 crisis, the other governments will follow, and it will be a disaster for markets. We learned some lessons from the 2006–2008 crisis that how countries should respond to COVID-19. Therefore, countries should lift export bans and import taxes because rising of the food prices due to low food supply can be prevented by lowering the import tariffs (FAO, 2020j; 2020c).

As a result, the protectionism in food trade included different forms of taxes, tariffs, non-tariff barriers, and restrictions (Beghin, 2014; Ghazalian, 2019). However, implementation of these policies resulted in a gap between demand and supply, leading to a sharp rise in global food prices in the medium and long term. Therefore, economically vulnerable customers are the most affected group in the remaining actors in the supply chain. However, the opposite was also possible in the short term since excess of national supply occurs because the export restrictions and small-holder farmers face economic problems due to the reduction in the domestic prices. Therefore, restrictions and bans should be lifted to improve farming productivity and ensure food and nutrition security during COVID-19 outbreak because the effects of COVID-19 on rich and poor people are different but we are connected to each other by mean of globalization and humanity

(Gardner, 2001; WFP, 2020b; Espitia *et al.*, 2020). Therefore, restraint of trade is not only unnecessary, and it also harms all the actors in the food supply chain and creates panic and fear in the markets (Liu *et al.*, 2020).

## Conclusions

During a pandemic, continuing the flow of the supply in agriculture and food sector, which is one of the most important sectors together with health, is vital to prevent the food crisis and reducing the negative impact on the global economy. Although no major problems have been observed in the food supply chains so far it remains unclear in the face of an uncertain future. As a result, each country has to realize the severity of the situation and sometimes should tighten or loosen the measures according to the spread of the pandemic. The supply chain also should be flexible enough to respond to the challenges in the food supply chain.

## Author Contributions

Serpil Aday and Mehmet Seckin Aday chose the review topic, conducted the literature review and wrote the manuscript.

## Conflicts of Interest

The authors declare no conflict of interest.

## References

- AgriLinks. (2020). Preventing global food security crisis under COVID-19 [Online]. <https://www.agrilinks.org/post/preventing-global-food-security-crisis-under-covid-19-emergency>. Accessed on Mar. 20, 2020.
- 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.
- Almena, A., Fryer, P. J., Bakalis, S., *et al.* (2019a). 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.
- Almena, A., Lopez-Quiroga, E., Fryer, P. J., *et al.* (2019b). Towards the decentralisation of food manufacture: effect of scale production on economics, carbon footprint and energy demand. *Energy Procedia*, 161: 182–189.
- Alonso, E., Gregory, J., Field, F., *et al.* (2007). Material availability and the supply chain: risks, effects, and responses. *Environmental Science and Technology*, 41: 6649–6656.
- Arellano, N. (2020). Norway denies seafood link to new COVID-19 infections in China. *Rastech Magazine* [Online]. <https://www.rastechmagazine.com/norway-denies-seafood-link-to-new-covid-19-infections-in-china/>. Accessed on Jul. 6, 2020.
- Arianina, K., Morris, P. (2020). COVID-19 Export Restrictions Threaten Global Food Supply [Online]. <https://www.squirepattonboggs.com/-/media/files/insights/publications/2020/05/covid-19-export-restrictions-threaten-global-food-supply/law360covid19exportrestrictionsthreatenglobalfoodsupply.pdf>. Accessed on Jul. 24, 2020.
- Artiga, S., Rae, M. (2020). The COVID-19 Outbreak and Food Production Workers: Who is at Risk?. Kaiser Family Foundation [Online]. <https://www.kff.org/coronavirus-covid-19/issue-brief/the-covid-19-outbreak-and-food-production-workers-who-is-at-risk/>. Accessed on Jul. 5, 2020.
- Askew, K. (2020). Life in lockdown: Coronavirus prompts half of French consumers to reappraise "value" of food [Online]. <https://www.foodnavigator.com/Article/2020/05/29/Life-in-lockdown-Coronavirus-prompts-half-of-French-consumers-to-reappraise-value-of-food>. Accessed on May 29, 2020.

- Bakalis, S., Valdramidis, V. P., Argyropoulos, *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.
- Baldos, U. L. C., Hertel, T. W. (2015). The role of international trade in managing food security risks from climate change. *Food Security*, 7: 275–290.
- Barichello, R. (2020). The COVID-19 pandemic: anticipating its effects on Canada's agricultural trade. *Canadian Journal of Agricultural Economics*, 68: 219–224.
- BBC (British Broadcasting Corporation). (2020a). Coronavirus: Five ways the outbreak is hitting global food industry [Online]. <https://www.bbc.com/news/world-52267943>. Accessed on Jul. 6, 2020.
- BBC (British Broadcasting Corporation). (2020b). Coronavirus: Virus outbreaks push Germany to clean up abattoirs [Online]. <https://www.bbc.com/news/world-europe-52738356>. Accessed on Jul. 5, 2020.
- Beghin, J. C. (2014). The protectionism of food safety standards in international agricultural trade. *Agricultural Policy Review*, 2014: 7–9.
- Bendeković, J., Naletina, D., Nola, I. (2015). Food safety and food quality in the supply chain. *Trade Perspectives*, 151–163.
- Bowler, A. L., Bakalis, S., Watson, N. J. (2020). A review of in-line and on-line measurement techniques to monitor industrial mixing processes. *Chemical Engineering Research and Design*, 153: 463–495.
- Carnevale, J. B., Hatak, I. (2020). Employee adjustment and well-being in the era of COVID-19: implications for human resource management. *Journal of Business Research*, 116: 183–187.
- CDC (Centers for Disease Control and Prevention). (2020a). Agriculture Workers & Employers [Online]. <https://www.cdc.gov/coronavirus/2019-ncov/community/guidance-agricultural-workers.html>. Accessed on Aug. 5, 2020.
- CDC (Centers for Disease Control and Prevention). (2020b). COVID-19 Critical Infrastructure Sector Response Planning, Centers for Disease Control and Prevention [Online]. <https://www.cdc.gov/coronavirus/2019-ncov/community/organizations/meat-poultry-processing-workers-employers.html>. Accessed on Jul. 22, 2020.
- Chin, A., Chu, J., Perera, M., *et al.* (2020). Stability of SARS-CoV-2 in different environmental conditions. *The Lancet Microbe*, 1(1): E10.
- Clift, K., Court, A., (2020). How are companies responding to the coronavirus crisis?. World Economic Forum [Online]. <https://www.weforum.org/agenda/2020/03/how-are-companies-responding-to-the-coronavirus-crisis-d15bed6137f>. Accessed on Aug. 5, 2020.
- Cranfield, J. A. L. (2020). Framing consumer food demand responses in a viral pandemic. *Canadian Agricultural Economics Society*, 68: 151–156.
- CREA (The Council for Agricultural Research and Economics). (2020). How did Italian eating habits change during lockdown? [Online]. <https://www.foodnavigator.com/Article/2020/06/05/Coronavirus-lockdown-found-toworsen-childhood-obesity>. Accessed on Jun. 12, 2020.
- Crisp. (2020). Get a LIVE view into COVID-19 effects on in-store purchases [Online]. <https://www.gocrisp.com/demandwatch>. Accessed on May 29, 2020.
- Dalton, J. (2020). Coronavirus: Fears of second wave in China as dozens test positive in outbreak at Beijing food market. *Independent* [Online]. <https://www.independent.co.uk/news/world/asia/coronavirus-beijing-china-outbreak-xinfandi-food-meat-market-a9564816.html>. Accessed on Jul. 5, 2020.
- Davison, L. (2019). The temporary liquidity guarantee program: a systemwide systemic risk exception. *Journal of Financial Crises*, 1: 1–39.
- DeBroff, S. (2020). How COVID-19 Has Impacted Consumer Food Habits [Online]. <https://www.foodmanufacturing.com/consumer-trends/blog/21133823/how-covid19-has-impacted-consumer-food-habits>. Accessed on May 22, 2020.
- Deng, Q., Zinoviadou, K. G., Galanakis, C. M. *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.
- De Sousa Jabbour, A. B. L., Jabbour, C. J. C., Hingley, M., *et al.* (2020). Sustainability of supply chains in the wake of the coronavirus (COVID-19/SARS-CoV-2) pandemic: lessons and trends. *Modern Supply Chain Research and Applications*, in press.
- Devereux, S., Béné, C., Hoddinott, J. (2020). Conceptualising COVID-19's impacts on household food security. *Food Security*, 12: 769–772.
- Dodson, C. (2014). Bank size, lending paradigms, and usage of Farm Service Agency's guaranteed loan programs. *Agricultural Finance Review*, 74: 133–152.
- Donohue, R. J., Lawes, R. A., Mata, G., *et al.* (2018). Towards a national, remote-sensing-based model for predicting field-scale crop yield. *Field Crops Research*, 227: 79–90.
- DOS (United States Department of State). (2011). Food prices crisis of 2007–2008: Lessons learned [Online]. <https://reliefweb.int/report/world/foodprices-crisis-2007-2008-lessons-learned>. Accessed on Apr. 17, 2020.
- Douglas, L. (2020). Mapping Covid-19 outbreaks in the food system, Food & Environment Reporting Network [Online]. <https://thefern.org/2020/04/mapping-covid-19-in-meat-and-food-processing-plants/>. Accessed on Jul. 4, 2020.
- EC (European Commission). (2020). COVID-19 and food safety-questions and answers, European Commission [Online]. [https://ec.europa.eu/food/sites/food/files/safety/docs/biosafety\\_crisis\\_covid19\\_qandas\\_en.pdf](https://ec.europa.eu/food/sites/food/files/safety/docs/biosafety_crisis_covid19_qandas_en.pdf). Accessed on Apr. 10, 2020.
- EDP (European Data Portal). (2020). Shedding Light on Changing Consumer Behaviour with Economic Data [Online]. <https://www.europeandataportal.eu/en/covid-19/stories/shedding-light-changing-consumer-behaviour-economic-data>. Accessed on Jul. 23, 2020.
- Espitia, A., Rocha, N., Ruta, M. (2020). 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. 1–30.
- FAO (Food and Agriculture Organization of the United Nations). (2005). Decentralized Development in Agriculture, Food and Agriculture Organization [Online]. [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 Jul. 23, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2011). Lessons from the world food crisis of 2006–08, Food and Agriculture Organization [Online]. <http://www.fao.org/3/i2330e/i2330e04.pdf>. Accessed on Apr. 02, 2020.
- FAO (Food and Agriculture Organization of the United Nations), WHO (World Health Organization). (2020). COVID-19 and Food Safety: Guidance for food businesses: Interim guidance [Online]. <http://www.fao.org/3/ca8660en/CA8660EN.pdf>. Accessed on Apr. 17, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020a). Adjusting business models to sustain agri-food enterprises during COVID-19 [Online]. <http://www.fao.org/3/ca8996en/CA8996EN.pdf>. Accessed on May 15, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020b). Ample supplies to help shield food markets from the COVID -19 crisis [Online]. <http://www.fao.org/documents/card/en/c/ca8445en>. Accessed on Apr. 10, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020c). COVID-19 and the risk to food supply chains: How to respond? [Online]. <http://www.fao.org/3/ca8388en/CA8388EN.pdf>. Accessed on Apr. 3, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020d). COVID-19 and smallholder producers' access to markets [Online]. <http://www.fao.org/3/ca8657en/CA8657EN.pdf>. Accessed on Apr. 17, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020e). Extension and advisory services: at the frontline of the response to COVID-19 to ensure food security [Online]. <http://www.fao.org/3/ca8710en/CA8710EN.pdf>. Accessed on Apr. 24, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020f). Food systems and COVID-19 in Latin America and the Caribbean: Impact and risks in the labour market [Online]. <http://www.fao.org/3/ca9237en/CA9237EN.pdf>. Accessed on May 8, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020g). Impacts of coronavirus on food security and nutrition in Asia and the Pacific: building more resilient food systems [Online]. <http://www.fao.org/3/ca9473en/CA9473EN.pdf>. Accessed on Jun. 12, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020h). Interim guidance: sustaining FAO's commitment to Environmental and So-



- cial Standards during the COVID-19 pandemic [Online]. <http://www.fao.org/3/ca9290en/CA9290EN.pdf>. Accessed on Jun. 5, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020i). Legal mechanisms to contribute to safe and secured food supply chains in time of COVID-19 [Online]. <http://www.fao.org/3/ca9121en/CA9121EN.pdf>. Accessed on May 29, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020j). Policy responses to keep input markets flowing in times of COVID-19 [Online]. <http://www.fao.org/3/ca8979en/CA8979EN.pdf>. Accessed on May 8, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020k). Responding to the impact of the COVID-19 outbreak on food value chains through efficient logistics [Online]. <http://www.fao.org/3/ca8466en/CA8466EN.pdf>. Accessed on Apr. 24, 2020.
- FAO (Food and Agriculture Organization of the United Nations). (2020l). Why export restrictions should not be a response to COVID-19: Learning lessons from experience with rice in Asia and the Pacific [Online]. <http://www.fao.org/3/ca9362en/CA9362EN.pdf>. Accessed on Jun. 5, 2020.
- FDA (The U.S. Food and Drug Administration). (2020). FDA Provides Temporary Flexibility Regarding Packaging and Labeling of Shell Eggs Sold to Consumers by Retail Food Establishments During COVID-19 Pandemic [Online]. <https://www.fda.gov/food/cfsan-constituent-updates/fda-provides-temporary-flexibility-regarding-packaging-and-labeling-shell-eggs-sold-consumers-retail>. Accessed on Jul. 22, 2020.
- Feng, E. Cheng, A. (2020). Lockdown Measures Return To Beijing As Testing Reveals Cluster At Major Food Market [Online]. <https://www.npr.org/sections/coronavirus-live-updates/2020/06/14/876750764/lockdown-measures-return-to-beijing-as-testing-reveals-cluster-at-major-food-mar>. Accessed on Jul. 6, 2020.
- Fitton, N., Alexander, P., Arnell, N., et al. (2019). The vulnerabilities of agricultural land and food production to future water scarcity. *Global Environmental Change*, 58: 101944.
- Fleetwood, J. (2020). Social justice, food loss, and the sustainable development goals in the Era of COVID-19. *Sustainability*, 12: 5027.
- Flynn, D. (2020). CDC provides first guidance to a specific meat plant for combating COVID-19 among employees [Online]. <https://www.foodsafetynews.com/2020/04/cdc-provides-first-guidance-to-a-specific-meat-plant-for-combating-covid-19-among-employees/>. Accessed on May 1, 2020.
- Fyles, H., & Madramootoo, C. (2016). Key drivers of food insecurity, In *Emerging Technologies for Promoting Food Security*. Woodhead Publishing, pp. 1–19.
- Galanakis, C. M., (2012). Recovery of high added-value components from food wastes: conventional, emerging technologies and commercialized applications. *Trends in Food Science & Technology*, 26: 68–87.
- Galanakis, C. M., (2013). Emerging technologies for the production of nutraceuticals from agricultural by-products: a viewpoint of opportunities and challenges. *Food and Bioprocess Technology*, 91: 575–579.
- Galanakis, C. M., (2020). The food systems in the Era of the Coronavirus (COVID-19) Pandemic Crisis. *Food*, 9: 523.
- Gardner, B. L., (2001). Agriculture, Economics of International Encyclopedia of the Social & Behavioral Sciences, Pergamon. In: Neil J. Smelser, Paul B. Baltes (Eds.). Elsevier Amsterdam, Netherlands, 2001: 337–344.
- Ghazalian, P. L. (2019). Canada's beef exports: border effects and prospects for market access. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 67: 53–74.
- Globaltimes. (2020). Beijing's largest vegetables supplying base shut down as novel coronavirus detected among some merchants [Online]. <https://www.globaltimes.cn/content/1191455.shtml>. Accessed on Jul. 5, 2020.
- Gneiting, U., Sonenshine, J. (2018). A living income for small-scale farmers: tackling unequal risks and market power. *Oxfam Discussion Papers*, 1–24.
- Good, K. (2020). China's Restrictions on Food Imports Meet Resistance from Exporters, Illinois Farm Policy News [Online]. <https://farmpolicynews.illinois.edu/2020/06/chinas-restrictions-on-food-imports-meet-resistance-from-exporters/>. Accessed on Jul. 3, 2020.
- Gulland, A. (2020). Revealed: why meat processing plants are the ideal incubator of the coronavirus. *The Telegraph* [Online]. <https://www.telegraph.co.uk/global-health/science-and-disease/revealed-meat-processing-plants-ideal-incubator-coronavirus/>. Accessed on Jul. 5, 2020.
- Headey, D., Heidkamp, R., Osendarp, S., et al. (2020). Impacts of COVID-19 on childhood malnutrition and nutrition-related mortality. *The Lancet*, 396: 519–521.
- Hobbs, J. E. (2020). Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 68: 171–176.
- Hua, J., Cadell, C., (2020). Beijing district in 'wartime emergency' after virus cluster at major food market. *Reuters* [Online]. <https://www.reuters.com/article/us-health-coronavirus-beijing-idUSKBN23K03V>. Accessed on Jul. 6, 2020.
- Hueston, W., McLeod, A., (2012). Overview of the global food system: changes over time/space and lessons for future food safety. In: Institute of Medicine (US). Improving Food Safety Through a One Health Approach: Workshop Summary. National Academies Press (US), Washington (DC), page.
- Hufnagel, J., Reckling, M., Ewert, F. (2020). Diverse approaches to crop diversification in agricultural research. A review. *Agronomy for Sustainable Development*, 40: 14.
- Hughes, M. (2020). Evolving eating habits as a result of COVID-19 [Online]. <https://www.newfoodmagazine.com/article/109890/evolving-eating-habits-as-a-result-of-covid-19/>. Accessed on May 15, 2020.
- IATA (International Air Transport Association). (2020). IATA Updates COVID-19 Financial Impacts -Relief Measures Needed [Online]. <https://www.iata.org/en/pressroom/pr/2020-03-05-01/>. Accessed on Jul. 22, 2020.
- ICC (International Chamber of Commerce), WHO (World Health Organization). (2020). ICC-WHO Joint Statement: An unprecedented private sector call to action to tackle COVID-19 [Online]. <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 Jul. 24, 2020.
- IFIC (International Food Information Council). (2020). COVID-19 Impact on food purchasing, eating behaviors, and perceptions of food safety [Online]. <https://foodinsight.org/consumer-survey-covid-19s-impact-on-food-purchasing/>. Accessed on Apr. 17, 2020.
- IFPRI (International Food Policy Research Institute). (2020). COVID-19 food trade policy tracker [Online]. <https://www.ifpri.org/project/covid-19-food-trade-policy-tracker>. Accessed on Jun. 12, 2020.
- ILO (International Labour Organization). (2020). COVID-19 and the impact on agriculture and food security [Online]. [https://www.ilo.org/wcmsp5/groups/public/-ed\\_dialogue/-sector/documents/briefingnote/wcms\\_742023.pdf](https://www.ilo.org/wcmsp5/groups/public/-ed_dialogue/-sector/documents/briefingnote/wcms_742023.pdf). Accessed on Apr. 24, 2020.
- IPES (The International Panel of Experts on Sustainable Food System). (2020). COVID-19 and the crisis in food systems: Symptoms, causes, and potential solutions [Online]. [http://www.ipes-food.org/\\_img/upload/files/COVID-19\\_CommuniqueEN.pdf](http://www.ipes-food.org/_img/upload/files/COVID-19_CommuniqueEN.pdf). Accessed on Apr. 17, 2020.
- Iqbal, J., Khan, Z. H., Khalid, A. (2017). Prospects of robotics in food industry. *Food Science and Technology*, 37: 159–165.
- ITC (International Trade Centre). (2020). Unsung Heroes: How Small Farmers Cope with COVID-19 [Online]. [https://www.intracen.org/uploadedFiles/intracenorg/Content/Publications/Unsung\\_Heroes\\_Low-res.pdf](https://www.intracen.org/uploadedFiles/intracenorg/Content/Publications/Unsung_Heroes_Low-res.pdf). Accessed on Jul. 24, 2020.
- Iyanda, J. O., Afolami, C. A., Obayelu, A. E., et al. (2014). Social capital and access to credit among cassava farming households in Ogun State, Nigeria. *Journal of Agriculture and Environmental Sciences*, 3: 175–196.
- Jackson, A., Yurkevich, V. (2020). Farmers are throwing out food that could go to food banks. American Farm Bureau and Feeding America want to change that, CNN [Online]. <https://edition.cnn.com/2020/04/13/business/farmers-food-supply-food-banks-donations-trnd/index.html>. Accessed on Aug. 6, 2020.
- Jeon, S. (2011). Mechanisms of labor transition during agricultural transformation: the cases of South Korea and Indonesia. *International Conference on Asia Agriculture and Animal IPCBEE*, 13: 21–26.



- Johr, H. (2012). Where are the future farmers to grow our food?. *International Food and Agribusiness Management Review*, 15: 9–11.
- Kaur, G. (2020). Meat Plants Become Hotspots for Covid-19 Across the World [Online]. <https://www.grainmart.in/news/meat-plants-become-hotspots-for-covid-19-across-the-world/>. Accessed on Jul. 3, 2020.
- Ker, A. P. (2020). Risk management in Canada's agricultural sector in light of COVID-19. *Canadian Journal of Agricultural Economics*, 68: 251–258.
- Khanal, A. R., Mishra, A. K. (2016). Financial performance of small farm business households: the role of internet. *China Agricultural Economic Review*, 8: 553–571.
- Levany, S. (2020). US producers “in tears” at having to cull livestock on their farms. *The Guardian* [Online]. <https://www.theguardian.com/environment/2020/jun/10/us-producers-in-tears-at-having-to-cull-livestock-on-their-farms>. Accessed on Jul. 23, 2020.
- Liu, K. (2020). Will COVID-19 lead to a global food crisis? [Online]. <https://news.cgtn.com/news/2020-04-07/Will-COVID-19-lead-to-a-global-food-crisis--Pv0dKM776E/index.html>. Accessed on Apr. 17, 2020.
- Liu, Y. C., Kuo, R. L., Shih, S. R. (2020). COVID-19: the first documented coronavirus pandemic in history. *Biomedical Journal*, in press.
- MAF (Ministry of Agricultural and Forestry). (2020). COVID-19 Precautions [Online]. <https://www.tarimorman.gov.tr>. Accessed on Jul. 26, 2020.
- Martin, P. L. (2016). Migrant Workers in Commercial Agriculture [Online]. [http://www.oit.org/wcmsp5/groups/public/---ed\\_protect/---protrav/---migrant/documents/publication/wcms\\_538710.pdf](http://www.oit.org/wcmsp5/groups/public/---ed_protect/---protrav/---migrant/documents/publication/wcms_538710.pdf). Accessed on Jul. 25, 2020.
- Martin, W. J., Glauber, J. W. (2020). In: COVID-19 and Trade Policy: Why Turning Inward Won't Work. CEPR Press, London. pp. 187.
- Mazili, S. R., (2020). How producers keep the egg supply chain going amid COVID-19 [Online]. <https://ew-nutrition.com/how-producers-keep-the-egg-supply-chain-going-amid-covid-19/>. Accessed on Jul. 22, 2020.
- MIA (Republic of Turkey Ministry of Internal Affairs). (2020). COVID-19 Precautions [Online]. <https://www.icisleri.gov.tr/>. Accessed on Jul. 26, 2020.
- Miranda, M. J., Mulangu, F. M., Kemeze, F. H. (2019). Warehouse receipt financing for smallholders in developing countries: challenges and limitations. *Agricultural Economics*, 50: 629–641.
- Mohan, S. (2020). Private standards and producer risk: a framework for analysis of development implications. *European Review of Agricultural Economics*, 47: 403–437.
- Morawska, L., Cao, J. (2020). Airborne transmission of SARS-CoV-2: the world should face the reality. *Environment International*, 139: 105730.
- 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: 120–128.
- Murphy, C. (2020). Costco to temporarily limit meat purchases to 3 items per person. *USA Today* [Online]. <https://www.usatoday.com/story/money/2020/05/04/costco-limits-meat-purchases-3-items-per-person/3078198001/>. Accessed on Jul. 23, 2020.
- Muscogiuri, G., Barrea, L., Savastano, S., et al. (2020). Nutritional recommendations for CoVID-19 quarantine. *European Journal of Clinical Nutrition*, 74: 850–851.
- Nature Plants. (2020). Food in a time of COVID-19. *Nat. Plants*, 6: 429.
- Ndemezo, E., Ndikubwimana, J. B., Dukunde, A. (2018). Determinants of capacity utilization of food and beverage manufacturing firms in rwanda: do tax incentives matter?. *SSRN*, 1–21.
- Ngai, E. W. T., Cheng, T. C. E., Ho, S. S. M. (2004). Critical success factors of web-based supply-chain management systems: an exploratory study. *Production Planning & Control*, 15: 622–630.
- Nicola, M., Alsafi, Z., Sohrabi, C., et al. (2020). The socio-economic implications of the coronavirus pandemic (COVID-19): a review. *International Journal of Surgery*, 78: 185–193.
- Novascotia. (2020). COVID-19: Agriculture Response Program [Online]. <https://novascotia.ca/coronavirus/agriculture-response-program/>. Accessed on Jul. 26, 2020.
- O'Brien, P., Kruse, J., Kruse, D. (2014). Gauging the farm sector's sensitivity to immigration reform via changes in labor costs and availability. American Farm Bureau Federation, Washington (DC), pp. 1–46.
- OECD (The Organisation for Economic Co-operation and Development). (2020a). COVID-19 and international trade: Issues and actions [Online]. <http://www.oecd.org/coronavirus/policy-responses/covid-19-and-international-trade-issues-and-actions-494da2fa/>. Accessed on Jul. 24, 2020.
- OECD (The Organisation for Economic Co-operation and Development). (2020b). Food Supply Chains and COVID-19: Impacts and Policy Lessons [Online]. <http://www.oecd.org/coronavirus/policy-responses/food-supply-chains-and-covid-19-impacts-and-policy-lessons-71b57aea/>. Accessed on Aug. 5, 2020.
- OECD (The Organisation for Economic Co-operation and Development). (2020c). Managing international migration under COVID-19 [Online]. <http://www.oecd.org/coronavirus/policy-responses/managing-international-migration-under-covid-19-6e914d57/>. Accessed on Aug. 5, 2020.
- OGUK (The UK Oil and Gas Industry Association Limited). (2020). COVID-19 Logistics Best Practice Guidelines [Online]. <https://oilandgasuk.co.uk/wp-content/uploads/2020/05/OGUK-Guideline-COVID-19-Logistics-Best-Practice-May-2020.pdf>. Accessed on Aug. 6, 2020.
- Patton, D. (2020). Food exporters to China asked to declare produce is coronavirus-free [Online]. <https://www.reuters.com/article/us-health-coronavirus-china-food/food-exporters-to-china-asked-to-declare-produce-is-coronavirus-free-idUSKBN23Q1SB>. Accessed on Jul. 3, 2020.
- Paul, S. K. and Chowdhury, P. (2020). A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19. *International Journal of Physical Distribution & Logistics Management*, in press.
- Petetin, L. (2020). The COVID-19 crisis: an opportunity to integrate food democracy into post-pandemic food systems. *European Journal of Risk Regulation*, 11: 326–336.
- Pressman, P., Naidu, A. S., Clemens, R. (2020). COVID-19 and food safety: risk management and future considerations. *Nutrition Today*, 55: 125–128.
- Reddy, V. R., Singh, S. K., Anbumozhi, V. (2016). Food supply chain disruption due to natural disasters: entities, risks, and strategies for resilience. Economic Research Institute for ASEAN and East Asia, pp. 1–36.
- Reiley, L. (2020). Stress-baking and hoarding have led to a retail egg shortage. There are eggs in the pipeline, but maybe not enough. *The Washington Post* [Online]. <https://www.washingtonpost.com/business/2020/03/26/shortages-eggs-stress-baking/>. Accessed on Jul. 24, 2020.
- Reuters. (2020). China finds heavy coronavirus traces in seafood, meat sections of Beijing food market [Online]. <https://www.reuters.com/article/us-health-coronavirus-china-seafood/china-finds-heavy-coronavirus-traces-in-seafood-meat-sections-of-beijing-food-market-idUSKBN23P20T>. Accessed on Jul. 3, 2020.
- Reynold, M. (2020). Supply Chains Race to Match Shifting COVID-19 Consumer Behavior. *Packaging World* [Online]. <https://www.packworld.com/covid-19/article/21132561/supply-chains-race-to-match-shifting-covid-19-consumer-behavior>. Accessed on Jul. 23, 2020.
- Richard, M., Kok, A., de Meulder, D., et al. (2020). SARS-CoV-2 is transmitted via contact and via the air between ferrets. *Nature Communications*, 11: 3496.
- Richards, T. J., Rickard, B. (2020). COVID-19 impact on fruit and vegetable markets. *Canadian Journal of Agricultural Economics*, 68: 189–194.
- Rizou, M., Galanakis, I. M., Aldawoud, T. M. S., et al. (2020). Safety of foods, food supply chain and environment within the COVID-19 pandemic. *Trends in Food Science & Technology*, 102: 293–299.
- Rodriguez-Pérez, C., Molina-Montes, E., Verardo, V., et al. (2020). Changes in Dietary Behaviours during the COVID-19 Outbreak Confinement in the Spanish COVIDiet Study. *Nutrients*, 12: 1730.
- Rossi, R. (2020). Protecting the EU agri-food supply chain in the face of COVID-19. European Parliamentary Research Service [Online]. [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 Jul. 25, 2020.

- Rude, J. (2020). COVID-19 and the Canadian cattle/beef sector: some preliminary analysis. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 68: 207–213.
- Sebastian, J. (2020). Crisis Communication Best Practices for Food Safety Professionals [Online]. <https://www.foodqualityandsafety.com/article/crisis-communication-best-practices-for-food-safety-professionals/>. Accessed on Mar. 27, 2020.
- Shafiee-Jood, M., Cai, X. (2016). Reducing food loss and waste to enhance food security and environmental sustainability. *Environmental Science & Technology*, 50: 8432–8443.
- 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: 1087–1094.
- Shahidi, F. (2020). *Journal of Food Bioactives*, 9: 1–3.
- Sharma, H. B., Vanapalli, K. R., Cheela, V. R. S., et al. (2020). Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic. *Resources, Conservation and Recycling*, 162: 105052.
- Staniforth, J. (2020). COVID-19 update: Worker health, absenteeism present largest risks to U.S. food supply chain [Online]. <https://www.foodqualityandsafety.com/article/covid-19-update-worker-health-and-absenteeism-present-largest-risk-to-u-s-food-supply-chain>. Accessed on Mar. 20, 2020.
- Stephens, E. C., Martin, G., van Wijk, M., et al. (2020). Editorial: impacts of COVID-19 on agricultural and food systems worldwide and on progress to the sustainable development goals. *Agricultural Systems*, 183: 102873.
- Stewart, A., Kottasova, I. Khaliq, A. (2020). Why meat processing plants have become Covid-19 hotbeds [Online]. <https://edition.cnn.com/2020/06/27/health/meat-processing-plants-coronavirus-intl/index.html>. Accessed on Jul. 3, 2020.
- Tetteh Anang, B., Sipiläinen, T. A. I., Bäckman, et al. (2015). Factors influencing smallholder farmers' access to agricultural microcredit in Northern Ghana. *African Journal of Agricultural Research*, 10: 2460–2469.
- Troskie, D. P. (2020). Impact of Covid-19 on Agriculture and Food in the Western Cape. Western Cape Department of Agriculture [Online]. <https://www.hortgro.co.za/wp-content/uploads/docs/2020/03/agricultural-scenarios.pdf>. Accessed on Aug. 6, 2020.
- UNTWO (World Tourism Organization). (2020). International Tourist Numbers Could Fall 60–80% In 2020 [Online]. <https://www.unwto.org/news/covid-19-international-tourist-numbers-could-fall-60-80-in-2020>. Accessed on Jul. 22, 2020.
- USDA (U.S. Department of Agriculture). (2020). Coronavirus and USDA Assistance for Farmers [Online]. <https://www.farmers.gov/coronavirus>. Accessed on Jul. 26, 2020.
- Valinsky, J. (2020). One in five Wendy's is out of beef, analyst says. CNN (Cable News Network) [Online]. <https://edition.cnn.com/2020/05/05/business/wendys-beef-shortage/index.html>. Accessed on Jul. 23, 2020.
- Van Doremalen, N., Bushmaker, T., Morris, D. H., et al. (2020). Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *New England Journal of Medicine*, 382: 1564–1567.
- Vasavada, P. (2020). COVID-19 and the food industry: What we know [Online]. <https://www.foodqualityandsafety.com/article/covid-19-and-the-food-industry-what-we-know>. Accessed on Mar. 27, 2020.
- Waller, M. A., Fawcett, S. E. (2013). Data science, predictive analytics, and big data: a revolution that will transform supply chain design and management. *Journal of Business Logistics*, 34: 77–84.
- Wang, J., Wang, Z. F. (2020). Strengths, weaknesses, opportunities and threats (Swot) analysis of china's prevention and control strategy for the covid-19 epidemic. *International Journal of Environmental Research and Public Health*, 17: 2235.
- Watts, J. (2020). World Food Safety Day Is an Opportunity to Thank Those at Every Step Along The Food Chain [Online]. <https://www.foodqualityandsafety.com/article/guest-column-world-food-safety-day-is-an-opportunity-to-thank-those-at-every-step-along-the-food-chain/>. Accessed on Jun. 12, 2020.
- WFP (World Food Programme). (2020a). COVID-19 will double number of people facing food crises unless swift action is taken [Online]. <https://www.wfp.org/news/covid-19-will-double-number-people-facing-food-crises-unless-swift-action-taken>. Accessed on Aug. 5, 2020.
- WFP (World Food Programme). (2020b). COVID-19: Potential impact on the world's poorest people [Online]. <https://www.wfp.org/publications/covid-19-potential-impact-worlds-poorest-people>. Accessed on Aug. 5, 2020.
- WHO (World Health Organization). (2020a). 2019 Novel Coronavirus (2019-nCoV): Strategic preparedness and response plan [Online]. [https://www.who.int/docs/default-source/coronaviruse/srp-04022020.pdf?sfvrsn=7ff55ec0\\_4&download=true](https://www.who.int/docs/default-source/coronaviruse/srp-04022020.pdf?sfvrsn=7ff55ec0_4&download=true). Accessed on Mar. 13, 2020.
- WHO (World Health Organization). (2020b). WHO Coronavirus Disease (COVID-19) Dashboard [Online]. <https://covid19.who.int/>. Accessed on Aug. 5, 2020.
- WHO (World Health Organization). (2020c). WHO Director-General's opening remarks at the media briefing on COVID-19 [Online]. <https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020>. Accessed on Mar. 13, 2020.
- Winter, C. K., Davis, S. F. (2006). Organic foods. *Journal of food science*, 71: 117–124.
- 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: 439–460.
- Ziady, H., Halasz, S., Kottasova, I. (2020). The giant meatpacking company at the heart of Germany's new coronavirus hotspot. CNN (Cable News Network) Business [Online]. <https://edition.cnn.com/2020/06/22/business/meat-plant-germany-coronavirus-outbreak/index.html>. Accessed on Jul. 5, 2020.