Research Article

The Disruption of the COVID-19 Pandemic on Farm Produce and its Implications for the Future of Food Security - A review

Salisu Monsuru[1], Che' Rus Ridzwan[1], Sulaiman Zulkefly[2], Yusuff Oladosu[3], Luqman Hussain[4], Adebayo Abdulkabir[5]

1. Department of Agricultural Science, Faculty of Technical and Vocational, Sultan Idris Education University, Tanjung Malim, Malaysia; 2. Department of crops Science, Faculty of Agriculture, Universiti Putra Malaysia, Malaysia; 3. Institute of Tropical Agriculture and Food Security, Universiti Putra Malaysia, Malaysia; 4. Department of Agriculture, College of Vocational and Entrepreneur Education (COVED), Lagos State University, Epe Campus, Epe, Nigeria; 5. Universiti Putra Malaysia, Malaysia

The Covid-19 pandemic has affected most of the industries all over especially the agriculture sector. Any disruptions in the agricultural sector would create supply and demand shocks that would impact the entire agro-food system by extension it creates immediate and long-term economic shocks. Amid the pandemic, Food Agriculture Organization (FAO) regularly releases updates on the effects of the COVID-19 on agricultural supply chains. Unfortunately, the effect is still largely unknown and countries especially some developing nations would face acute food insecurity. The World Food Programme (WFP) of the United Nations has estimated that 265 million people would face food insecurity by the end of 2020, an increase from 135 million people before the pandemic crisis. Generally, the COVID-19 pandemic reduced food by 3.11%, or 17.03 million tonnes, during the first quarter of 2020 due to the effects agricultural labor force (ALF) especially in Southeast Asia (SA) where ALF reduced by 100,77 million people in the amount of production in Southeast Asia. The GDP in the SA was equally reduced by 1.4% which amounted to USD3.69 billion for good on business due to the pandemic. Noticeably, Agriculture and the agro-food industry significantly contribute to the region's economy. This systematic review critically looked at the implications of the pandemic and its effects on the future of food security. It revealed the need to build productive, sustainable, and inclusive food systems that are resilient enough to revamp the agro-food industry and withstand the future crisis. This is essential for the future of many countries to achieve a systemic transformation and maintain the self-sufficiency level (SSL) planned before the pandemic. This review indicated that a specific disruption to the agro-food supply chain had occurred and consumer's consumption patterns had been significantly changed which could lead to the post-COVID-19 food crisis. This study presented a framework that could be adopted to ensure the global future of food security in post-COVID-19 with a specific focus on building a resilient agro-food system.

Corresponding author: Salisu Monsuru, salisuadekunle@gmail.com

Introduction

The COVID 19-pandemic a novel coronavirus acute respiratory distress epidemic originated from the city of Wuhan, China in December 2019. The pandemic has spread globally. The outbreak was categorized as a pandemic by the world health organization (WHO, 2019) when it shows a continuous human-to-human infection, Qiu, et al., (2017). The pandemic is worse than the major epidemics that happened two decades ago, like the SARS (Severe Acute Respiratory Syndrome) epidemic between 2002 and 2003; the H5N1 avian influenza epidemic between 2003 and 2004; and financial crises such as that in Asia in 1997, and the global financial crisis between 2007 and 2009. Consequently, the International Monetary Fund concluded that the current pandemic is the worst financial and economic crisis since the Great Recession of 1929 IMF, (2020). This was due to the rapid infection rates, highest daily numbers recorded, and death rates compared by Liu, et al., (2020).

The imposition of the movement restriction in most countries and social spasms are seen as the best approach to control the spread of infectious diseases like the coronavirus (Chinazzi, et al, 2020; Sohrabi, et al, 2020; Smith and Freedman, 2020). Lockdown imposed by the most affected countries has not only affected human behavior and psychology such as depression, rumble and stress (Ghani, 2020), and even impact on activity economy due to the closure of retail premises and disruption of the supply chain (Karabag, 2020). According to the World Bank, the impact of the pandemic could push about 100 million people into extreme poverty. It could increase the unemployment rates, income losses and rising food costs are jeopardizing food access in developed and developing countries alike. This will have long-term effects on food security. Furthermore, the pandemic may plunge national economies into recession, and countries ought to take urgent measures to mitigate the longer-term impacts on food systems and food security.

There is a serious concern that producers might not be able to plant this year, or not plant enough, as normally. If we do not help producers to plant this year, this will translate into a lack of food later this year and in 2021. Equally urgent is the compounding threat of the pandemic on existing crises - such as conflict, natural disasters, climate change, pests and animal diseases that are already stressing our food systems and triggering food insecurity around the globe. Recent Integrated Food Security Phase Classification (IPC) analyses point to a worrying deterioration of acute food insecurity in countries already suffering from other crises. **Before the pandemic crises, flood threatened rice production in some of the Asian countries which plunged about 700 million**

people in acute food insecurity. Many of these people resides in flood-prone regions in the South Asia like Bangladesh, Nepal and India. These countries produce above half of rice in the region Oladosu et al., (2020).

To avert a food emergency, there is an urgent need to: protect the most vulnerable, keep global food supply chains alive, mitigate the pandemic's impacts across the food system, protect and even ramp up food production as much as possible, and looking beyond the pandemic, building back better, more resilient food systems. It is believed that much can be done to pull people back from the edge now FAO, (2020). According to the latest UN estimates (SOFI 2020), almost 690 million people went hungry in 2019 - up by 10 million from 2018, and by nearly 60 million in five years. High costs and low affordability also mean billions cannot eat healthily or nutritiously. Across the planet, the report forecasts, the COVID-19 pandemic could tip as many as 132 million more people into chronic hunger by the end of 2020 FAO, et al., (2020). The systematic review aimed to analyze the effect of the COVID-19 pandemic on the future of food security, to determine the causes and policy response by the Asia and Pacific countries to mitigate these effects on the food sufficiency plan before the pandemic.

Impact of the Pandemic on Agriculture

The agricultural sector is one of the most affected sectors by the pandemic. Many farmers cannot carry out their farming activity due to the outbreak (FAO 2020). The pandemic outbreak has impacted the entire food supply chain. The food system is interconnected and fragile. Consequently, solutions must be developed together to cope with the current challenges that are posed by the pandemic. This is because each component of the food supply chain has an impact on farming activities. Where any part of the supply chain is affected, farmer's activities will be seriously impacted. It was observed that farmers all over the world are letting their crops rot in the fields as the Covid-19 disrupts supply and demand for a wide variety of perishable goods including fruits and vegetables (Huileng, 2020). Because Farming is an essential activity and farmers are working harder to face the new normal that has been created by the pandemic.

In many countries, the lock-down and borders' closure are strongly affecting farmers' access to inputs like seeds, fertilizers, and agrochemicals World Farmers Organization (2020). According to the study, the movement restriction method is seen as the best approach for control the spread of infectious diseases such as coronavirus (Chinazzi, et al, 2020; Smith & Freedman, 2020). For the Covid-19 outbreak crisis, most countries have ordered travel restrictions, social spasms, and event delays for no less than 14 days in each country. An emergency order or a quarantine carried out not only affects human behavior and psychology such as depression, rumble and stress (Ghani, 2020), and even impacts on activity economy due to the closure of retail premises and disruption of the supply chain (Karabag, 2020).

Agricultural Labour Force within the Pandemic in Southeast Asia

Decreased agriculture labor force, caused by COVID-19 might result in a decline in the volume of agricultural production in Southeast Asian countries, including Malaysia Table 1. Overall, the COVID-19 pandemic during the first quarter of the year 2020 was estimated to lead to a 3.11 percent or 17.03 million tons' reduction in the amount to volume of agricultural production in Southeast Asia due to decline in agricultural farm labor affecting 100.77 million individuals Gregorioa, and Ancog, (2020). Travel restrictions and Labor shortages during extended lockdown would have a greater impact on the supply of high-value, labor-intensive crops such as leafy vegetables and fruits. The shock in the labor supply has led to greater loss and decrease farm produce to the market (Brinca et al., 2020; Benzeval et al., 2020), eventually led to the wasting or dumping of foodstuffs on farms disrupted the supply chain.

With the COVID-19 Scenario						
Country	**The volume of Agricultural Production* (Million Tons)**	**Labor productivity (Ton/ Worker)****	**Estimated ALF in 2020 Due to COVID-19 (Million)******	**Estimated Volume of Agricultural Production (Million Tons)********	**% Change in Volume of Agricultural Production Due to Decrease in ALF**	**Reduction in Volume of Agricultural Production (Million Tons)**
Year	**2018**	**2018**	**2020**	**2020**		**2020**
Vietnam	5.492	120.67	116.056	21.13	-3.82%	-4.614
Timor-Leste	1.595	0.38	0.377	0.24	-1.40%	-0.005
Thailand	9.002	112.53	109.442	12.16	-2.74%	-3.084
Singapore	6.163	0.18	0.182	0.0296	-1.40%	-0.003
Philippine	9.379	99.98	97.011	10.34	-2.97%	-2.972
Myanmar	5.302	64.47	63.096	11.90	-2.13%	-1.373
Malaysia	80.932	132.73	129.274	1.60	-2.60%	-3.454
Lao PDR	5.211	12.30	12.230	2.35	-0.56%	-0.069
Indonesia	0.001	0.05	0.045	38.05	-3.28%	-0.002
Cambodia	1.580	4.88	4.705	2.98	-3.63%	-0.177
Brunei	15.793	0.16	0.156	0.01	- 1.40%	-0.002
Southeast Asia	5.272	548.33	531.295	100.77	-3.11%	-17.034

Table 1. The estimated reduction in the volume of agricultural production, due to a decrease in the agricultural labor force in Southeast Asia

** Computed using crops and livestock production*

*** Computed using the agricultural production in 2018 as the base year*

**** Computed assuming 1.4 percent reduction in the agricultural labor force (Source: Vos, Martin, and Labourde 2020)*

***** Estimated based on 2018 production, and with 1.4 percent reduction in ALF.*

Source: *Gregorioa, G. B., & Ancog, R. C. (2020).*

The decline in the agricultural labor force as a result of the COVID-19 pandemic could reflect the reduction of agriculture's share in the total GDP among Southeast Asian countries. This is because the food sectors that contribute enormously will be drastically affected. In total, an estimated 1.4 percent drop in GDP (USD 3.76 billion) is expected in the whole of Southeast Asia (SEA) as shown in Table 3. Almost all SEA countries, apart from Brunei, could show more than one percent decrease in the share of agriculture to overall GDP Table 2.

With the COVID-19 Scenario							
Country	**Estimated GDP (Billion USD)****	**Estimated ALF in 2020 Due to COVID (Million)***	**%Change In GDP**	**The difference in GDP (Billion USD)**	**Total Population (Million)**	**Estimated Increase in the Number of Population Living Below USD 1.90 a Day (Million)**	**Percentage Increase in Poverty Rates Due to ALF Reduction*****
	2020	**2020**	**2000**	**2020**	**2020**		
Cambodia	4.70	2.978	-1.39%	-0.066	16.50		
Brunei	0.14	0.01	0.00%	0.000	0.43		
Indonesia	142.50	38.05	-1.40%	-2.022	266.10	5.51	2.07
Vietnam	34.51	21.13	-1.40%	-0.490	96.48	0.93	0.96
Timor-Leste	0.41	0.237	-1.25%	-0.005	1.30	0.02	1.63
Thailand	38.06	12.157	-1.40%	-0.542	66.56	1.57	2.36
Singapore	0.08	0.0296	-1.33%	-0.001	5.71		
Philippine	30.26	10.343	-1.40%	-0.430	108.80	3.23	2.97
Myanmar	17.16	11.901	-1.40%	-0.244	54.10	1.61	2.97
Malaysia	27.90	1.597	-1.42%	-0.402	32.60		
Laos	3.03	2.347	-1.39%	-0.043	6.70	0.20	2.97
Southeast Asia	264.60	100.769	-1.40%	-3.758	655.28	14.68	2.24

Table 2. The estimated reduction in GDP due to the decrease in the agricultural labor force in Southeast Asia

** Computed assuming 1.4 percent reduction in the agriculture labor force (Vos, Martin and Labourde 2020).*

*** Computed using the estimated 2020 ALF and the computed labor productivity.*

**** Based on the estimates of IFPRI from 1.4 percent reduction in labor supply, except for Brunei, Cambodia, Malaysia, and Singapore, for which data are not available.*

COVID-19 Pandemic Scenario for Farmers

The short-term outlook for Australian Agriculture is increasingly uncertain due to slowing demand in China, however, the virus is not only impacting Australia but is also impacting global (Jared, 2020). The Australian farmer also has to face off the problem of labor availability, it is because the Australian government wants to decrease the risk of the pandemic by not gaining manpower from migrant workers. (Jared, 2020). Horticultural and intensive production enterprises are particularly concerned about access to migrant labor needed to get products from the farm to consumers. (Heather McGilvray, 2020). In Italy, the main reason for the loss of vegetables and fruit was due to transports' slowdown, which causes the perishment of products. A collapse in consumption of up to 1/3 is at risk due to the regulatory restriction (Coldiritti's, 2020)

The problem is facing all countries all around the world. The farmers also had problems doing their normal farming, they lack equipment, fertilizer and seed due to the restriction and control order that closes the agricultural shop (FAO 2020). Countries like Malaysia also have agricultural problems due to the impact of coronavirus. The Farmer in Cameron Highland dumped hundreds of tons of their vegetable because no collector and buyer want to buy their fruit (Malaysia Kini 2020). The dairy farmer in the European Union was badly impacted which could eventually have a broader impact on the agricultural economy and the countries involves are likely to have a sporadic increase in the prices of the dairy product. Noting that many countries especially in the European Union were faced with a recession before the outbreak of the viral and this could be likely to push them over the edge.

The dairy farmers in the U.S. were not equally spared of the impact of the virus even though they have earlier enjoyed economic strength. This was as a result of the lockdown of industries processing that lower their purchases of the dairy products, eventually led to the price reduction, bringing heavy costs for the farmers. Many farmers in the U.S during this period had to dump their products like milk due to poor sales. The wastage experienced by many farmers especially in the developing countries was partly due to the inadequate or lack of infrastructure and longer distances from rural to urban areas make which had made it difficult for many to access stores especially during the pandemic crisis Dick (2020). As a result, most countries especially the developing countries would experience food crises or food insecurity as a result of the physical and economic accessibility issues associated with the pandemic. This was revealed in the Global Food Security Index (GFSI) that focuses on three main issues of availability, quality and safety and affordability, based on quantitative food security benchmark Figure 1.

Figure 1. *Overall Food Security Environment in the Era of the COVID-19 Pandemic*

For the member countries to survive the food crisis imposed by the COVID-19 pandemic, the benchmark must be strictly adhered to and ensure the future of food security. Food security consists of two key elements: people have enough money to buy food economic access, physical access, or whether people can find available food Shaikh (2020). Consequently, the World Trade Organization (WTO), FAO, and WHO released a joint statement that uncertainty about food availability could experience a shock due to the export restrictions, creating shortages on the global market world at the pick of the global fight against the COVID-19 pandemic (Dongyu et al, 2020).

Fresh Farm Produce Disruption in the Pandemic Era

Perishable food supply chains (PFSC) struggle against greater wastage but perform under higher risks of the COVID-19. Undoubtedly, Food Supply Chains (FSCs) are part of the important services during the pandemic. As such product encounter financial, operational, health and logistics risks during the pandemic Kumar et al., (2021). Perishable product entrepreneurs such as agricultural and food products felt the pandemic more as they cannot be sold directly to customers as a result of the disrupted shipping chain (Barnes et al., 2021). The disruption has made the farmers develop phobia which could have resulted in dwindling production in the subsequent planting seasons. Where farmers anticipated that it will be impossible for them to sell their farm produce due to the strict travel restrictions, the production will likely be affected by reducing their farm size and their production targets in the subsequent planting seasons. In Malaysia, the farmers experience a lot of food waste whereby farmers dumped fresh produce like durian and vegetables. If the waste persists or unable able to meet their profit to cover the cost of production, especially where the farmers experience unsold 30% farm produce, the future production targets could be cut by 30% to prevent additional costs on storage or wastage of food Lim (2020).

Apart from the pandemic outbreak which has evidently disrupted the farm-level production that could have resulted in the present and the future of food security, farmers in any part of the world experience severe or unfavorable weather conditions especially a rearguing where farming face high frequencies of environmental stressors Wood (2018). Consequently, The COVID-19 pandemic is poignant to both food supply and demand with uncertain future effects on food security and its affordability. The severity of the food supply is subject to the period of the pandemic and the ability of the farmers to cope with the new normal. To overcome the dynamism that has occurred in the demand and supply of food, a workable policy is required to ease effects is considered necessary (Schmidhuber, Pound, and Qiao 2020).

Impact of the Pandemic on the Global Food Security

Many countries are still going through a rise in food price at the retail level, showing continuing disruptions of supply as a result of the COVID-19 physical distancing measures, devaluations of currency, and other factors. The low-and middle-income feels the impact more because food takes most of their income compare to the people in high-income countries. The number of people who faced acute food insecurity in the year 2020 was at alarming rates. Consequently, the World Food Program (WFP) has estimated that 149 million people (including refugees) were severely affected the worse which was higher than the 2019 estimation across 79 countries. The pandemic brought the total number of severely food insecure people to 272 million by the end of 2020 in those same countries. According to the World Bank, inflation on the global food prices increased by 20% between January 2020 and January 2021 consistent with broad movements of other commodity prices and US currency trends World Bank (2020).

The food security of crisis of most of the countries started with the panic buying when the pandemic broke out that led to empty shelves of many supermarkets. In the history of humans, that pandemic created the highest levels of food insecurity on the planet. At the inception of the outbreak of the COVID-19, many supermarkets experienced chaotic scenes due to the impatience of many buyers who purchased larger quantities of rice, pasta and other important food and non-food items. This high demand did not reflect the shortage of food rather it indicated that the demand supersedes supply. A year after, the supermarket had relief, but the global food security crisis continues Niall McCarthy (2021). This shows that food security problems created by the pandemic will persist in many countries even after the COVID-19 because the initial food security or sufficiency plan had been disrupted by the pandemic even the high-income countries.

The 2020 Global Food Security Index compiled by the Intelligence Unit of the Economist had shown that the global food security crisis will continue to deteriorate globally because of different factors such as climate change and intensive farming. It was observed that the world was battling with food security issues before the pandemic, unfortunately, the COVID-19 made life even more difficult for farmers and worsened existing problems. 59 unique indicators that measured the Global Food Security Index considered the parameters such as food availability, affordability, safety, quality, and resilience / natural resources in 113 countries (The Econimist, 2020). This is following the United Nations on food security that encourage each nation to ensure that individual should adequately have access to food while nutrition and safety are not compromised at all time to ensure active and healthy life (FAO 2003). The overall Food Security Environment Changes in 2020 is presented in Table 4. Consequently, many researchers and world food organizations have observed that the type of crisis like the COVID-19 pandemic is unprecedented that is likely to have a long-lasting consequence on the future of food security if resilience agro-food system with crisis-proof food security strategies at regional and national levels is not developed. This would enable an adequate response to the multi-faceted disruption that could occur in the future.

Countries	Availability	Affordability	Quality & Safety	Natural Resources & Baseline	Overall Scores	2020
Australia	62.4	83.7	87.8	48.3	71.3	-1.8
Azerbaijan	63.3	75.9	60.9	37.1	62.3	-1.0
Bangladesh	64.4	48.3	40.9	35.8	50.0	-1.6
China	73.7	72.8	72.5	51.2	69.3	-0.1
Cambodia	57.4	57.5	40.1	41.2	51.5	-0.9
India	64.3	55.0	59.0	40.8	56.2	+1.1
Indonesia	64.7	73.5	49.6	34.1	59.5	-1.4
Japan	73.0	90.4	83.4	58.6	77.9	-0.5
Kazakhstan	65.7	79.0	83.7	52.4	70.8	+2.7
Laos	47.8	45.8	46.2	45.1	46.4	-1.1
Malaysia	58.8	85.5	72.5	47.5	67.9	+0.2
Myanmar	53.9	58.1	59.3	56.3	56.6	+0.3
Nepal	58.8	54.6	48.0	44.2	53.0	+1.8
New Zealand	64.0	90.6	83.1	69.9	77.0	-0.8
Philippines	57.6	66.5	52.0	35.8	55.7	-1.9
Pakistan	57.7	51.1	54.8	42.1	52.3	+2.6
Sri Lanka	51.8	64.0	52.0	46.3	54.8	-1.2
Singapore	75.8	87.3	82.3	47.4	75.7	-0.7
South Korea	67.7	81.8	78.4	56.1	72.1	-0.7
Thailand	55.3	82.8	59.5	50.0	64.0	+1.1
Tajikistan	50.9	52.7	53.1	37.0	49.4	+0.9
Uzbekistan	50.6	47.1	62.1	47.4	50.9	+0.9
Vietnam	61.3	66.7	61.4	45.9	60.3	-0.5

Table 3. Overall Food Security Environment Changes in 2020, compared with 2019

Source: *2020 Global Food Security Index Ranking*

Asia and Pacific subset of 23 countries

Scores are normalized 0-100, where 100=most favorable food security environment

Sorted by food security environment in 2020, best to worst.

Changes in Consumers' Lifestyle in the COVID-19 and Post-Pandemic Era

People share different reactions and behavior regarding their food choices in this pandemic. Changes in consumer's preferences have been well documented. Due to the long period of the lockdown, consumers prefer durable foods like frozen foods, dried and canned. Consumer's food lifestyle preferences equally shifted to foods to long-lasting products such as Ultra-High Temperature Processing (UHT) pasteurized milk, canned vegetables, and packet soups Schmidt et al., (2020). Nevertheless, the essentiality of the foods in terms of their nutritional value (these products are generally high in sugar, salt, and saturated fats) these products have proven to be essential in fulfilling global food requirements during the pandemic crisis Bree, (2020). On the other hand, the pandemic has caused a shift in people's consumption lifestyle. Interestingly, most people who looked for processed bread, packaged meals, and snack foods indulge in some comfort eating and reduce their movement that could expose them to the pandemic. In contrast, consumer behavioral characteristics and their preferences have changed recently as many begin to sought fresh foods, beverages and additive-free foods like in the

pre-pandemic period Devitt, (2020). As a result, there would be the need for many countries to strategize in building a post-pandemic robust agro-food system to cater for the need of the people as life-style could switch to the normal lifestyle after the pandemic. It has been undeniably reported that during the crisis and economic downturn, consumer's desire tends to shift towards a moderate lifestyle as many might prefer frozen and shelf-stable foods. The pandemic crisis creates paralleled recessionary economic and changes human consumption attitudes as many preferring budget-friendly foods, large portion and durable foods Devitt, (2020). Post- COVID-19 pandemic would lead to a change in consumer's lifestyle and behavior. Based on the findings by the EY Future Consumer Index by Rogers and Cosgrove Rogers and Cosgrove (2020), amongst the five consumer segments that are considered important when the pandemic crisis is over, there would be a proportion of 28% of cautiously flamboyant consumers. The study was based on 25% of the 4859 consumers surveyed conducted in the Canada, USA, France, the United Kingdom, and Germany during the pandemic crisis.

There would be a change in their eating habits due to the pandemic whilst only 14% agreed that they would maintain their normal consumption pattern and (31%) envisage that their consumption behavior would change. Characteristically, the former group is assumed to increase their expenses between +15–55%), the spending would notably reflect on restaurant food and to a lesser extent fresh food, ready meals, and frozen foods. Consequently, the need to increase agricultural food production and build a resilient food system after the pandemic is considered necessary to prevent food insecurity in the future.

Food Insecurity by Countries in the Era of COVID-19 Pandemic

The level of food insecurity created by the COVID-19 pandemic cannot be ignored without exception of the developed nations despite adequate levels of agricultural production, consumers experienced demand-induced scarcity Trollman et al., (2021). Before the COVID-19 pandemic, the modern agricultural practices and urbanization of the global population has led to complex food supply chains, often requiring long transportation of raw materials especially the staple commodities like wheat, maize, corn, soybeans and oil seeds) and facing significant sustainability challenges as well as decay in quality. Long supply chains (in terms of both time and distance) require the addition of a range of links in the chain that can impose significant risks and loss of control especially in most developing countries Bakalis et al., (2020). Consequently, many experienced food waste as the situation worsened according to major food producers due to the broken food chains. The developed countries were not left out. An interesting case was the low production of flour, one of the basic products that abruptly came into short supply on the supermarkets' shelves, especially in the UK. Australia, New Zealand, and European countries were equally affected. Unfortunately, the pandemic made worsen the situation Bakalis et al., (2020).

The World Bank has raised concerns about a potential rise in food insecurity during the COVID-19 pandemic. Even the global production levels for wheat, corn and rice, were not seriously affected (The World Bank, 2020), this has not stopped consumers from experiencing demand-induced scarcity during COVID-19 lockdowns in many countries due to domestic food supply chains and other shocks. In determining the food security, many researchers and other consensus had suggested a holistic approach that considers sustainable diets to achieve healthy dietary patterns from sustainable food systems (Comerford et al., 2020). The effect of the pandemic on the agriculture cannot be underestimated which led to the disruption of food supply chain primarily affect food demand with indirect effect on food security (Siche, 2020). The sudden panic buying created by the COVID-19 were not prepared for by the food retailers especially at the inception stages of the pandemic (Barnes et al., 2021). For example, a survey study conducted by Trollman et al., (2021) in the UK which attracted 243 respondents. Of these 243 respondents, 222 experienced reduced availability of wheat flour or eggs during the COVID-19 lockdown. In terms of growth and innovation the sector is in a state of flux. There had been reported case of relatively slow growth of business among the food manufacturers prior to the pandemic (<3%) while some SMEs reported growths of up to 10%. The World Food Program (WFP, 2020) reported that the pandemic has dramatically increased the number of people facing acute food insecurity in 2020. The estimated includes 149 million refugees. The following countries have been list in the World Bank's FY21 list of Fragile and Conflict Situations (FCS) as shown in Figure 2.

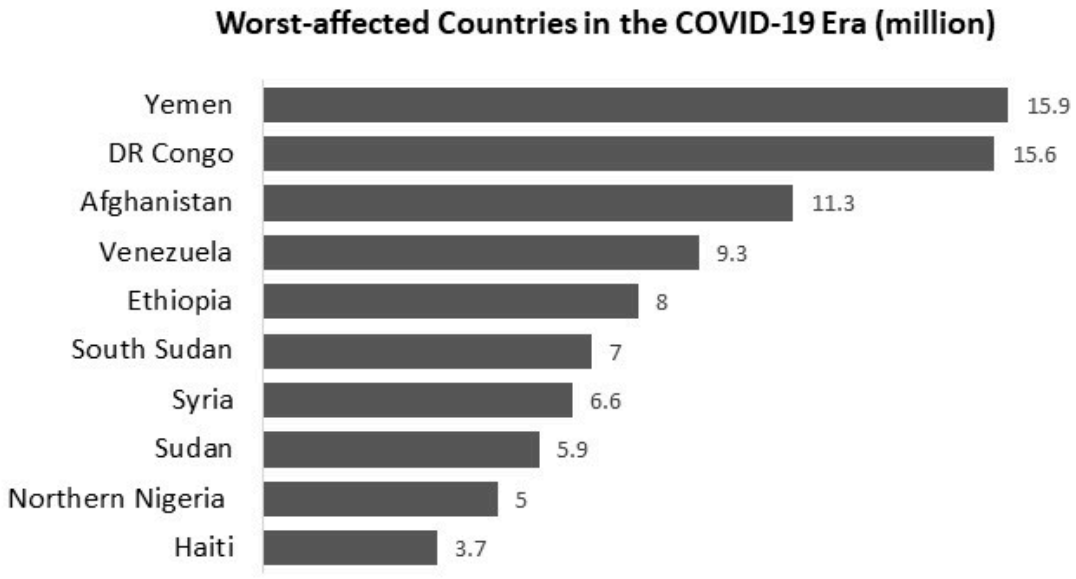

Figure 2. *People who faced severe Food Insecurity During the COVID-19*

Source: *Federation of Sovereign Indigenous Nations (FSIN), Global Report on Food Crises (GRFC) and World Food Program (WFP) 2020.*

The WFP and World Bank in a latest report reported an additional 150 million people has been added to the already affected people in the countries that is most affected by the food insecurity and many of them could fall into extreme poverty level by the year 2021. Another study conducted by Kansiime et al., (2021), showed that more than two-thirds of the respondents experienced income shocks due to the pandemic crisis. Food security and dietary quality worsened, as measured by the food insecurity experience scale and the frequency of consumption of nutritionally-rich foods. The proportion of food insecure respondents increased by 38% and 44% in Uganda and Kenya respectively, and in both countries, the regular consumption of fruits decreased by about 30% during the COVID-19 pandemic, compared to a normal period (before the pandemic).

Future of Food Security and Resilience Agro-Food System for Post-COVID-19 Pandemic

The COVID-19 pandemic has created a food deficit in many countries and create uncertainty. As such future of food security is threatened as the food sufficiency plan (FSP) of most countries especially the developing countries have been greatly affected. Consequently, many countries are calling for the promotion of sustainability and further reduction of food waste during and post COVID-19 pandemic Borsellino, et al., (2020). Policymakers and researchers are always concern about the food consumption pattern and sustainability that is frequently discussed before the pandemic (Vermeir and Verbeke 2006; Joyce et al., 2014; Hyland et al., 2016; Hyland et al., 2017). In establishing a sustainable food system, the role of food consumption must be thoroughly considered. In food supply chains, consumers are considered as stakeholders that determine the final link because they influence food systems eating habits and own food choices Payne, (2016). Consequently, food consumption has the potential to greatly influence the economy, the environment, and the well-being of society (Payne et al., 2016; Reisch, et al., 2013; Lim et al., 2019; Azzurra et al., 2019). Undeniably, the world population increases to occupy the cities, so it creates additional demand for agricultural production, sustainability issues relating to the food sector arise; these would require the globalization of the agri-food trade, more industrialization of agriculture, increasing intake of animal protein in Western diet patterns, the spread of eating habits involving increasingly processed products after in the post-pandemic food security. As the world hopes to recover from the effect of the COVID-19, building a sustainable agro-food ecosystem that would ensure successful delivery of food and nutrition security in a way that would take into consideration social, economic and environmental aspects to generate food security comprising the nutrition for the present and the future generations. A framework to ensure the global future of food security must be developed as shown in Figure 3.

Figure 3. *Framework for ensuring Global future of Food Security in Post COVID-19*

It is equally important for the nations to build crisis resilient agro-food systems but flexible with the strength to recover and withstand the effects of the COVID-19 pandemic agro-food economic crisis and disruptions. COVID-19 offers an opportunity to enhance the resilience, sustainability, and productivity of the agriculture and food sector.

Conclusions

The COVID-19 crisis has drawn attention of people to the importance of agro-food products. The lockdown imposed by many countries to break the chain of pandemic transmission had exposed many countries to food insecurity and threatened food self-sufficiency level (SSL) planned. This systematic review revealed the factors that have significantly contributed to the food insecurity in the pandemic era, the challenges of sustainability and the framework to ensure resilient agriculture and food systems for the future of food security without compromising the nutrition security, particularly in times of crises such as the current pandemic. The findings presented in this paper emphasized the need to build a sustainable agro-food industry due to the change in consumption pattern and lifestyle in the pandemic era which could change drastically after the COVID-19 pandemic. The study shows that food consumption preferences will develop along different trajectories. To understand future consumer behavior and satisfy the global demand for foodstuffs, the authors of this paper believe that the stakeholders in the agro-food industry should focus on issues such as the re-engineering of a more sustainable

and a strengthened FSC food security, prevent future disruption of perishable food supply chain (PFSC), unfettered access to food, and healthier eating patterns. A feeling of food insecurity in post-COVID-19 and the perceived scarcity effect must trigger development of crisis resilient agro-food system. These would be able to address erratic consumer behavior and mitigate crisis side effects, such as panic buying and its related consequences, during future public health emergencies or natural crises. Most importantly, shortage in the agriculture labor force (ALF) must be prepared for to serve as a catalyst to food security during crisis.

Acknowledgments

The authors would like to extend their gratitude to the Research Management and Innovation Center (RMIC), Sultan Idris Education University (UPSI) for the support during the preparation of the manuscript.

References

- Azzurra, A., Massimiliano, A. and Angela, M. 2019. Measuring sustainable food consumption: A case study on organic food. Sustainable Production and Consumption, 17, 95-107.
- Barnes, S.J. Diaz, M. and Arnaboldi, M. 2021. Understanding panic buying during COVID-19: A text analytics approach. Expert Systems with Applications, 169: 114360.
- Bakalis, S. V. (2020). Perspectives From Co+Re: How Covid-19 Changed Our Food Systems And Food Security Paradigms. Current Research in Food Science, 166–172.
- Brinca, P. J. B., Duarte et, M. and Faria e, C. 2020. Is the COVID-19 Pandemic a Supply or a Demand Shock? Federal Reserve Bank of St. Louis Economic Synopsis, no 31.
- Borsellino, V., Kaliji, S.A. and Schimmenti E. 2020. COVID-19 Drives Consumer Behaviour and Agro-Food Markets towards Healthier and More Sustainable Patterns. *Sustainability*. 12 (20): 8366.
- Benzeval, M., Burton, J. Crossley, T. F. Fisher, P. Jäckle, A. Low, H. and Read, B. 2020. The Idiosyncratic Impact of an Aggregate Shock: The Distributional Consequences of COVID-19. Available at SSRN 3615691.
- Bree, A. 2020. How Will Covid-19 Change Our Relationship with Food? Retrieved on March 14, 2021 from nutrition connect Website: https://nutritionconnect.org/resource-center/how-will-covid-19-change-our-relationship-food .
- Chinazzi, M., Davis, J. T. Ajelli, M. Gioannini, C. Litvinova, M. Merler, S. and Viboud, C. 2020. The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak. Science, 368(6489): 395-400.
- Comerford, K. Arndt, C. Drewnowski, A. Ericksen, P. Griffin, T. Hendrickson, M. Nicholls, J. 2020. Proceedings of a Workshop on Characterizing and Defining the Social and Economic Domains of Sustainable Diets. Sustainability, 12(10): 4163.
- Coldiritti's, 2020. What Italian farmers need to address COVID 19 challenges? Retrieveon 10, 2021 from FAO Website: https://www.wfo-oma.org/covid-19/what-italian-farmers-need-to-address-covid-19-challenges/
- Dongyu, Q., Adhanom, G. T. and Azevedo, R. 2020. Mitigating impacts of COVID-19 on food trade and markets. Retrieved on February 12, 2021 from FAO Website: http://www.fao.org/sustainability/news/detail/en/c/1269096/ .
- Dick, N. K. 2020. Form a National Food and Nutrition Security Task Force to Avert the Effects COVID-19 Pandemic in Uganda. Retrieved on March 3, 2021 from WFO Website: https://www.wfo-oma.org/covid-19/farmers-challenges/form-a-national-food-nutrition-security-task-force-to-avert-the-effects-covid-19-pandemic-in uganda/
- Devitt, A. 2021. Comfort Food during COVID-19. Retrieved on March 10, 2021 from Kerry Website: https://kerry.com/insights/kerrydigest/2020/comfort-food-during-covid-19.
- Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP) and World Health Organization (WHO) .2020. The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. Rome, Retrieved on March 19, 2021 from FAO Website: http://www.fao.org/3/ca9692en/online/ca9692en.html .
- FAO, 2020. Q & A: COVID-19 pandemic – impact on food and agriculture. Retrieved on March 10, 2021 from FAO Website: http://www.fao.org/2019-ncov/q-and-a/impact-on-food-and-agriculture/en/
- FAO. 2003. Trade Reforms and Food Security: Conceptualizing the Linkages. Commodity Policy and Projections Service Commodities and Trade Division. Retrieved on February 10, 2021 from FAO, Rome Website: http://www.fao.org/3/y4671e/y4671e00.htm
- Gregorioa, G. B. and Ancog, R. C. 2020. Assessing the impact of the covid-19 pandemic on agricultural production in Southeast Asia: toward transformative change in agricultural food systems. Asian Journal of Agriculture and Development, 17(1362--1097): 1-13.

- Ghani, F. A. 2020. The psychological impact of an epidemic Covid-19. Retrieved on March 14, 2020, from AstroAwani Website: http://www.astroawani.com/berita-malaysia/impak-psikologi-akibatwabak-covid-19- 233648.
- Global Food Security Index. 2020. Food Security Environment. Retrieved on March 5, 2021 from GFSI Website: https://foodsecurityindex.eiu.com/index
- Hossain, S.T. Impacts of COVID-19 on the Agri-food Sector: Food Security Policies of Asian Productivity Organization Members. J. Agric. Sci. Sri Lanka 2020, 15, 116–132.
- Hyland, J.J.; Styles, D.; Jones, D.L.; Williams, A.P. Improving livestock production efficiencies presents a major opportunity to reduce sectoral greenhouse gas emissions. Agric. Syst. 2016, 147, 123–131.
- Hyland, J.J.; McCarthy, M.B.; Henchion, M.; McCarthy, S.N. Dietary emissions patterns and their effect on the overall climatic impact of food consumption. Inst. Food Sci. Technol. 2017, 52, 2505–2512.
- IMF. International Monetary Fund. (2020). Available online: https://www.imf.org/en/News/Articles/2020/03/23/pr2098-imf-managing-director-statement-following-a-g20-ministerial-call-on-the-coronavirusemergency (accessed on 12 May 2020).
- Jared Greenville, (2020, April). Impacts of COVID-19 on Australian agriculture, forestry and fisheries trade. Retrieve from: https://www.agriculture.gov.au/abares/research-topics/trade/impacts-of-COVID-19-on
- Joyce, A.; Hallett, J.; Hannelly, T.; Carey, G. The impact of nutritional choices on global warming and policy implications: Examining the link between dietary choices and greenhouse gas emissions. Energy Emiss. Control Technol. 2014, 2, 33–43.
- Karabag, S. F. (2020). An unprecedented global crisis! the global, regional, national, political, economic and commercial impact of the coronavirus pandemic, Journal of Applied Economics and Business Research,10 (1), 1-6.
- Kansiime, M. K., Tambo, J. A., Mugambi, I., Bundi, M., Kara, A., & Owuor, C. (2021). COVID-19 implications on household income and food security in Kenya and Uganda: Findings from a rapid assessment. World development, 137, 105199.
- Kumar, A., Mangla, S. K., Kumar, P., & Song, M. (2021). Mitigate risks in perishable food supply chains: Learning from COVID-19. Technological Forecasting and Social Change, 166, 120643.
- Liu, Y., Gayle, A. A., Smith, A. W. & Rocklov, J. (2020). The reproductive number of Covid-19 is higher compared to SARS coronavirus, Journal of Travel Medicine, 27(2).
- Lim, J. (2020). The Big Read: Global supply chain shock has farmers dumping food as consumers fret over shortages, price hikes. Channel News Asia, 20 April 2020. Accessed 1 June 2020, https://www.channelnewsasia.com/news/singapore/big-read-covid19-global-supply-chain-shockfood-shortages-12655836.
- Lim, E.; Arita, S.; Joung, S. Advancing Sustainable Consumption in Korea and Japan—From Re-Orientation of Consumer Behavior to Civic Actions. Sustainability 2019, 11, 6683.
- Niall McCarthy (2021) https://www.Statista.Com/Chart/21206/Index-Scores-For-The-Affordability-Availability-Safety-And-Quality-Of-Food/
- **Oladosu, Y., Rafii, M. Y. Arolu, F. Chukwu, S. C. Muhammad, I. Kareem, I. Monsuru, A.S and Arolu, I. W. 2020. Submergence tolerance in rice: Review of mechanism, breeding and, future prospects. Sustainability, 12(4): 1632.**
- Payne, C.L.; Scarborough, P.; Cobiac, L. Do low-carbon-emission diets lead to higher nutritional quality and positive health outcomes? A systematic review of the literature. Public Health Nutr. 2016, 19, 2654–2661.
- Qiu, W., Rutherford, S., Mao, A. & Chu, C. (2017). The pandemic and its impact, Health, Culture and Society, 9(10).
- Schmidhuber, J., J. Pound, and B. Qiao. 2020. COVID-19: Channels of Transmission to Food and Agriculture. Rome: FAO.
- Rogers, K.; Cosgrove, A. Future Consumer Index: How COVID-19 Is Changing Consumer Behaviors. Available online: https://www.ey.com/en_id/covid-19/enterprise-resiliency-nine-areas-of-focus-for-covid19-crisis-management (accessed on 20 June 2020).
- Reisch, L.; Eberle, U.; Lorek, S. Sustainable food consumption: An overview of contemporary issues and policies. Sustain. Sci. Pr. Policy 2013, 9, 7–25.
- Schmidt, C.; Goetz, S.; Rocker, S.; Tian, Z. Google Searches Reveal Changing Consumer Food Sourcing in the COVID-19 Pandemic. J. Agric. Food Syst. Community Dev. 2020, 9, 1–8.
- Siche, R. (2020) What is the impact of COVID-19 disease on agriculture? Scientia Agropecuaria, 11(1), 39. doi: 10.17268/sci.agropecu.2020.01.00
- The Economist Intelligence Unit. (2019). Global Food Security Index. Accessed 15 January 2020, https://foodsecurityindex.eiu.com/. Australiantradetext=Summary, agriculture%2C%20forestry%20and%20fisheries%20sectors.&text=However%2C%20because%20agricultural%20exports%20principally,rather%20th
- Trollman, H., Jagtap, S., Garcia-Garcia, G., Harastani, R., Colwill, J., & Trollman, F. (2021). COVID-19 demand-induced scarcity effects on nutrition and environment: investigating mitigation strategies for eggs and wheat flour in the United Kingdom. Sustainable Production and Consumption.

- The World Bank. (2020a, July 8). Food Security and COVID-19. Retrieved from UnderstandingPoverty: https://www.worldbank.org/en/topic/agriculture/brief/food-security-and-covid-19
- VOS, ROB; WILL M and DAVID, L (2020). "How much will global poverty increase because of COVID-19?" IFPRI Blog: Research Post, 20 March 2020, International Food Policy Research Center (IFPRI). https://www.ifpri.org/blog/how-much-will-global-poverty-increasebecause-covid-19 .
- Vermeir, I.; Verbeke, W. Sustainable Food Consumption: Exploring the Consumer "Attitude – Behavioral Intention" Gap. J. Agric. Environ. Ethics 2006, 19, 169–194.
- Wilder-Smith, A., & Freedman, D. O. (2020). Isolation, quarantine, social distancing and community containment: pivotal role for old-style public health measures in the novel coronavirus (2019-nCoV) outbreak. *Journal of travel medicine*, *27*(2), taaa020.
- World Farmers Organization (2020). COVID-19 pandemic outbreak: Overview of the impact on the Agricultural Sector. A Technical Assessment of the Undergoing Situation.
- World Bank (2020). Food Security and COVID-19. https://www.worldbank.org/en/topic/agriculture/brief/food-security-and-covid-19
- Wood, J. (2018). Why Asia-Pacific is especially prone to natural disasters. World Economic Forum. Online Publication. Accessed 5 June 2020, https://www.weforum.org/agenda/2018/12/why-asia-pacific-is-especially-prone-to-natural-disasters/.
- World Food Program (2020). WFP Global Update on COVID-19: November 2020 Growing Needs, Response to Date and What's to Come in 2021. Report.

Declarations

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.