Heliyon 10 (2024) e35154

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

Global impact of COVID-19 on food safety and environmental sustainability: Pathways to face the pandemic crisis

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ARTICLE INFO

Keywords:
Post COVID-19 era
Environmental impact of COVID-19
Global price index
Nutrition
SARS-CoV-2 detection
COVID test

ABSTRACT

The COVID-19 pandemic poses ongoing challenges to the sustainability of various socioeconomic sectors, including agriculture, the food supply chain, the food business, and environmental sustainability. This study employs data obtained from the World Health Organization (WHO), and Food and Agriculture Organization (FAO), as well as scientific and technical research publications, to evaluate the impacts of COVID-19 on agriculture and food security. This article seeks to highlight the profound influence of the COVID-19 pandemic on agriculture, the supply and demand of food, and the overall safety of food. The article also explores the several pathways by which COVID-19 can be transmitted in these areas and the various technologies employed for its detection. The ongoing and post-pandemic ramifications are substantial since they could decrease agricultural output due to limitations on migration, a downturn in international trade, less buying capacity, and disturbances in food production and processing. Therefore, based on this thorough investigation, recommendations are issued for mitigating and controlling the pandemic's effects.

1. Introduction

The coronavirus first occurred in China in late 2019 and has since erupted around the world, making it one of the most challenging human pandemics in recent history. The coronavirus SARS-CoV-2 is recognized to produce COVID-19, a contagious infection that can be passed from one person to another person easily since such a virus is airborne through the cough, sneeze, or exhalation of respiratory droplets [1. Animals can contact coronaviruses, and occasionally humans can get them as well. Indeed, zoonotic transmission is thought to be responsible for the banquet of MERS, SARS-CoV, and SARS-CoV-2 [2,3]. Nonetheless, the only one with pandemic potential is SARS-CoV-2 [4]. The Coronavirinae subfamily of the Coronaviridae family comprises the genera Alpha, Beta, Gamma, and Delta, which are all coronavirus varieties identified so far. Positive-sense RNA, single-stranded coronaviruses can infect either zoonotic or human animals [5,6].

In May 2023, more than three years after the pandemic began, the World Health Organisation (WHO, https://www.who.int/) determined that COVID-19 was no longer a global emergency and encouraged states to treat it in the same manner that other infectious diseases are. The COVID-19 pandemic's negative consequences on the social, economic, and psychological sectors are still being felt today [7]. The COVID-19 pandemic has posed significant challenges for global health, economic, and political institutions As of March 3, 2024, there have been about 774.8 million confirmed cases and 7 million fatalities globally [8]. As the illness has spread over the

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https://doi.org/10.1016/j.heliyon.2024.e35154
Received 23 October 2023; Received in revised form 22 July 2024; Accepted 23 July 2024
Available online 24 July 2024
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world, there has been a growing interest in identifying the elements that contribute to COVID-19 fatalities and cases. Understanding the socioeconomic, demographic, and health factors that impact COVID-19 cases and mortality is crucial. COVID-19's impacts began in late 2019 and peaked in 2020, with rising death rates. Vaccines were authorized in late 2020, and most nations began using them about 2020, spreading by 2021 [9]. The Omicron variety, on the other hand, was introduced in late 2021 and had a significant influence in 2022 [10].

Animals that serve as reservoir hosts for Coronaviruses include cats, bats, cattle, mammals, and other species. Bats and other mammals are hosts to alpha- and beta-coronaviruses. Delta coronaviruses infect birds and mammals, whereas gamma coronaviruses mainly infect birds and a few mammalian species [11,12]. Animal Coronaviruses are recognized to cause severe infections in animals and have the potential to inflict financial losses in birds or domestic animals [13,14]. Eating non-common creatures like horseshoe bats, which are a massive resource of SARS-related viruses, was connected to the early SARS-CoV-2 cases [15,16]. Living and dead snakes, muskrats, rabbits, and reindeer organs are among the items sold at Huanan Seafood Market. 2020. Apart from killing millions of humans, this virus also affects society by disrupting health systems, upending the global economy, including food and agriculture, and causing long-term geopolitical developments [17]. An international state of emergency has been declared in response to the coronavirus pandemic, which threatens food security, food systems, and agriculture [18,19]. Historic epidemics that the world has endured, the alarming COVID-19 situation and the advised quarantine have been viewed for their impact on productivity and human enterprises [20].

Coronavirus has caused significant danger to agricultural production as of early 2020 [21], and the pandemic would have caused an additional 80.4 million people (9.1 %) to be included in the poverty list. Due to lockdowns, about 65 % of the current poor population would have suffered [22]. Due to complete or partial job closures, the International Labor Organization (ILO) calculated that COVID-19 overestimated the size of the global labor force by 81 % (2.7 billion workers) [23]. Life and livelihood are at risk due to the COVID-19 pandemic, it has a negative impression on agricultural and global food security. Furthermore, it also increases the [24] mine and starvation at a higher rate. However, the prevalence of the epidemic is gradually declining and even rising in some countries [25]. There is a need to address this issue on a global scale. Without prompt action, emergency conditions threaten the security of the worldwide food supply [26].

Businesses have been forced by COVID-19 to reassess risks and possibilities, rethink fundamentals, and change their procedures in a direction to guarantee superior worker protection while also giving consumers assurance and building confidence among all parties [27]. Due to government restrictions, most businesses were forced to close their doors. Still, the food industry and agriculture, as the backbone of the economy of developing countries [28] are vital components of the nation's infrastructure and continued to function along the supply chain to feed the population [29]. Because of uncertainty and people's limited purchasing power, the demand for food has decreased marginally. However, if the pandemic persists for longer as a consequence of new appearances of COVID variants, the situation could worsen because of reduced earnings and job losses [30]. The COVID-19 outbreak created major financial challenges for people with low incomes, affecting them in several ways, including job loss, restricted working hours, and lost employment benefits [31].

The disruption of international trade in commodities has prevented exporting food goods and importing raw materials [32]. The pandemic has more negatively obstructed some food supplies than others. As a result, it is fair to expect significant trade restrictions, such as more expensive inspections, onerous rules, and protectionist acts from competitors [27]. Food stability depends extensively on international trading as part of supply or distribution systems; if any global shock disrupts this, the consequences for food security could be severe and long-lasting. Historically, trade barriers or limits executed by governments to regulate pricing have dominated possible motorists of changes in worldwide commerce on the harmful side, and trade agreements aimed to secure local food supply on the positive side [33]. For instance, throughout the 2007–2008 global hunger crisis, 33 out of 105 countries implemented food policy restrictions [34].

Due to restrictions on movement and low purchasing power, as well as a significant effect on the most susceptible population groups, there is a significant effect on food demand and, subsequently, food security. COVID-19-related shutdowns, mobility restrictions, and supply-demand imbalances seriously affected the food economy in Bangladesh [35].

Since the food supply chain is a must, governments implement more extensive and successful steps to halt the virus's transmission as cases increase, influencing the international food system [36]. The COVID-19 epidemic is predictable to have adverse health and economic effects in Africa [37]. This goal of this paper is to analyze the recent research and effects of COVID-19 on agriculture and food security to provide some prognostications based on projections of the pandemic's evolution.

Furthermore, COVID-19 has had severe and indirect effects on the physical world. Over the previous several months, there has been a dramatic rise in the use of environmentally damaging products including pesticides, soaps, detergents, single-use plastic, etc. [38,39]. In the case of hygienic use products for hand disinfection may also provoke chemical cross-contamination in food elaboration. Several communities have undergone a massive cleanup effort in recent months, sprucing up everything from roads and buildings to whole neighborhoods and downtown cores. Furthermore, there has been an enormous surge in the use of hand sanitizers. Key preventative measures during the continuing pandemic include using personal protective equipment (PPE) kits, face masks, and gloves [40–42]. The environment may suffer the ill effects of further pollution if their usage suddenly increases. The quantity of clinical trashes being created not only in China but worldwide is very high, with estimates putting the number at almost four times the average number of rubbish days [43]. Therefore, this paper also covers an overview of COVID-19's effects on the agricultural industry, food supply, food chain, and environmental sustainability, focusing on issues with global food security and consumer behavior during lockdowns. Additionally, it emphasizes the necessity of resource management by enforcing justifiable rules and suggests feasible strategies for reducing a pandemic's instant and long-term effects.

2. The advent of COVID-19 pandemic

Wuhan, Hubei Province, China, stated the discovery of the seventh human coronavirus related to severe acute respiratory disease [44]. In December 2019, there were an alarming number of pneumonia cases with no recognized cause in Wuhan. Later, the unidentified viral infection was thought to have originated in a small, restricted fish and wild animal market [45]. The World Health Organization designated the sickness as COVID-19, or coronavirus disease 2019, and the virus as SARS-CoV-2 on February 11. Since then, the virus has been exponentially propagated all across the world [46].

Coronavirus is a member of a vast virus family that socializes with both animals and humans. (Table 1). SARS-CoV-2 has distinctive characteristics that set it apart from other coronaviruses, conferring to genomic study and comparison with formerly identified coronavirus genomes: The S1/S2 spike junction has a polybasic cleavage site and the highest attraction for the angiotensin-converting enzyme 2 (ACE2) receptors, which determines contamination and host diversity [47,48].

Patients infected with SARS-CoV-2 may experience minor to severe symptoms, and a significant minority of hosts are asymptomatic. The most commonly reported indicators are fever (83 %), cough (82 %), and shortness of breath (31 %). Chest X-rays of pneumonia patients frequently show mottling and ground glass opaqueness [49,50]. Nevertheless, a significant proportion of COVID-19 patients develop a severe case of the infection, which can result in serious respiratory illnesses, hypoxia, dyspnea, neurological insufficiencies, acute heart injury, severe kidney, liver, and abdominal problems, secondary bacterial infections, and even death [51,52]. COVID-19, like other respiratory viruses, distributes mainly by the respiratory route with a high propagation rate and contamination [53,54].

The usual time between the symptoms appearing and mortality is 2–8 weeks, with the most prolonged incubation period reported to be 14 days [55]. Nevertheless, depending on the patient's age, immune response, and other comorbid conditions like diabetes, cardiovascular infection, cerebrovascular disease, lingering lung kidney disease, endocrine disease, and respiratory insufficiencies, the commonness and maturation for trifling or severe cases may vary [56,57]. Healthcare facilities are the most vulnerable to coronavirus. Many studies have found significant environmental adulteration in COVID-19 patients' quarters [58–61].

The COVID-19 crisis has changed individual daily habits: isolation, remote working, raised sedentary behavior and the frequency of eating and snacking, mood changes, anxiety, and health concerns have molded the choices and motives behind food preferences, outlet selection, and purchasing methods. The COVID-19 has changed the world and will continue to evolve, care for one another, and live, rehabilitation services now need to adjust to a COVID-infected environment [62]. Cross-sector, multiagency working must continue at scale as countries appear from the COVID-19 epidemic to address the need for rehabilitation brought on by the epidemic. To enable older people to live well for longer despite COVID-19, our revolution of rehabilitation must give a needs-based, individualized approach close to home [63], while the epidemic's major impact on agricultural labor input was directly on the mobility restriction of raw materials, affecting the food supply chain and the food industry [64]. This latter aspect is fully addressed and analyzed on the next section of this review.

3. Impact of COVID-19 on agriculture

COVID-19 affects the agricultural sectors, plus horticultural activities, livestock and fisheries. The crop farming events are adjourned due to a sanction on going outside the houses. A lot of farmers avoid conducting business because they must be at home. This latter aspect affects the issue of sustaining crops, which have poorly become conserved, and farmers are far less able to rheostat insect assault, thus reducing farmers' turnover [65]. According to research conducted by Asegie et al. in Ethiopia, COVID-19 affected 88.89 % of smallholder farmer families. Interruptions have resulted in significant losses and the destruction of some farmers' entire harvests [66].

Due to the lack of manpower and admittance to animal feed, COVID-19 has significantly influenced livestock farming in South Asia [67]. As a consequence of manpower shortage, this could impede agricultural activities, such as planting, fertilizer presentation, drainage, weed management, and harvest dates. Ordinal agriculture and interrelated tools may provide workable substitutes for manpower shortages and ways to reduce human contact during the COVID-19 pandemic. The best chance of overcoming the trouble of maintainable agriculture and enhancing agricultural output through monitoring, analyzing, and management of soil, climatic, and genetic resources is to use a collection of digital and geospatial information technology [68].

Food export regulations and employee behavior might make it difficult for farmers to carry out agriculture and food processing businesses, as shown in Fig. 1. Additionally, a scarcity of supplies, such as veterinary medications, pesticides, fertilizers, and among other inputs, might have a negative impact on agricultural output [30]. Movement constraints have limited the availability of migratory labor, causing some harvesting and agronomic activities to be disrupted, resulting in aggregate post-harvest damages due to a decreased staff, and postponing new product distribution to several target marketplaces [69]. A few examples comprise exaggerated

Table 1
New Coronaviruses identified from 2001 to 2020, their reservoir and final host.

Initial Name	Official Name	Origin of discovery	Reservoir	Final Host
2002-nCoV	SARS-CoV	Foshan China	Cattle, Birds, Bats, Rodents	Human
2005-nCoV	HCoV-HKU1	Hong Kong, China	Mice	Human
2012-nCoV	MERS-CoV	Jeddah, Saudi Arabia	Bats, Civets, Camels	Human
2019-nCoV	SARS-CoV-2	Wuhan, China	Wild animals, Bats	Human

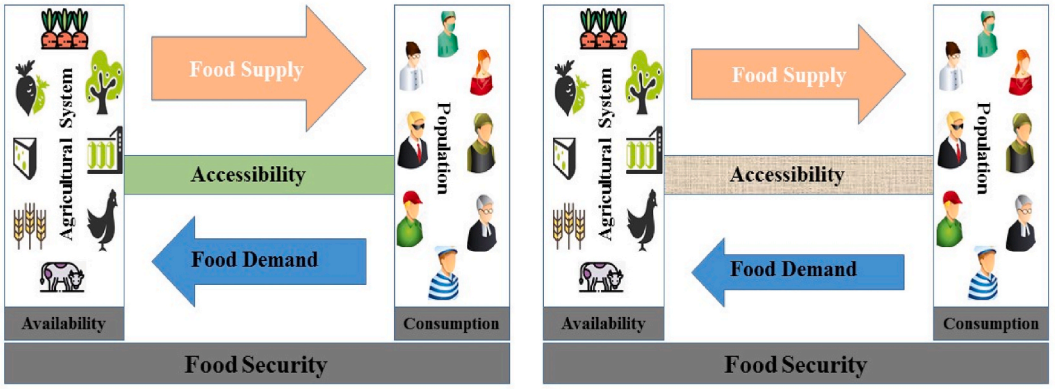

Fig. 1. Scenarios of food security system without and with COVID-19, respectively [36].

coffee farmers in Brazil and Colombia, mango growers in Pakistan, and poultry in the United Kingdom [70].

Lockdown has hampered the establishment of spring crops worldwide, primarily spring wheat, barley, canola, sorghum, sunflowers, and horticulture [71]. The lockdown confines the progress of agricultural goods and societies, notably laborer's, who often migrate from one region to another to find work and earn a living. Travel bans, border closures, and crop export restrictions have also been implemented by nations [72,73]. The COVID-19 pandemic may impact the import of veterinary medications, feed ingredients, such as soybean meal, and feed supplements. As a result, it is anticipated that the prices of chicken and eggs will also rise substantially. In addition, the COVID-19 pandemic may cause feed and medicine costs for cattle industries to increase [74]. In the absence of a cure or viable therapy, countries worldwide are turning to non-pharmaceutical methods such as communal isolation programs and communal lockdowns to halt the spread of the virus. Economic activity has been significantly harmed, especially in the financial and agricultural sectors, by restricting employees from working, meeting, and interacting socially [75]. Lockdowns are now being gradually lifted in several countries depending on the pandemic situation, but their effects can be measured [73,76,77].

The agricultural areas caused the Southeast Asian country's gross domestic product (GDP) to decline by 1.4 %, or USD 3.76 billion [78]. In addition to the health issue, the virus significantly affects the agriculture, fisheries, and livestock segments, ultimately impacting a nation's economy. The COVID-19 scenario has had the most significant impact on agrarian economies in entities, such as India, Bangladesh, and Vietnam, where food production contributes 12–16 % of GDP [79].

Demand for a product is influenced by consumer desire and purchasing power. COVID-19 has a significant brunt on agriculture in two ways, accordant to the Food and Agriculture Organization (FAO), food supply and demand, as shown in Table 2. These two dynamics threaten agricultural production because they are intrinsically linked. Due to the pandemic, many people in developing nations like Bangladesh lose their jobs, which decreases their purchasing power. As a result, there is a diminution in demand for expensive goods. Agriculture is most severely impacted by perishable products, such as fruits, vegetables, horticultural products. The loss of perishable goods is a result of inadequate storage facilities, transportation problems, and a decline in demand. The consumer, on the other hand, paid particular consideration to fruits high in vitamin C because they can strengthen the immune system to face the side effects and symptoms generated by the virus [30,79].

The key components of re-enforcing the agricultural system rely on maintaining an active international food supply chain and reducing the endemic's effects on the entire food structure by putting anti-crisis measures in place. Consequently, it is vital to maintain open borders for the movement of goods and agricultural products such as seeds, fertilizers, and crop protection products [80]. It is demonstrated that small agricultural producers play a crucial part in the subtleties of the resident food system. This conclusion become from an investigation including data from 159 households spread over 15 nations in Central America, Asia, and Africa. At least 570 million trivial farmsteads (2 ha) are operated by entities or families and account for more than 80 % of the world's production in terms of value [81]. The agricultural output of these family groups serves as the foundation for both tactical and local food networks in the global food system reorganization [82].

Table 2
Situation of price for agriculture and homemade merchandise during COVID-19 pandemic in 2020 [73].

Raw materials	Effects on price		Homemade Products	Effects on price	
Product Name	Increase	Cost	Product Name	Increase	Cost
Cake	Yes	High	Cake	Yes	Low
Fruit	Yes	High	Fruit	Yes	Low
Animal	Yes	High	Animal	Yes	Low
Others	Yes	High	Others	Yes	High

4. Effect on food demand and food supply

Food is a significant sector, and staff was deemed necessary at all stages of the food supply chain, from key production through processing and transportation to delivery. However, at the apex of the first phase in March 2020, the food-service sector (which includes cafeterias and bars, grounds, schools, music venues, etc.) saw a 28 % fall in spending on food far from home because it was mainly viewed as unnecessary. The handling of the current epidemic so far shows that the effect of the declining human population on world food consumption will be minimal. Until now, the effects on the public's admittance to food in the industrialized world have been relatively small, but more major issues are starting to emerge in developing nations [83]. The rapid and dramatic shifts have had far repercussions for employees in ambitious parts of the food supply chain, as the share of customers' food expenses spent on food service manufacturing has climbed from 47.1 % in 1997 to 54.4 % in 2018 [84].

Demand denotes the ability and willingness of clients to spend money on a particular good or service at a specific interval [85]. The food ultimatum has been reduced slightly as a result of ambiguity and people's weaker spending capacity, however, if the pandemic lasts for prolonged period of time, the scenario may worsen due to subordinate income and job losses [30]. Another important consideration is the detrimental effect on export flows brought about by the international restrictions implemented by many nations [86]. Customers are compelled by the situation to consider food storage as well as other food sourcing options due to supply chain disruptions, business directives in various states for social distance, and a decrease in grocery store visits [87]. Eminently, the effects of export restrictions have already been enormously variable, dependent on the countries and product sectors concerned. Nowadays, the epidemic has erupted several times in several states, each of which has chosen a different restriction method [88], envisaging a decline in international food exports and an increase in food prices, notably for emerging economies that rely heavily on food imports, as reported in Table 3. Sub-Saharan Africa (SSA) has seen a more severe impact on food costs due to the pandemic due to its reliance on imported food merchandise such as rice and the labor-intensive nature of their manufacturing.

COVID-19 impends the existence of farming systems, merchants, food manufacturers, transporters, and dealers in the food chain due to their inability to pursue pandemic-appropriate development and survival methods. As a result, the supply side of the food market might be harmed, and macroeconomic factors could have an adverse effect on the price of food manufacture and distribution [90]. Also, the slowdown in the food supply has impacted food chains locally, which has led to a resurgence of understanding of regional procedures. Many societies are the guardians of ancient food structures that modern ones have gradually exchanged due to trade globalization. As the COVID-19 pandemic has spread, these societies have recognized the necessity for this indigenous knowledge to manufacture their specialized diet. This phenomenon has been mainly detected in Latin America, Asia, and Africa [91,92].

The food supply chain is a system that joins an agricultural system (the farmland) to the customer's plate and includes activities such as dispensation, packing, distribution, and storage [45]. Food insecurity may arise due to deterioration in worldwide trade and problems in the foodstuff production and supply chain [93]. It is critical to examine the likelihood of COVID-19 spreading through the food chain. Both for the dangers linked with the virus's prevalence in the workshop and the associated risks with the probability that food items or grocery bags could be contaminated by a septic individual [94]. Food supply volatility affects other aspects of society, like employment, in food-producing countries [95].

Hand wash or the use of a hand disinfectant should be monitored when handling packages and items to prevent the risk of coming into touch with potentially contaminated food [96]. The Food and Drug Administration (FDA) also has stated that excellent health standards, along with cleaning and disinfecting guidelines in kitchen and restaurant surfaces, are preferable SARS-CoV-2 environmental monitoring approaches [97]. Additionally, blows, doorknobs, fridge grips, and additional "high touch" places must be cleaned regularly and effectively. Employees in the food preparation industry should be exhilarated to adhere to the standard hygiene practices used to regulate known foodborne viruses and bacteria [98,99]. These include eating uncooked animal products with caution to avoid cross-contamination with other foods, washing vegetables and fruits before eating, properly cooking meat, and covering the nose and mouth while coughing or sniffing [94]. Meat dispensation plants, the meat storage industry, and the livestock distribution industry have all been entangled in COVID-19 super spreading actions, primarily in the United States, where the Smithfield plant in South Dakota, for example, interprets for 44 % of all identifies in the state, making it the state's single most significant hot spot for the virus [100]. For instance, Table 4 gives information about the effect of COVID-19 on a global price index over the last decade.

The implementation of stay-at-home instructions caused a significant change in the type of food consumed, from restaurants to homes. The pandemic also affected a person's eating habits [76]. Slaughterhouses and food processors were considered necessary

Table 3
Price fluctuation in different food items from Jan 2019 to July 2022 [89].

Month	US, USD/Kg	Europe and Oceania, USD/Kg	Pakistan, USD/Kg	Brazil, USD/Kg	Australia, USD/Kg	ICE Futures, USD/Kg
Jan-19	0.84983	2.89472	0.319	0.1804	0.2994	2.1798
Jun-19	1.05897	3.14444	0.32425	0.18325	0.25175	2.3372
Nov-19	0.90141	3.30796	0.3194	0.17375	0.235	2.79335
Apr-20	0.98447	2.82169	0.3965	–	0.27675	2.27925
Sep-20	0.94312	3.043	0.3715	0.1916	0.2316	2.625
Dec-20	0.96091	3.219	0.37225	0.2412	0.2462	2.744
Apr-21	1.18911	3.97096	0.3828	0.288	0.272	3.12283
Sep-21	1.20561	3.7312	0.32075	0.26175	0.30375	3.12432
Feb-22	1.18147	4.60375	0.331	0.30445	0.32225	4.09683
Jul-22	1.295	4.3511	0.35	0.27581	0.383	4.00153

Table 4
Food price index issued by FAO [89].

FAO food price index							
Year		Food Price Index 1	Meat 2	Dairy 3	Cereals	Vegetables Oils 5	Sugar 6
2006		72.6	70.5	73.1	71.2	70.5	91.4
2007		94.3	76.9	122.4	100.9	107.3	62.4
2008		117.5	90.2	132.3	137.6	141.1	79.2
2009		91.7	81.2	91.4	97.2	94.4	112.2
2010		106.7	91.0	111.9	107.5	122.0	131.7
2011		131.9	105.3	129.9	142.2	156.5	160.9
2012		122.8	105.0	111.7	137,4	138.3	133.3
2013		120.1	106.2	140.9	129.1	119.5	109.5
2014		115.0	112.2	130.2	115.8	110.6	105.2
2015		93.0	96.7	87.1	95.9	89.9	83.2
2016		91.9	91.0	82.6	88.3	99.4	111.6
2017		98.0	97.7	108.0	91.0	101.9	99.1
2018		95.9	94.9	107.3	100.8	87.8	77.4
2019		95.1	100.0	102.8	96.6	83.2	78.6
2020		98.1	95.5	101.8	103.1	99.4	79.5
2021		125.8	107.7	119.6	131.2	164.9	109.3
2022		144.7	118.8	149.5	154.7	187.8	114.5
2023		124.7	114.7	123.7	130.9	126.3	145.0
2023	February	131.1	113.3	138.6	146.7	135.9	125.2
	March	128.2	114.7	135.3	138.6	131.8	127.0
	April	128.7	116.8	129.2	136.1	130.0	149.4
	May	124.7	118.1	121.7	129.3	118.7	157.2
	June	123.1	119.0	119.9	126.6	115.8	152.2
	July	124.6	118.5	119.1	125.9	129.8	146.3
	August	122.0	115.2	114.3	125.0	125.8	148.2
	September	121.9	114.1	112.0	126.3	120.9	162.7
	October	120.9	112.5	114.7	124.8	120.0	159.2
	November	120.8	112.0	116.5	121.0	124.1	161.4
	December	119.2	111.6	118.8	122.8	122.3	134.2
2024	January	118.2	110.5	118.7	119.9	122.5	136.4
	February	117.3	112.4	120.0	113.8	120.9	140.8

because they are fundamental to the food supply chain. As of the close quarters and indoor working environment, these facilities prone employees at an increased risk of catching the coronavirus. For instance, factory managers tried to reduce the danger to employees by employing social isolation whenever possible, grouping personnel, isolating affected work groups, and briefly closing down the plant in the event of an outbreak [101,102]. Due to COVID-19, international air travel has been substantially affected, making it more challenging to transfer some expensive food shipped by air. Uncertainty exists on how the pandemic will affect the world food trade in the long run. The epidemic has drawn attention to how crucial it is to maintain food production and circulation (see Fig. 2), and few of the strategies created to ensure a food supply may be kept in place in the long term [103].

Since human health is the primary concern worldwide, the main effects of the pandemic on the food supply chain and food industries have yet to be determined. Nevertheless, the adverse impact on food systems and those relying on them is already visible. It is

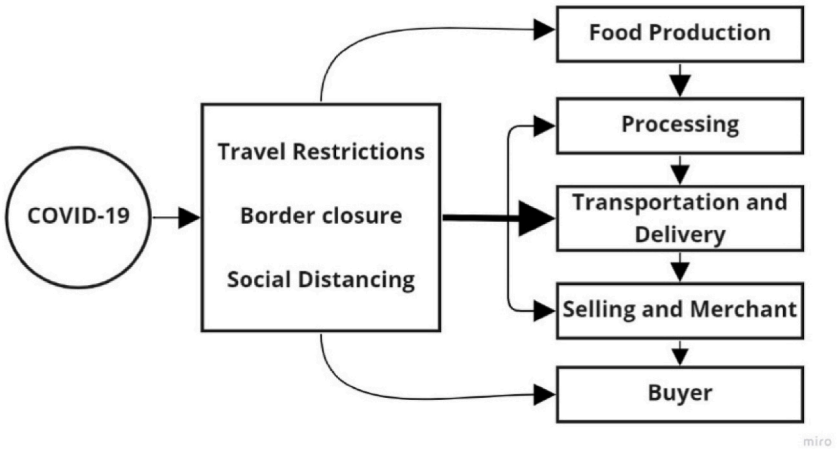

Fig. 2. COVID-19 affects the food supply and transportation [104].

critical to creating Coronavirus revealing procedures that can be utilized on foods to maintain food safety and avoid disrupting food supply networks. Accurate detection of viruses in meals remains challenging due to the uneven dispersal of viral elements, low viral load, and time-consuming non-optimal seclusion [105]. Several techniques have been proposed for this purpose, including enzyme-free immunosorbent assays nano-ELISA, and molecular detection assays based on quantitative real-time polymerase chain reaction (RT-qPCR) [106–108]. This latter assay method is based on identifying the presence of the virus and the serological tests, detecting either the antibodies towards the virus (or the viral antigens) [109]. Unfortunately, the sensitivity of such a method is ranged from 66 to 80 % along with high rate of false-negative inputs. Basically, such issue has been credited to sampling errors, or testing at the beginning of the disease, when the viral load is apparently below the detection limit [110].Unfortunately, all these concerns have directed a greater demand for homemade foods, which increases the cost. The price of agricultural products and homemade goods increased, with the price of farm products being higher while the price of homemade goods being lower [111].

Since new varieties of COVID-19 are appearing, lockdowns are being reintroduced worldwide, businesses are closing again, and corporations have not yet resumed as usual. The pandemic forced agri-food supply chains to re-evaluate opportunities and threats, reassess their top priorities, and modify their systems. This crisis is not going to last forever. Due to this, more research should be done to consider its long-term effects, such as adverse effects on supply chains, globalization, and job security.

4.1. *Food safety*

While predicting how the (COVID-19) pandemic will affect food security in the short and long terms is complex, a possible risk can be anticipated [30]. According to the FAO of the United Nations, "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." Food security mentions to the consistency and availability of a sufficient supply of wholesome foods [112]. Food insecurity may arise as an outcome of a decrease in global trade, disruptions in the food supply chain, or changes in food consumption. Early in the COVID-19 pandemic, the level of food insecurity in the United States is estimated to have risen to 22.8 %, owing partly to job disruptions caused by state lockdowns [113]. Globally, there are 2 billion people with knowledge of severe food insecurity. The danger of malnourishment and poor health increases with irregular access to nourishing and sufficient meals. Food instability caused by grain shortages has grown more severe than ever before in a number of developing countries due to increasing commodity, fuel, and raw material costs brought on by ongoing SC disruptions, such as the COVID-19 pandemic [114].

8 % of North American and Europe people experience moderate to severe food insecurity, while it is more prevalent in low- and middle-income nations. The occurrence rate is marginally greater among females than men on each continent [30].

Currently, 113 million people experience acute severe insecurity, and 820 million people experience chronic hunger. The FAO had warned that small farmers and fishermen might have suffered from selling their goods, which would reduce their salary and purchasing capacity. Food insecurity caused by COVID-19 will disproportionately affect the poorest and utmost vulnerable sections of the population [30,115]. The COVID-19 epidemic compromised the security of certain UK citizens. It reduced labor hours and raised unemployment, along with the forced isolation of specific vulnerable populations could result in a proliferation of food insecurity and diet-related health inequalities in the UK [116].

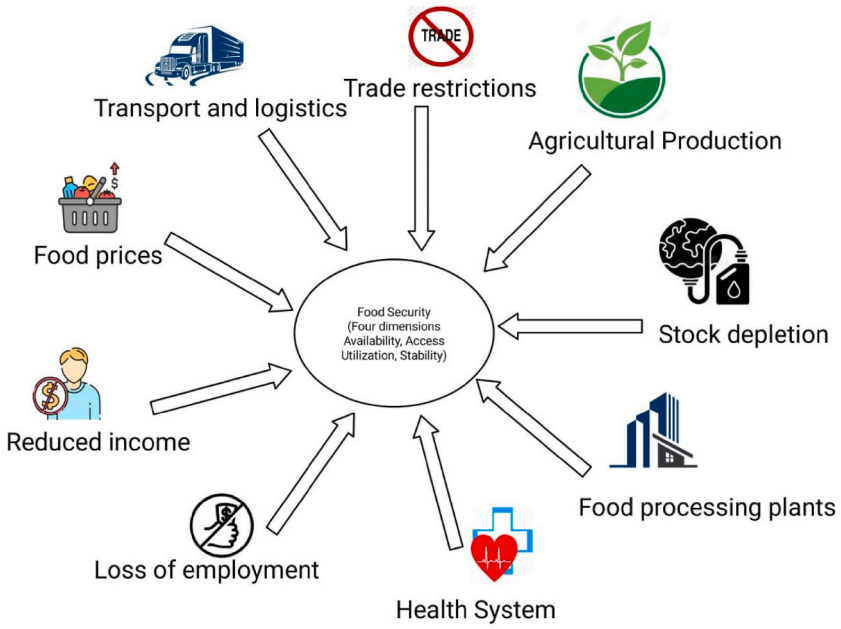

Fig. 3. Main factors affecting food security at macro-level [124].

Employees determined to be COVID-19 positive were unwilling to go to work because they feared that they might become ill on the job, causing production to be restricted, postponed, or temporarily halted in numerous plants during the outbreak, mainly in meat-processing industries. Because of these dynamics, food manufacturing capacity has been fallen down dramatically.

Due to the lockdown, social programs, such as school meals and family/grandparent assistance, have primarily been suspended. Low-income households' lack of contact with food was exacerbated by induced unemployment. This is a clear example of how the COVID-19 pandemic subsidizes food poverty. Food insecurity is a worldwide issue that impacts every country, but it is most acute in countries that use agricultural systems sensitive to climate change [91,92]. People in food catastrophe zones usually have higher rates of fundamental health conditions, i.e. non - communicable disease and malnourishment, which reduces the immune system and increase the risk of severe COVID-19 signs [95].

The flexibility of each country's economy has an impact on worldwide agri-food. To maintain national food authority, these economies have applied public policies to ensure food supply on their respective soils; as a result, import-dependent nations already face risks to their food security due to restrictions on their food inventories [30,90]. The extent to which the COVID-19 pandemic affects food security diverges from one state to the next, since it is based on the size of each nation's agricultural production and the anticipated duration of the epidemic's containments. It is also being researched to see if there are any alterations in the consumption of different fruits and vegetables based on food security levels. It was discovered that plaintiffs who stated being food insecure consumed less frozen, fresh, and preserved fruit and vegetables [117]. In contrast to respondents who reported being in control of their meals, they were more likely to increase their use of canned fruit and vegetables. These discoveries are consistent with a former study, which found that since the beginning of the COVID-19 outbreak, there has been a rise in the use of shelf-stable foods and a decrease in the consumption of fresh foods [118–121].

Data implies that encouraging food-insecure people to consume canned fruits and vegetables may be a realistic technique for increasing fruit and vegetable intake during pandemics, as overviewed in Fig. 3. Relatively few people shop for groceries now than before the pandemic began, canned food offers the advantage of being less perishable. Since canned products are generally less expensive and frequent, they have comparable nutritional value to fresh and frozen which represents a more cost-effectively way to satisfy dietary fruit and vegetable guidelines [118,122,123].

Three main groups are more susceptible to food crises during the COVID-19 pandemic. The first susceptible group comprises approximately 820 million people who agonize from prolonged starvation and do not ingest adequate calories to have an everyday existence [30]. This clutch of people cannot manage any potential disturbance to their way of life or their ability to get food that a COVID-19 situation would bring (see Fig. 4). The consequences could be severe if countries where these people live are infected with the virus and health systems are underdeveloped. Secondly, small farmers are the next susceptible category who may be barred from working on their land or traveling to markets to sell their crafts or purchase seeds and other supplies. Children from low-income families are the third vulnerable group; they are usually fed through social programs; if these programs were halted owing to the epidemic, they would starve. It will put food security and diet in danger, reducing children's ability to fight off infections [30]. To maintain social food programs and prevent the virus from spreading, each country must attention to its efforts in this direction.

4.2. *Detection of COVID-19 in food items*

The phases of social transformation ongoing in recent decades have drastically reshaped the world food system and the agri-food industry [125,126]. To some extent, the effects on food systems and people are already evident at all points in the food chain.

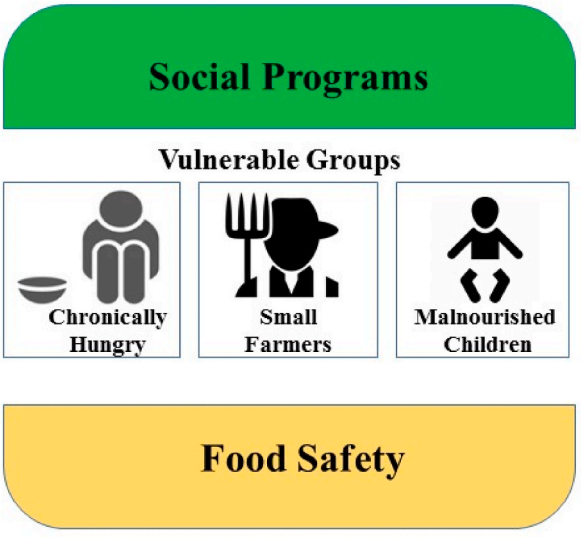

Fig. 4. Most vulnerable groups in jeopardy of food shortage [36].

Developing SARS-CoV-2 detection technologies applicable to foods is critical for ensuring food safety and preventing disruptions in food supply chains. It is still challenging to detect viruses in food reliably due to various aspects, such as the uneven distribution of viral particles, the low viral load, and the ineffective and time-consuming isolation processes [127,128]. To date, several molecular biology techniques, such as RT-qPCR-based molecular detection assays, enzyme-free immunosorbent assays, and nano-ELISA, have been suggested for this purpose [107,129]. For SARS-CoV-2 detection in the lab, the two most frequent methods are the molecular test (which can identify the existence of the virus) and the serological test (which can detect either the antibodies against the virus or the viral antigens) (Table 5). RT-qPCR method is recommended by the World Health Organization (WHO) for detecting viral RNA in respiratory tract samples, with confirmation by sequencing performed if necessary [130]. However, as mentioned previously, this method limitations, including poor sensitivity and a high rate of false-negative results, still remains a challenge [110]. Table 5 reports the main advantages and disadvantages of the current methods used for COVID-19 detection.

In addition to molecular diagnostic testing, serological approaches employing blood serum samples for detecting antibodies against SARS-CoV-2 have been developed. According to research, the immune response to the virus often does not kick in until at least 7 days following the onset of symptoms [131]. The WHO does not recommend employing serological assays for identifying COVID-19, even though diagnostic tests are available [132]. Conversely, it might help monitor the population's resistance to disease [133]. Since the antigen test can detect proteins from the COVID-19 virus, it may be utilized for this purpose [1]. Acute phase diagnosis might benefit from antigen tests like polymerase chain reaction (PCR) analysis, which can potentially identify the virus's presence in respiratory tract samples. It is possible that the test's accuracy might be affected by the viral load present during infection [134]. Several recently developed rapid diagnostic techniques for COVID-19 rely on testing for antigens.

Identifying SARS-CoV-2 in food, surfaces, and the environment might make the problem much more complex. Since there is no evidence suggesting that coronavirus is transferred via food, neither has any study been conducted nor have any tests been devised for detecting the virus in foods [135]. But as we've seen, infected workers in the food industry and supply chain can transmit the illness to others via the sector's surfaces and the surroundings. Numerous studies have been carried out, usually in artificial settings, to detect SARS-CoV-2 in environmental samples. Using the RT-qPCR method, the virus was detected in all fomites [136]. While this study is still in its infancy, many companies have already developed commercially available kits for detecting SARS-CoV-2 in environmental swabs [94]. The results of these studies are similar [137]; however, the high price of the test kits is a significant barrier to adoption by large-scale food processing facilities.

Wastewater-based epidemiology (WBE) is another method attracting scientists' attention. In particular, monitoring viruses has shown efficacy for early warning reasons, such as recognizing the existence of infections before the manifestation of symptoms in the population. Real-time pandemic simulation may be possible with the help of quantitative monitoring of viruses in municipal wastewater. It is expected that testing wastewater using paper-based kits might lead to the discovery of possible disease carriers, even if they are asymptomatic since live SARS-CoV-2 has been isolated from the feces and urine of sick persons [138]. This technology makes rapid screening of targeted regions possible, allowing authorities to respond swiftly when necessary [139].

4.3. Post-Covid 19 recovery and their long-term effect

The post-pandemic consequences for food security have received great scrutiny and concern. The impact on food security is obvious as the globe emerges from the shadow of the COVID-19 epidemic. The pandemic's disruption of global supply chains, labour shortages, and alterations in consumer behavior have had a long-term impact on the food business. Amid post-pandemic talks and efforts to improve food security, a feeling of scrutiny and alarm persists. The COVID-19 epidemic has acted as a sobering warning of the vulnerabilities in our world's food supply systems. The lessons learnt from this catastrophe have caused a communal awareness of how important it is to be more prepared for potential pandemics or global upheavals that might once again undermine our food security [140].

The COVID-19 epidemic has disrupted the food supply chain, prompting calls for greater openness, efficiency, and safety in the food business. As a result, there is an increased interest in using blockchain technology to address these concerns. Blockchain technology allows for the secure and transparent monitoring of food goods from farm to table, minimizing food waste while also maintaining food safety and quality. Blockchain, with its ability to improve supply chain management and food safety, is expected to play a major role in

Table 5
Various diagnostics tests to identify SARS-CoV-2.

Testing method	Sample Source	Merits	Demerits	References
Antibody tests	Plasma Serum, Whole blood	Short time to diagnosis, Low cost, Can detect past infection	Cannot diagnose active infection, Under validation	[109]
quantitative real-time polymerase chain reaction	Nasopharyngeal swab	Robustness, High sensitivity, Can detect active infection	False-negative results, Labor intensive	
Antigen tests	Nasopharyngeal swab, Whole blood, Plasma, Serum	Less time to diagnosis	Under validation	

the post-COVID-19 pandemic food business [141].

The COVID-19 pandemic has increased demand on natural resources and reduced biodiversity. The post-COVID-19 pandemic provides an opportunity to build more resilient and sustainable food systems that benefit both human welfare and biodiversity conservation. By establishing a secure and transparent record of food production and distribution, stakeholders will be able to better understand the environmental effect of food systems and strive towards more sustainable practices. Furthermore, the adoption of blockchain technology in the food supply chain can contribute to biodiversity conservation by encouraging sustainable agricultural practices and minimizing food waste [142]. Nature-based solutions (NbSs) comprise a broad range of techniques that can be used in the agri-food supply chain to address many environmental concerns in the post-COVID-19 age, while bringing economic and societal benefits. The post COVID-19 customers are seeking quality, innovative, healthy foods with natural ingredients to protect themselves, the environment and provide sustainability to local economies. Traditional foods (TFs) can potentially play a crucial role as the food of choice for "new" customers, the "anti-consumers" in the post-COVID-19 time globally [143].

5. An outlook on COVID-19 effects on the environmental sustainability

It has been widely acknowledged that the dilemma we are trying to solve has severe implications for the future of human civilization. The economic, social, and ecological dimensions of sustainability are all interconnected. The rapid development of COVID-19 has resulted in a significant decline in financial results, the expansion of social issues, including marital violence, and the plight of many animal species due to the absence of protective forces by conservationists trapped inside their houses [144]. Initially, the global economic element has been severely hit, with many individuals, particularly those who live day-to-day, seeing their savings evaporate. As a result of the epidemic, several companies have taken drastic measures to prevent the collapse of their operations. Due to the inability of their companies to make payroll, many people lost their employment during the crisis. Many sectors, including aviation, tourism, and transportation, have turned to the government for help after suffering catastrophic setbacks. As a result of the crisis, there is increasing pressure on businesses to weigh the benefits and costs of their international supply chain process against the efficiency of their domestic one. Reduce its dependency on the fractured global supply system by switching to a local supply chain [145]. The change is expected to improve the ability to meet the demands of the public, but it may lead to an increase in manufacturing costs. Second, the economic impact of the crisis is growing. Due to the lack of an appropriate setting for remote workers, many individuals have lost their careers and the support of their families. People who cannot work remotely may take up product distribution or other comparable activities, significantly increasing their risk of infection. Furthermore, political power is affected negatively by the economic discrimination gap. When there is an income disparity, those on the receiving end are more stressed, which may lead to a corresponding rise in isolation [146]. Consequently, these results have exacerbated people's feelings of crisis and harmed their psychological well-being. Finally, the pandemic and its effects are believed to be necessary for such a rapid transformation of the global landscape [147]. To improve global biodiversity, we need effective methods. At this point, governments must rethink, examine, and manage unresolved problems to implement effective environmental restoration strategies and continued economic growth [148].

5.1. Influence of COVID-19 on the environment

The virus has caused tremendous effects throughout the world at medical, social, economic and environmental levels [149]. As for the environmental aspect, both positive and negative impacts on environment have been raised due to COVID-19 pandemic and lockdown measures, as presented in Table 6.

Therefore, according to the evidence in Tables 6 and it seems like the world has been forced into a reset state. The closure of industrial facilities, and power plants, reduced traffic and shipping led to lower levels of criterion pollutants, i.e., nitrogen oxide (NO_2), carbon monoxide (CO), black carbon (BC), Sulphur dioxide (SO_2), methane (CH_4), and particulate matter (PM10 and PM2.5) [151,155, 156]. Due to reduced commercial activities and public transportation, noise pollution decreased substantially [157,158]. While mobility was restricted by about 90 %, Muhammad et al. [134] studied and proved that air pollution dropped by 30 % due to the lockdown (in China, France, Europe, Italy, Spain, and the United States). Though the mandatory lockdown brought about these positive results in many countries, this was especially true during the first phase of the coronavirus, and these positive effects were only

Table 6
Environmental impact of COVID-19 pandemic and lockdown restrictions [150–154].

Positive impacts	Negative impacts
Improvement in outdoor air quality	Decrement in indoor air quality
Surface water quality improvement	Substantial medical waste production
Decrement in pollution noise	Decrease in waste recycling with an increase in incineration and landfilling
Decrement household food waste	Increased usage of hazardous chemical substances in household and outdoor environments due to multiple disinfection routines
Better use of food	Major ecological risk to environmental ecosystems due to the use of disinfectants and their packing materials
Mitigation of deforestation	
Global decrease in wildlife trade	
Decrease in energy consumption and greenhouse gasses (GHG) emission	

temporary [157].

There has been a rise in alcohol and isopropanol-based hand sanitizers for massive disinfection and distribution worldwide [159]. Large quantities of disinfectants, such as chlorine, hypochlorous acid, and sodium hypochlorite, are utilized in almost every area with a human population. Therefore, they do not bioaccumulate and do not persist in the environment since they are rapidly degraded in the presence of organic molecules. Using sodium hypochlorite to disinfect public spaces (including waiting rooms, elevators, corridors, offices, rooms, hospitals, etc.) effectively eliminates the virus and stops its transmission. As a disinfectant, sodium hypochlorite has catastrophic effects on animals and bacteria. However, sodium hypochlorite and related compounds may react with organic molecules in the drain and be cleared from the system before reaching the environment due to their high reactivity. The virus may also be killed by isopropanol/ethanol and other alcohol-based therapies [160]. Antibacterial soaps include the active chemicals triclosan and triclocarban, which are worldwide used in household personal care. Particularly, it has been shown that triclosan is terrible for human health and contributes to the rise of bacteria that are resistant to many antibiotics [161]. Disruption of hormone systems, carcinogenesis in the liver, and other neurological effects are a result of these chemicals. Since neither is readily degraded, they constitute a risk to environmental health and account for sixty percent of the total quantity of medicines found in sewage and wastewater sludge [162,163]. These chemical contaminants have a devastating effect on aquatic life [164]. In addition to this, the large amounts of generated plastic due to the disposal of bottles and main packing materials of disinfectants also represent a serious environmental issue and compromise the ecological systems [165].

5.2. Environmental factors affecting COVID-19

It has been reported that health, economy, environment and society are the key challenges to be protected during pandemic [141, 142]. Protecting the health sector is essential to ensuring our survival [166]. The wide spread of COVID-19 has led to significant gaps in global climate data. For the time being, the standard climatic data acquired for human safety will not be used to fill the gaps that occurred during lockdowns. More than a hundred delicate sensors, which are part of a US$44 million annual system, are cleaned and repaired by a staff supervised by Professor Ed Dever of Oregon State University in Corvallis twice a year. The scientific community dubbed it the Ocean Observatories Project. "If this had been a regular year, I would have been at sea right now," the late Ed Dever once quipped [144]. In contrast, city air and water pollution are experiencing a down mode due to lockdowns and industrial shutdowns as an effect imposed by COVID-19. This is because there is no significant utilization of fossil fuels and discharge of industrial effluents [145]. Emission of various oxides of nitrogen, Sulphur and carbon has significantly reduced during COVID-19 in different countries, mainly in USA, UK, Germany, among many others [146]. Environmental variables may have a role in Coronavirus transmission and illness, although this has not been well studied. The virus's stability at high temperatures was a topic of considerable debate. However, a new study published in Lancet finds no positive correlation between COVID-19 and temperature, refuting this notion. According to the results, SARS-CoV-2 was cultivated for up to 14 days in viral transport medium (final concentration 68 log units of 50 % tissue culture infectious dose [TCID50] per mL) and then tested for infectiousness. The virus is relatively stable above 4 °C, but it kills off rapidly beyond that. As of day 14, the infectious antibody titer had dropped by around 0.7 log units at 4 °C. When the temperature was increased to 70 °C, the incubation time needed to inactivate the viruses was reduced from 10 to 5 min [147]. The researchers also found that the virus stays put when placed on a horizontal surface. Two days after being exposed to cloth or wood, the virus was no longer contagious. The virus has a 4-day survival rate on stainless steel, 7 days on plastic, and 4 days on paper cash. The pathogen might survive on the surgical mask for up to seven days. At 22 °C, the virus only stays for 5 min, yet it can tolerate pH levels between 3 and 10. This means that the virus's lifespan may be increased under optimum conditions, but it is still susceptible to commonly available disinfectants. Although the virus's susceptibility to the environment, especially temperature, varies widely, standard alcoholic-based disinfectants must be used to sterilize hands [148].

Air pollution and COVID-19 infections are strongly correlated with mortality rates. Case studies in a variety of countries, including Italy, Mexico, the United States, Philippines, Chile, Denmark, Brazil, and Peru, have confirmed this conclusion. One study in the United States indicated that a 15 percent increase in COVID-19 fatalities was seen in areas where even a slight rise in the fine-particle pollution level was discovered compared to the pre-COVID-19 period. In the northern Italian provinces of Lombardy and Emilia Romagna, where air pollution is terrible, the death rate is 12 and 4.5 percent higher than in less polluted parts of the country, respectively. Since COVID-19 is a respiratory disease, it stands to reason that people who are already unwell may not have much time to live if exposed to polluted air. More than 90 % of the world's population lives in locations where air pollution exceeds guideline levels, and these are often low-income countries [150].

5.3. Will COVID-19's environmental effects be everlasting?

Overwhelmingly, places around Earth have a self-regenerating nature that seeks to nourish itself. The intended location of the UN climate debate, Glasgow, was deemed unfeasible for such tender care of the planet's ecology as was envisioned for Cop26. Thus, the public argument among UN officials, scientists, and environmental activists for the green recovery of the environment and clean energy is still ongoing. Strengthening global ecosystems is prioritized via the use of eco-friendly construction methods. Public letters should be published, urging governments to develop parallel plans for environmental and economic revitalization in the wake of the disasters. According to UN environment Chief Inger Andersen, "75 % of new infectious diseases are usually animal born, and they are communicated to humans more rapidly through wildlife trafficking (by direct contact), deforestation (force wildlife to invade human habitats), and then the epidemics spread in the world via air travel and cruise-ship tourism. It would seem that the government has finally come to this point of view, outlawing the commercial production, eating, and trade of wild animals. This alarmist rhetoric also

picks up speed in "wet markets" worldwide. On the other hand, the COVID-19 outbreak refers to a clear message that human activities such as excessive resource extraction, the destruction of natural habitats, and the failure to address deforestation, and similar activities adequately threaten human security on Earth. Therefore, the present pandemic's impact on the environment, whether positive or negative, is entirely attributable to humans and not to COVID-19, which has just served as an effect. To come out of the COVID-19 outbreak with a healthier environment, the time after the outbreak must be used to pressure all parts of society, especially political sections, to not return to unsustainable business as usual [40].

The Chinese government may decide to resume social and economic activities as usual in April 2020 after discovering that the COVID-19 graph has flattened. There is, therefore, uncertainty about how long pollution levels will remain below the threshold and whether NO_2 emissions will immediately recover to their pre-pandemic levels. The term "revenge pollution" describes the rebound effect that can counteract the overall reduction in emissions. There is a possibility that the post-COVID-19 pandemic phase will be similar for all countries, even those not now benefiting from the auto-regeneration of their environment. Expecting a decrease in emissions in the face of a global epidemic is rare. The worldwide impact of the spread of COVID-19 has been devastating, with severe consequences for human health, economic security, and psychological well-being. If COVID-19 has repaid humanity for anything, it's been to help the climate recover. Humans may learn from the successful reversal of social lockdowns in many nations that it is feasible to restore normal functioning when people work together. It is possible to conserve nature at this time with a strong desire at the national or worldwide level. So, why haven't we done it with the weather? And not only with words, but with concrete results" [151]. It is also essential to observe how governments are preparing the economy for a return to business as usual, which will ensure that any improvements to the environment will be short-lived at best.

In contrast, Qatar is the first nation to regularly demand a shutdown of its landscape because its citizens realized that pollution significantly harmed the ecosystem [99]. This included rising sea levels, temperatures, and the severity of sand storms. They believe that by periodically enforcing lockdown, many ecological problems brought on by human activity may be halted or diminished [152].

6. Potential recommendation to reduce the impact of COVID-19

The FAO cautioned against implementing broad restrictions on food imports. The transportation of individuals and things across borders can exacerbate epidemiological difficulties, making this concept problematic. Although these restrictions may be necessary for rare circumstances to protect the health of people, animals, or plants, FAO considers that they should be time-limited, minimize impediments to worldwide trade, and ensure that food is available and accessible [153].

The FAO, WHO, and World Trade Communications (WTO) highlighted the importance of protecting industrial employees to "minimize the virus's spread in the sector" and "maintain food chains." M. Torero warned: "Do not speculate with fear because the consequence may be the introduction of an embargo on exports. We must continue to ensure the movement of goods because panic can have serious negative consequences". The Ministry of Agriculture and the Aptitudes of Agriculture must work closely with the Ministry of Health and other sectors to respond to COVID-19. To comply with health standards, all required precautions should be taken to protect workers and customers. The workers should be properly trained about the self-protection methods and must be aware about the protection of others as well, especially health workers should be highly expert in disinfection processes [162]. During the current outbreak, agricultural-related associations should function as much as feasible so that producers and processors may maintain productivity and keep supply lines open. Relative to COVID-19 restrictions, there are numerous strategies to assist farmers in identifying their needs. There should be a large variety of online functions available. Farmers should always keep in mind to abide by fundamental

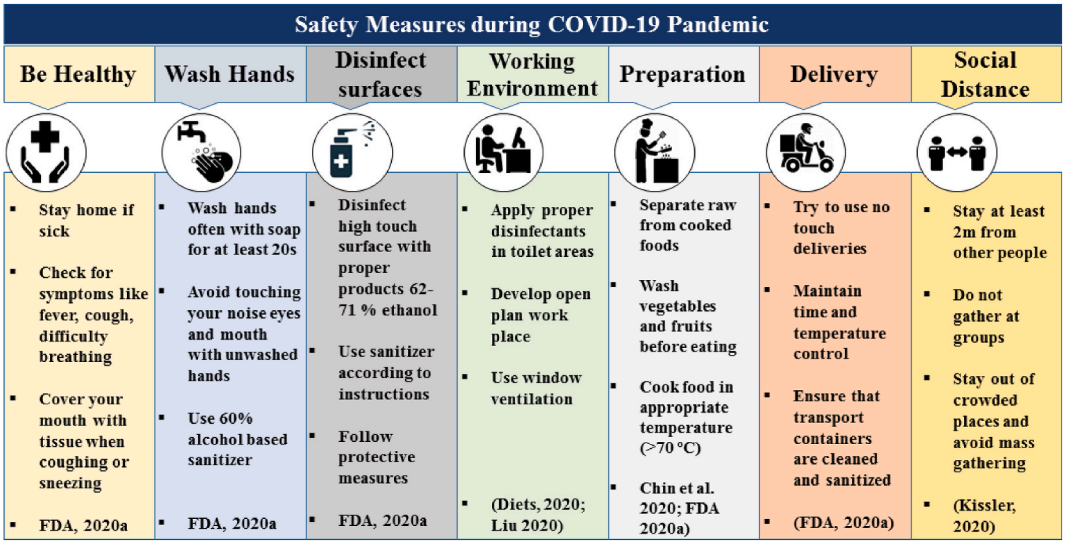

Fig. 5. Some essential safety measures during COVID-19 disease [109].

environmental protection procedures and security regulations when occupied on the farm [155]. Decentralization of food production may also be adopted to avoid COVID-19 period hazards and downsides of the centralization paradigm (see Fig. 5). Nearby low-scale facilities limit the environmental effects while saving money on storage and shipping. The supply chain can be shortened by locating manufacturing facilities nearer to customers, and energy and emissions used for storage and transportation can be reduced [167].

Devolution permits the supply chain to be suppler and allows consumers to purchase natural and fresh commodities. It also helps streamline administrative processes to reach better the impoverished and destitute [156,157]. Food banks can play a significant role due to the parallel and vertical synchronization procedures with farmer groups that generate predetermined agricultural preparations. It would primarily help farmers build new markets by donating unsold items to food stock and developing links among farmers and disadvantaged individuals during the COVID-19 eruption [102]. Governments should also improve and implement emergency provisioning plans to aid with manufacturing. Short-term input subvention programs should protect the areas most obstructed by the outbreak. The sowing season for the upcoming spring requires urgent help. To ascertain when and where the migrants are needed, data assemblage and calculation methods should be implemented [158].

7. Lessons learned and future perspectives

- Despite countries' high interdependence, there was insufficient coordination among governments on pandemic policies such as travel protocols to slow global virus transmission, methods for testing, public health and social policies, supply chains, standards for data and reporting systems, and public advice.
- Epidemic management was severely hampered by widespread public hostility to regular public health and social measures such as wearing properly fitting face masks and becoming immunized.
- The world requires internationally coordinated measures to bring a stop to the COVID-19 epidemic and future pandemics on a timely and fair manner.
- WHO should extend its Science Council to apply crucial scientific evidence to global health issues, such as new infectious diseases. This Council ought to include specialists from a variety of professions and all six WHO regions, as well as younger people and gender equality.
- We should improve the amount and quality of output by using sustainable, 'green' technology, resource management systems, and minimizing pre- and post-harvest losses and waste.
- Improve trade facilitation, economic integration, and market access.
- Ensure food security, safety, improved nutrition, and equitable distribution.
- Improve resilience against climate change, natural catastrophes, and other shocks.

8. Study limitations

The current study has several limitations. The first is the breadth of generalizability, since the review only covers certain geographic locations and nations within the food business, rather than all regions. Being unable to cover all data owing to time and data availability may result in biases.

The review may have biases due to the selection criteria for included research, such as language limitations and the inclusion of specific data on this issue. The evaluation may not fully address all the aspects impacted by Covid 19 in the food sector and supply chain. The review identifies areas where further research is needed but does not give suggestions on how to handle these issues.

The COVID-19 pandemic has served as a wake-up call to think about supply chains and the resilience of the future food system. Many previously established concerns in food sustainability and nutrition have been brought back into clearer focus, coupled with the need to consider longer-term transformations coming from a delayed economic recovery, changes in consumer behaviour, and mitigating the risk of future upheaval.

COVID-19 has underlined the need of supporting smallholders, who continue to play an important role in the global food chain. Over 90 % of food processors and manufacturers are small and medium-sized enterprises (SMEs).

9. Conclusion

The COVID-19 outbreak became an unprecedented global pandemic attacking all sectors of life. Over the course of this review, it can be concluded that agriculture, food supply, food security and environmental sustainability is a precarious phase that exaggerated the communal and ecological position in the world during the COVID-19 pandemic. As for the food supply chain and the food sector, the COVID-19 pandemic ushered in a new era. The significance for humankind, economics, and food safety is still being worked out. New COVID-19 detection methods are needed to study, and existing methods need improvements for better identification. Lockdowns are being reinstituted globally, businesses are closed repeatedly, and operations have not yet resumed as usual at those open. The pandemic forced food supply chain networks to reevaluate possibilities and hazards, evaluate their top priorities, and modify their systems. It is observed that most of the developed countries are resilient to disruptions in the food supply. Although major cereal producers' domestic supply has increased, COVID-19 trade limitations may negatively impact their earnings and GDP due to a decline in global trade and pricing. This problem is not going to last forever, or it will be part of our new reality. COVID- 19 has a significant impact on the environment. More effects and studies are required to evaluate the effect of COVID-19 on our environment. Due to this, more research should be done to consider its long-lasting effects, such as harmful impacts on agriculture, food supply chains, food security and environmental sustainability. According to the experts [159] food manufacturing industries must focus on new

innovations and technology disruptions in the food sector within the COVID-19 pandemic and post-lockdown era.

Ethical Approval

Not applicable.

Funding

Not applicable.

Availability of data and materials

Not applicable.

CRediT authorship contribution statement

Muhammad Ehsan Maqbool: Writing – review & editing. **Ahmad Farhan:** Writing – review & editing, Supervision. **Muhammad Azam Qamar:** Writing – original draft, Visualization, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

Not applicable.

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