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The vulnerability of a centralized food system: An opportunity to improve food security in times of COVID-19-Peru perspective

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COVID-19 has had a strong impact on the food supply chain (FSC) in many countries. The objective of this study was to determine the vulnerability of the FSC in a developing country, namely Peru. The main weakness of the FSC is its centralization, and COVID-19 aggravated this deficit in Peru. This prevents its stability on a large scale, especially in rural areas, which suffer from food and nutritional insecurity. In spite of this, the food system was stabilized due to agricultural, livestock and fishing potential of Peru. In addition, the efforts of local producers and informal vendors helped to maintain the availability of food throughout the country. Several examples of short (and decentralized) FSC were described, highlighting their importance for supplying the population in different areas of the country. In addition, they allow for rapid resolution of interruptions such as the current health crisis. Also mentioned are some suggestions for strengthening Peru's FSC such as the use of new technologies, self-production of food and the exploitation of non-conventional food sources. Emphasis is placed on the importance of environmental sustainability of the FSC and of implementing strategies to prevent illness among workers. This study aims to reflect on the importance of having a resilient and flexible FSC. Taking Peru as a model, the information provided is useful to understand how to improve the food system through the intervention of all the agents involved, such as government, academia, industry and the population.

KEYWORDS

coronavirus, SARS-CoV-2, Peru, food supply chain, food system, food and nutrition security, sustainability

Introduction

As of 29 July 2022, there have been 572,239,451 confirmed cases of infection and 6,390,401 deaths due to coronavirus disease 2019 (COVID-19) (WHO, 2022). This is caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). COVID-19 has caused great impact in social and economic terms, affecting all industries (Singh et al., 2021). Specifically, COVID-19 has significantly affected the food sector. The food and beverage sector is one of the most relevant and fastest growing industries in the world (Mukhamedjanova, 2020; Memon et al., 2021). It had global revenues of $8 trillion in 2020 and is forecast to increase to $9.1 trillion by 2025 (STATISTA, 2021). On average, food manufacturing represents 12% of the Gross Domestic Product (GDP) of all countries (Bakalis et al., 2020).

The international blockade and the measures imposed by national governments to deal with the pandemic have disrupted the food supply chain (FSC) (Rizou et al., 2020). More than 450 meatpacking plants, more than 250 food processing plants and more than 90 farms were reportedly affected by COVID-19 in the United States. In addition, more than 54,000 workers in the FSC were infected by COVID-19 and more than 200 workers lost their lives. Similar cases were shown in Brazil, Ghana, Germany and France (Aday and Aday, 2020). Farmers in Bangladesh had significant losses of pointed gourd, yardlong beans, bottle gourd, cucumber and brinjal, valued at $692, $633, $223, $223, $131 and $59 per acre, respectively (Alam, 2021). In India, a 10% reduction in the availability of fruits, vegetables and edible oils was witnessed (Mahajan, 2021). In this context, the pandemic has demonstrated the vulnerability of the FSC at critical times and globally.

The impact on imports and exports was severe due to the disruption of international physical supply chains, resulting in high costs. Government restrictions on economic and personal activity (e.g., labor shortages due to not being able to go to work) threw the FSC into chaos, creating an economic crisis (Kerr, 2020) and disrupting the production of farmers, ranchers and fishermen. In the slaughterhouses of France, there was a 30% reduction in the labor force, and in India, the shortage was so high that it reduced cereal production by more than 20% (Rahimi et al., 2021). In addition, there was evidence of low demand and consequent significant loss of food due to the closure of restaurants and related businesses. In Arequipa, Peru, a large number of restaurants were closed, seriously affecting producers/sellers of chicken and potatoes (Malone et al., 2021). All this generated unprecedented food insecurity, a global problem that is being fought every day.

Arguably, all countries have the same battle against COVID-19, but developing countries have a greater challenge, primarily because many of them have a centralized food supply chain (CFSC), with participation and decision making by one or a few responsible agents. For example, the products are sold in a few markets, which are far from a large part of the population. In the case of exports, there are no seaports (there is only one in most cases) close to the production areas. According to Kumar et al. (2021), this makes production, processing, marketing and provisioning difficult. The pandemic has arrived late in Latin America, which has allowed Latin American countries to be better prepared. However, their health and technological deficits and socioeconomic inequalities have had a serious impact from which they have not yet fully recovered (Benítez et al., 2020). There are few studies in this field related to Latin American countries. Specifically, in Peru, although it is a world power in terms of agriculture and fisheries, its food security was strongly affected by COVID-19, leaving its vulnerability exposed. The objective of this study is to determine the vulnerability of the food system in Peru and the impact caused by COVID-19. In addition, some challenges of the topic will be defined and multiple alternative solutions will be offered to improve the country's food system. This is the first study of its kind focused on Peru and the information provided will also be useful for implementing strategies to improve food systems in other countries.

Peru's measures to combat the pandemic

Unlike in other continents, COVID-19 spread relatively late to Latin American countries. Peru was able to establish a contingency plan. It reported its first case of infection on 6 March 2020. On 11 March 2020, through Supreme Decree No. 008-2020-SA, a health emergency was declared at the national level, for a period of ninety (90) calendar days (Parlamento Andino, 2022).

On March 15, the government provided intensive and rapid responses to prevent the spread of the virus such as Ministerial Resolution N° 039-2020-MINSA and Emergency Decree N° 025-2020 focused on improving surveillance, containment and response systems to reduce the impact of COVID-19 (Parlamento Andino, 2022). Quarantine measures (for 3 months) and curfew (until January 2022) were established. The use of masks was enforced, it was suggested to keep a minimum distance of one meter, to wash hands frequently with soap and water and to avoid crowded spaces without natural ventilation (Velásquez-Quispe et al., 2021). A large number of health professionals were hired, and intensive care beds and equipment were acquired for cases of severe symptomatology (Benítez et al., 2020; Romero, 2020). In addition, social programs were implemented, early retirement pensions were allowed, and economic bonuses (such as the Urban, Rural, Independent and Universal Family bonus) were granted to maintain short-term stability for poor families (Siche, 2020), who were affected by the massive loss of jobs. Similarly, the government provided

economic assistance to micro and small micro and small businesses (MYPES) to reduce the impact of the pandemic. The financings were quickly implemented through Emergency Decree N° 029-2020. Credits were also provided through the Business Support Fund for MYPES and the Reactiva Peru Program (Parlamento Andino, 2022).

According to Marco (2020), the Peruvian government first spent more than US$25 billion, which represents 12% of GDP. This proportion was the largest in all of Latin America. Argentina, for example, spent only 1% of its GDP. Despite this, Peru has multiple deficiencies due to its health system, labor informality, and the large number of migrants from Venezuela, among other factors (Vázquez-Rowe and Gandolfi, 2020). These factors make it vulnerable, also considering that, as an emerging economy, it faces greater barriers to its sustainability (Bunclark, 2021). Shrestha et al. (2020) determined that Peru is one of the countries with the highest pandemic vulnerability index in the world, considering factors such as economy, health capacity, globalization through travel, event cancellation, work index, FSC and academic level. Therefore, in relation to COVID-19, Peru is one of the countries with a very high mortality rate. As of 01 August 2022, 3,909,870 positive cases and 214,303 deaths have been confirmed (Worldometer, 2022).

It should be noted that Peru remains in a state of health emergency until August 2022 according to Supreme Decree N° 003-2022-SA (Parlamento Andino, 2022).

Food and nutrition insecurity

Background

During this health crisis, life-saving activities are essential, but the scarcity and inaccessibility of food makes this battle difficult (Singh et al., 2021). Therefore, it is also vital to maintain and improve food and nutritional security, through its four fundamental pillars (Figure 1) (Sharma, 2020; Burlea-Schiopoiu et al., 2021; Kumar et al., 2021). One of the factors causing the food security deficit is food waste (sale and consumption) and loss (production, transformation, etc.) at the stages of the FSC, especially if the food is perishable. This leads to a reduction in the availability of nutritious foods and a substantial increase in costs. For example, due to low demand, if a farmer, rancher or fisherman does not sell their food, they must store it. This means an increase in costs and also a reduction in product quality.

Peru is one of the countries with the highest rate of food loss and waste in Latin America, with annual values of approximately 12.8 million tons, representing more than 47% of total production (Banco de Alimentos Perú, 2021). According to the study by Bedoya-Perales and Dal' Magro (2021), based on data from Peru from 2007 to 2017, the average loss/waste per capita was 426.56 kg/year across all FSC stages, and 67.34 kg/year at the final consumer stage. In the study by Requena-Sanchez et al. (2022), from 2019 to 2020 there was no evidence of an increase in food waste in Comas, Lima, Peru. However, an increase in the waste of single-use plastic containers and bags was reported, which is related to the increase in food delivery services.

Impact on Peru

Restrictions on business, people and transportation affected local commerce. In the food sector, the stability in the capacity and efficiency of farmers, food manufacturers, wholesale distributors and retailers has been lost (FAO, 2020a). Border closures, trade measures in Peru, crisis in foreign markets and with strategic partners [Ministry of Agriculture and Irrigation of Peru (MINAGRI, 2020)] affected the FSC (Mukhamedjanova, 2020). The impact was more severe than expected due to Peru's dependence on imports and its leading position in agri-food exports (van der Ploeg, 2020). In addition, the isolation affected the dynamics of economic activity in general (Varona, 2021). For example, transit restrictions limited the fishing and subsequent distribution of different marine products in Lima (Peru's capital) and other areas of the country (Bassett et al., 2021).

Several studies have confirmed the vulnerability of the Peruvian food system. Erokhin (2020) analyzed the impact of COVID-19 in 45 countries, concluding that Peru was severely affected in trade, foreign exchange and food supply. From March to August 2020 there was a reduction in fishing and purchase of fish (e.g., 83% less hake). As a result, 620 jobs were affected with an overall loss of approximately US$913 thousand (Grillo-Núñez et al., 2021). In addition, in one of the first studies conducted at the beginning of the pandemic, it was determined that there was a significant reduction in income of 37% of the participants (Sanchez et al., 2020). This generated greater limitations in the acquisition of food, mainly for Peruvians who subsist on their daily income (Cañari-Casaño et al., 2021). This deficit increased health problems and the prevalence index of food insecurity (PIFI) (Bakalis et al., 2020; O'Hara, 2021).

Regarding socioeconomic status, a study conducted from March to December 2020 found that Peruvian families with low incomes were 42% more likely to experience food insecurity (Curi-Quinto et al., 2021). From May to June 2020, Cañari-Casaño et al. (2021) found that Peruvians with incomes below $255/month were highly likely to experience moderate or severe food insecurity. This is ironic considering that currently (25 February 2022) the minimum salary in the country is PEN 920 (US$ 242.17). According to the study by Cuenca Jaque et al. (2020), from March to April 2020, 57.3% of Peruvians were already experiencing economic problems and difficulties in acquiring basic necessities. In addition, 69.8% of Peruvians indicated that they only had enough food for 1 week and 56.8% indicated that with the money they had they could only buy enough food for 2 weeks. A study conducted in May 2020 found that 56.9% of Peruvians spent more on food than before the

FIGURE 1
Basic dimensions of food and nutrition security.

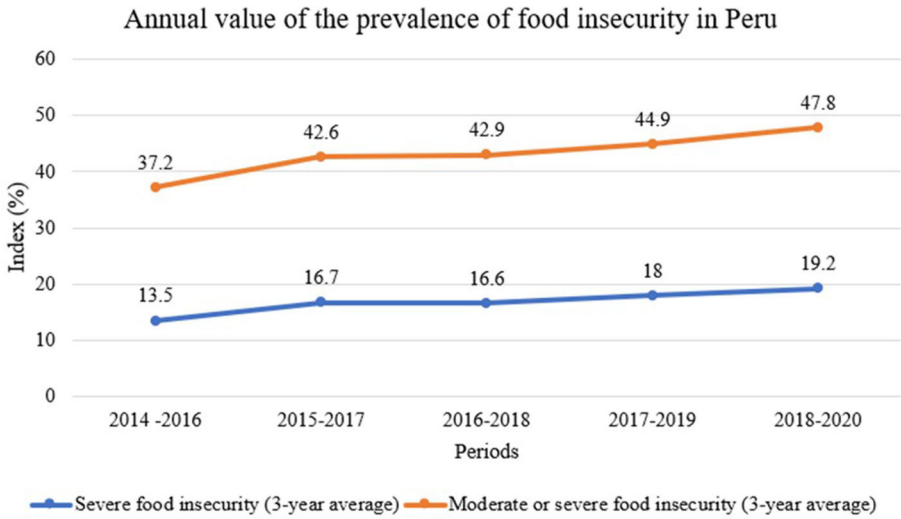

FIGURE 2
Prevalence of food insecurity in Peru. Based on data from (FAOSTAT, 2021).

pandemic (Cequea et al., 2021). These results are worrisome and the crisis increased as the isolation prolonged. It should be considered that the PIFI before the pandemic was already negative. From the period 2014–2016 to 2018–2020 in Peru, severe food insecurity increased by 10.6% and moderate or severe insecurity by 5.7%, as shown in Figure 2.

Centralization in the food supply chain

A food system must be multidisciplinary and interconnected (Han et al., 2021). It should cover the greatest number of people (producers, government, industry, consumers) and avoid inequalities regardless of their geographic location within the country (Cable et al., 2021). The main factor contributing to internal food shortages is centralized distribution, which, due to lack of adequate logistics, concentrates all raw materials and/or products in one place or in very limited areas. This affects the availability of food for the population living in *discriminated* cities (Cullen, 2020). It also increases the costs of products when they are sold in areas far from production and/or transformation. This is chaotic when crises such as the current pandemic occur because it is more difficult to solve problems (Abdullah et al., 2021). Does not allow for quick responses to disruptions at any stage, demand surges or product shortages. Figure 3 shows the United Kingdom's FSC with the number of participants at each stage. Compared to the other stages, there

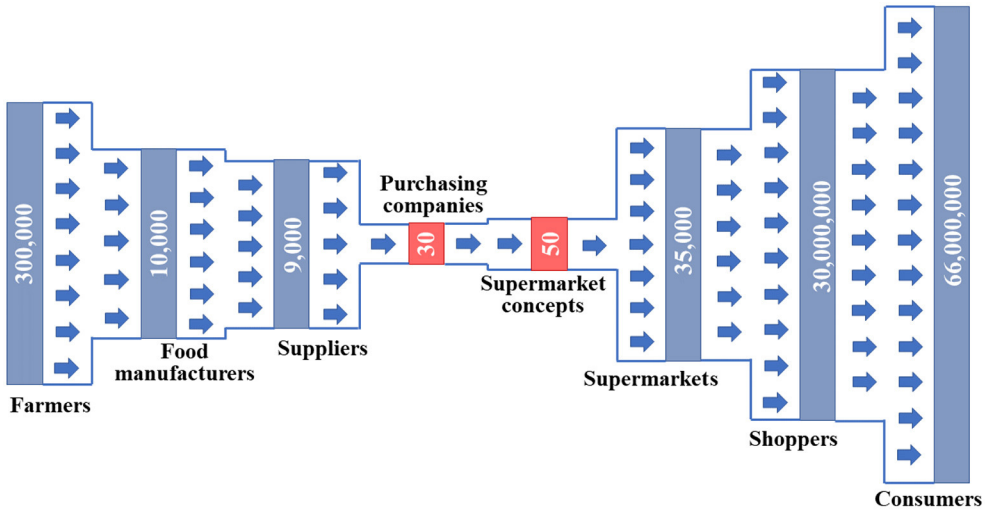

FIGURE 3
Graphical representation of the agents (numbers in white) involved in each stage of the United Kingdom's FSC. Adapted from Bakalis et al. (2020).

is a bottleneck in the Suppliers and Supermarkets stage. The number of agents involved in the Purchasing companies and in Supermarket concepts (red boxes) stage is very low. This means that only a selected group of organizations acquire and control a large part of the food consumed. In the event of a crisis in this small group of organizations, the FSC would suffer an untimely and difficult-to-solve disruption. This example clearly shows how most FSCs are vulnerable because they are dominated by a few large, but centralized, organizations (Hobbs, 2020).

To solve this problem, FAO (2020b) mentions that it is essential to create regionalized food supply chains (RFSCs) at strategic points throughout the country. This will provide greater linkages between urban and rural areas, allowing for local production and availability, short-distance transportation and few intermediaries between producers and consumers (Marusak et al., 2021). The short distance also makes it possible to obtain fresher and cheaper foods (Barman et al., 2021). In case of risk, the self-sufficiency of each RFSC allows mitigating the adverse effects, reducing the overall damage (Thilmany et al., 2021). This confirms the resilience of RFSCs, which means that they are flexible and adaptable. This type of short chain has been successful in rural and urban areas in all European Union countries (Bakalis et al., 2020). Marusak et al. (2021) evaluated the effect of RFSCs on the resilience of food systems based on seven case studies from Texas and Iowa. It was concluded that the RFSCs are faster in terms of adaptation, managing to be efficient in maintaining sustainability in this COVID-19 context. Chenarides et al. (2021) used a FSC model for fresh onions in the United States based on real options theory. Increased flexibility was found to increase the resilience of the FSC. The results also showed that these types of adaptable FSC have a higher value in the market.

Resistance of the Peruvian food system to centralization

Despite the efforts made, Peru has greater centralism than other Latin American countries such as Brazil, Chile, and Colombia (Binder, 2018). This is due to the few initiatives taken by the authorities, the lack of infrastructure, the scarce and deficient interconnection routes between regions. The food industry in Peru is conditioned to serious structural and logistical limitations that force it to be dependent on privileged zones (Lazo, 1984). A clear example is Lima, which receives the highest proportion of state support. Although moderate poverty and chronic malnutrition have been significantly reduced throughout the country in the last two decades, progress has been uneven in rural and Amazonian areas (Vargas et al., 2021). Useche (2016) highlight that between urban and rural areas in Peru there is a wide gap in terms of food security. According to Castro-Bedriñana et al. (2021), the average chronic malnutrition rate in Lima is 5% and in rural areas it is over 33%. In rural areas of Peru, 4 out of every 5 children between 6 months and 2 years old suffer from malnutrition (UNICEF, 2019). Similarly, Abizaid et al. (2020) evaluated the effect of the pandemic in marginalized areas of Ucayali, a region of the Peruvian Amazon. It was corroborated that the population of Ucayali received fewer economic bonuses and there is no guarantee that the people who needed them received them.

TABLE 1 Examples of some CFSCs in Peru.

Product	Place of production	Main port of export	Approximate distance (km)	References
Cocoa	Cusco	Callao (97% of total production)	1,000	(Briceño-Garmendia et al., 2016a)
	Piura		900	
	San Martín		800	
	Amazonas		700	
	Ayacucho		500	
	Junín		200	
Quinoa	Puno	Callao (88.4% of total production)	1,200	(Briceño-Garmendia et al., 2016c)
	Arequipa		1,000	
	Cusco		1,000	
	Ayacucho		500	
	Apurimac		400	
	Junín		200	
Coffee	Huánuco	Paita (54.8% of total production)	1,100	(Briceño-Garmendia et al., 2016b)
	Ucayali		1,000	
	Junín		1,000	
	Pasco		800	
	Cajamarca		500	
	Piura		Same region	

There was also a scarce and unequal distribution of food by the state.

Coffee, cocoa and quinoa exports are some examples of non-integrated logistics chains (or RFSCs). Briceño-Garmendia et al. (2016d) mention that these products are transported in small and medium-sized informal vehicles that travel long distances. As shown in Table 1, the production areas are very distant from the seaport destined for export. New ports should be implemented in different strategic areas of the country to reduce the distance with the production areas. In the case of cocoa cultivation in Piura, the port of Paita can be used, which is located in the same region. Quinoa is mainly produced in the south of the country; however, this area lacks seaports. In the case of coffee, the port of Paita can be used to receive coffee from Piura, and for the production of other zones, the port of Callao can be used. Similarly, potatoes are produced in cities such as Junín and Ayacucho, but are processed in Lima, with a significant number of intermediaries between each stage (Delgado et al., 2021).

Regarding onion, 52% of its production occurs in the south of the country, but only 2% is shipped through the port of Matarani, which is located in the same region (Arequipa). The rest of the production is transported to the ports of Callao and Paita, which means an increase in distance of up to 1,000 km (Briceño-Garmendia et al., 2016d). In addition, it should be considered that onion is a susceptible product that loses its quality during long transportation. This can be solved with the decentralization of the ports, considering that the ports of Callao and Paita should not cease to be used. On the contrary, it is important to take advantage of the fact that onions can be produced in all areas of Peru.

Other evidence of the importance of decentralization in Peru comes from Mercado (2017), who evaluated the quinoa FSC in Puno and Junín. They concluded that the chain containing linkages between collectors, processors and exporters ensured a more efficient and coordinated trade. However, producers acting alone had a very poor organization and lower sales of quinoa. Contreras (2018) determined that the CFSC of non-perishable foods manufactured in Lima and Callao produce a substantial increase in costs when distributed to supermarkets in the south of the country. Long distances restrict a quick response in case of any problems during transport, if there are shortages in the supermarket or if demand increases.

Peru's potential to combat food and nutrition insecurity

Despite the difficulties due to the pandemic and the centralization, Peru's megadiversity makes it possible to produce a large quantity and variety of foodstuffs and to regulate their cost. As shown in Figure 4, the production index has remained stable and dynamic.

The panic due to the pandemic caused people to buy essential products excessively. This increase in demand caused producers and/or merchants to raise the price of products (law of supply and demand). The price of foods such as lemons,

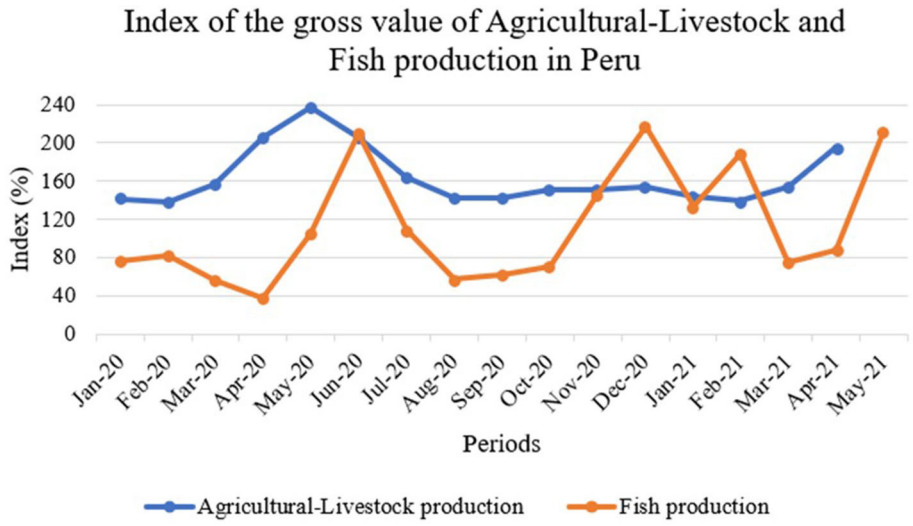

FIGURE 4
Food production indicators. Based on information from INEI (2021), provided by MINAGRI and the Ministry of Production (PRODUCE), on agricultural-livestock and fishery production, respectively.

sugar, potatoes, beans, tomatoes, spinach and peas increased from 14 to 30% (Enfoque Derecho, 2020). For price control purposes, through article 2 of Supreme Decree 044-2020-PCM, the Peruvian government guarantees the supply of food and medicines during the state of emergency. MINAGRI was in charge of monitoring the supply and price of products. Also, agricultural products were rapidly depleting due to increased exports, and as a result, decentralized production increased in fertile areas such as Olmos (Lambayeque region), Majes (Arequipa) and Chavimochic (La Libertad).

The resilience of the Peruvian food system was also due to the massive appearance of street vendors, as in the case of Arequipa. They indiscriminately distribute the products of necessity, through the modality of peasant markets, rural agricultural fairs and itinerant markets. Although sales conditions are in very poor sanitary conditions (Ramirez-Hernandez et al., 2020), this increases product availability and is reported to have influenced a 15–20% reduction in prices (Vargas et al., 2021). This information was verified in the study by Zimmerer (2020). The population of South America, specifically Peru, relied on informal traders to access a wide variety of food products. When the large markets (such as La Parada) closed in Lima, a large number of street vendors appeared and were able to supply food to the population of each locality. Even with their own funds, the vendors bought biosafety equipment to sell in the early hours of the morning, thus reducing the risk of COVID-19 infection (Coletto et al., 2021). However, informal vendors in Peru, who represent more than 50% of the population, have no benefits and are vulnerable to critical situations, especially due to the lack of health insurance (Vázquez-Rowe and Gandolfi, 2020). According to the above, emphasis is placed on supporting informal producers/traders as they represent a key point in support of decentralization. In this case, MINAGRI provided financing to small producers throughout the country to organize their itinerant markets.

Challenges and solution strategies

This COVID-19 pandemic is an opportunity to address FSC weaknesses and enhance its strengths by transitioning from CFSC to RFSCs. According to the survey conducted by Luckstead et al. (2020), with this pandemic, the U.S. population is more aware of the importance of FSC, especially at the stage of small producers. The study by Blazy et al. (2021) found that, although COVID-19 severely affected the Caribbean agricultural system, weaknesses were improved. These include the search for short marketing channels, the cultivation of more varied products according to the needs of the population and mutual assistance among farmers. To achieve this in Peru in the long term requires the support of industry, academia and other stakeholders (Ramirez-Hernandez et al., 2020). Solutions should be focused on achieving a resilient food system at local, regional, national and global scales (Han et al., 2021). Hecht et al. (2019) interviewed 26 companies and organizations in the food sector and identified 10 factors with significant influence on FSC resilience. It was concluded that the resilience and strengthening of the food industry is achieved with the active participation of government, industry, policy makers and consumers.

We must eliminate the erroneous idea that Peru is only the capital and other privileged cities (Lazo, 1984). The central government must improve and create new policies to support

RFSCs, considering their high deficit in infrastructure, logistics, experience and knowledge (Gemmill-Herren, 2020). The first step toward decentralization is to interconnect all cities, through strategic routes that allow rapid communication between all FSC agents (Bedoya-Perales and Dal' Magro, 2021).

On the other hand, labor is required in large quantities and restrictions were a limiting factor. This mainly affected countries where foreigners represent a considerable percentage of the workforce, such as the United States, Mexico, China and India. In Canada, more than 60,000 Mexicans work in agribusiness, and in India, the reduction of labor affected vegetable and fish farming, significantly reducing production (Chitrakar et al., 2021). In the case of Peru, in July 2020 there were 1.2 million Venezuelan migrants (more than 3.5% of the Peruvian population), of which a large part worked in the country's food industry [World Bank (Banco Mundial, 2020)].

Understanding the stages of FSC will allow us to identify bottlenecks and propose alternative solutions. Human (knowledge) and social (connections) capital and strong investments are required to support the community, mainly in rural areas. In a study focused on Bangladesh, Amjath-Babu et al. (2020) found that maintaining the robustness of a food system requires important components such as logistics for distribution of safe and quality inputs with circular flow. Adequate storage facilities, efficient management tools and, above all, credit opportunities to cover essential expenses, especially for small farmers, are also required (Aday and Aday, 2020). Support can also be received from international entities related to the field of food and nutrition security. An appropriate funding tool for this context is the Global Agriculture and Food Security Program, founded in response to the 2007–2008 food crisis (Cullen, 2020). It was reported that in Tunisia, Egypt and Morocco, financing was provided to workers, mainly temporary and informal workers (Hashem et al., 2020). Limited support does not allow the full potential of food products to be exploited. Ramos et al. (2021) indicate that cañihua, quinoa and kiwicha have received greater attention in the world for their nutritional quality, but deficits in seed supply, transportation, storage and packaging limit their true potential.

Use of new technologies

To improve the interconnection between each stage of the FSC and between each RFSC, Bakalis et al. (2020), García et al. (2020), Siche (2020), Vaio et al. (2020), Chitrakar et al. (2021) suggest implementing automation. This includes the application of digital and intelligent systems such as the internet of things (IoT), artificial intelligence (AI), and information and communication technologies (ICT). For example, drones can be used to deliver products, monitor and evaluate crop fields, farms, and aquaculture areas. In South Africa, an IoT system was created to manage social distancing and monitor the number of people in a facility in real time (IoT.nxt, 2020). In Shanghai, China, drones are widely used to deliver food and other products without contact (Parkhill, 2022). These technologies reduce person-to-person contact and should also be applied for e-commerce, which has increased significantly (Thilmany et al., 2021) with promising results shown in Morocco and China (Hashem et al., 2020).

Smart packaging technology (modified/controlled atmosphere packaging, active packaging and intelligent packaging) can be used in the food industry. In addition, smart detection systems (electronic tongue, electronic nose, spectroscopic techniques, machine vision and artificial intelligence) and thermal (sterilization) and non-thermal (cold plasma, pulsed electric fields, ultrasound and microwave) technologies can be used with emphasis on virus elimination (Chitrakar et al., 2021). According to the above, extensive training on these tools should be provided to FSC agents. A study assessed the effect of the pandemic on the FSC of JD.com, an Asian e-commerce giant that sells a wide variety of products, including food. Shen (2021) determined that, although JD.com did not take many actions to combat the crisis, the impact was minimal due to the proper management achieved by the smart platforms.

The importance of self-production of food

Lal (2020) recommends home production through home gardens. Another option could be hydroponics, aquaponics, small animal husbandry, which is practiced in many remote areas of Peru. Through online surveys, it was determined that due to the food impact of COVID-19, 96% of Latin American people had to carry out home farming. 90% of them indicated that their initiative contributed to preventing imminent food insecurity (Tittonell et al., 2021). In addition to home production, Castro-Bedriñana et al. (2021) indicate that more than 71% of rural families in Andean communities in Peru have farmland (potatoes, corn, barley, beans, etc.). They also raise cows, sheep, pigs, chickens/hens and guinea pigs for self-consumption and sale, in proportions greater than 44%, 34%, 29%, 40% and 63%, respectively. To this measure, the range of cultivation/breeding options can be expanded. For example, 25% of potato producers and 74% of coffee producers interviewed in Peru indicated that they would introduce new crops to improve food security (Vargas et al., 2021).

Castro (2015) evaluated the effects of these measures on the reduction of nutritional problems in children under 5 years of age in Andean communities (Acobamba, Chambará, Huamalí, Pancán and Tapo) in Peru. For a period of 3 years, assistance was provided in the development of the necessary capacities for the production of potatoes, corn, barley and

mashua vegetables (in orchards and farms), the raising of guinea pigs and chickens, including their consumption and sale. This influenced the reduction in the prevalence of chronic and anemic malnutrition in ranges from 0.75% to 31.35% and from 3.2% to 20.3%, respectively.

Alternative/non-conventional food sources

It is projected that in 2050 there will be 34% more people in the world and in turn, the demand for food production will increase by 70% (Mariutti et al., 2021). In this sense, researchers are making immeasurable efforts to find new sources of food. They must be mass-produced, renewable and low-cost. It was determined that cockroach milk and flour will contribute to the prevention of food shortages due to their high protein content (Galanakis, 2020).

In the pandemic context, it was determined that the population of Cusco, Peru increased the use of edible plants such as eucalyptus, kion, garlic, matico, chamomile and coca, in proportions of 70.2%, 68.3%, 58.8%, 49.6%, 34.0% and 21.6%, respectively. These plant products have a high biological activity with potential in the prevention and possible therapeutic treatment of COVID-19 (Villena-Tejada et al., 2021). With respect to decentralization, the curious thing is that the population of the Peruvian capital has migrated to the country's marginalized cities because there is greater food potential in these areas. At the beginning of the pandemic, more than 700 people from Lima went to live in the Andean communities mainly to grow their own food and subsist (Lanza and Narváez, 2020).

Other new sources of protein-rich foods include insects (such as cockroaches), algae, and by-products of meat, fish and dairy processing (Hashem et al., 2020). The substitution of red meats such as poultry and pork for vegetable sources such as quinoa was reported (Galanakis, 2020). Other widely studied sources include pseudocereals and grains, and edible flowers. Amaranth, chia and quinoa grow in tropical and subtropical regions and have been included in the diet of the Incas for centuries. A relevant pseudocereal is kiwicha, which is cultivated in several American countries, including Peru (Mariutti et al., 2021). Other Andean grains cultivated in the country are quinoa, cañihua and tarwi, which have a high nutritional value (Padulosi et al., 2014). Regarding edible flowers, flowers of *Brassica rapa* subsp. Campestres L., *Tropaeolum dipetalum* R. et P., *T. minus* L., *T. peregrinum* L., *T. seemanni* Bush., T. *smithii* D.C., *T. tuberosum* R. & P., *Typha dominguensis* Persoon., *Carica papaya* L., *Cucúrbita moschata* Duch., *Typha angustifolia* L. are consumed in Peru (Súmar, 2004).

This measure is also aimed at animal feed. In the Amazon region of Peru, Godoy et al. (2021) evaluated the effect of supplementation with rice polishing and a new alternative supplementation based on coconut flour, cocoa husk, rice polishing and rice flour in lactating cows. Cows supplemented with the non-conventional mixture produced more milk (1.4 kg/cow/day extra) and had more weight (0.13 kg/day extra). In addition, with the alternative supplementation, there was an extra income of US$ 1.72/day (considering US$ 1 = PEN 3.846).

Does food transmit SARS-CoV-2?

Although COVID-19 has not been shown to spread through food, constant vigilance during FSC is crucial. The necessary activities to prevent the transmission of SARS-CoV-2 should be carried out (Han et al., 2021), which are more risky during the later stages due to the greater involvement of peoples (Rizou et al., 2020). According to current sanitary requirements, some strategies implemented in two food markets in Lima are shown in Table 2. In the case of La Parada market, many vendors did not continue with online sales because it was less profitable than going to the market (Coletto et al., 2021). On the other hand, in the Santa Anita Market, the measures implemented were stricter (Table 2). This was due to formality, which generates greater support from the authorities.

Although it is difficult to maintain distance under these sales conditions, these measures were necessary to prevent person-to-person transmission of the virus. At that time, measures were also aimed at preventing the presence and survival of the virus on surfaces, but currently, that is considered unlikely. Singh M. et al. (2021) did not detect the presence of SARS-CoV-2 on high-contact surfaces ($n = 97$) with food in retail stores in Canada.

Current recommendations for reducing the economic and public health impacts of COVID-19 in the food sector can be found in FoodCoVNET (https://foodcovnet.ces.ncsu.edu/welcome-to-foodcovnet/).

Another key element: Sustainability of the food system

The correct implementation of RFSCs must also be evaluated in terms of environmental sustainability. The strategies employed are often not sufficiently sustainable (Hashem et al., 2020). For example, artificial meat farming is not a sustainable source of protein, but it is possible to use biological and recoverable sources such as algae (Galanakis, 2020) or others previously mentioned. Likewise, although the cold chain is essential during food distribution, if the distance is very short, it is recommended to transport fresh and not frozen food to reduce energy consumption (Ramos et al., 2018).

Food sustainability is a scenario that is often overlooked, but we must be aware of its consequences. Food contributes

TABLE 2 Measures implemented in two of the most important food markets in Lima, Peru.

Market	Type of trade	Measures
La Parada	Informal street vending	Acquisition of a large number of masks and biosafety suits for personnel.
		Weekly cleaning and disinfection of the market.
		Online sales option (*via* Facebook, whatsapp, etc.), mandatory for vulnerable persons.
Santa Anita	Formal closed market	Regular COVID-19 testing.
		Acquisition of masks.
		Installation of water faucets and use of liquid soap.
		Installation of footbaths.
		Floor painting to define the distance between people.
		Temperature control of vendors and customers prior to entering the market.
		Prohibition of entry to vulnerable persons.
		Private security to prohibit the entry of informal workers who disturbed the order and established measures.
		Organization of buyers in rows.

Prepared from information from Coletto et al. (2021) obtained from February to September 2020.

approximately 17% of the total carbon footprint (Bakalis et al., 2020). According to a study on the evaluation of restaurants in Lima and Tacna, only 18% indicated that they manage organic waste (Cordova-Buiza et al., 2022). Ramirez-Hernandez et al. (2020) suggest applying sustainable strategies at each stage of the chain based on national and international standards. This will ensure food quality and safety and increase consumer confidence, as well as national and international markets.

Conclusion

COVID-19 has aggravated existing vulnerabilities in Peru's FSC due to its centralization. According to the literature, Peru has a weak food system in terms of knowledge, technology, infrastructure, logistics, transportation, interconnection routes, among other factors. In addition, the scarce support provided by the government is only directed to privileged areas, causing serious food insecurity in rural areas. However, despite the crisis generated by the interruption of the FSC, Peru remained stable due to its high agricultural and fishing potential. In addition, thanks to the support of small producers and informal vendors, food supply was ensured throughout the country. This has demonstrated the importance of decentralizing FSC, transcending to a robust, adaptable and sustainable food system at local, regional, national and global levels. The RFSC also offers the advantage of being more resistant to disturbances and of acting quickly in case of risk. The information obtained serves as a reflection to take advantage of the current situation and improve the Peruvian food system. It is suggested to implement strategies such as the use of technologies, self-production of food, ingestion of non-conventional food sources, in addition to improving hygiene measures to ensure food safety and the protection of the agents involved in the different stages of the FSC.

Author contributions

VT-K: conceptualization of the idea, bibliographic search, writing, and preparation of the original draft. WM-Z: conceptualization of the idea, writing, and preparation of the original draft. EH-M: conceptualization, drafting, preparation of original draft, and supervision. TC-R and OL-V: reviewing, drafting, and proofreading and editing. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Abdullah, D., Rahardja, U., and Oganda, F. P. (2021). Covid-19: decentralized food supply Chain management. *Syst. Rev. Pharm.* 12, 142–152. doi: 10.31838/srp.2021.3.25

Abizaid, C., Panduro, L. Á. C., and Egusquiza, S. G. (2020). Pobreza Y medios de subsistencia en la amazonía peruana en tiempos de la Covid-19. *J. Lat. Am. Geogr.* 19, 202–214. doi: 10.1353/lag.2020.0080

Aday, S., and Aday, M. S. (2020). Impact of COVID-19 on the food supply chain. *Food Qual. Saf.* 4, 167–180. doi: 10.1093/fqsafe/fyaa024

Alam, G. M. M. and Khatun, M. N. (2021). Impact of COVID-19 on vegetable supply chain and food security: empirical evidence from Bangladesh. *PLoS ONE* 16, e0248120. doi: 10.1371/journal.pone.0248120

Amjath-Babu, T. S., Krupnik, T. J., Thilsted, S. H., and McDonald, A. J. (2020). Key indicators for monitoring food system disruptions caused by the COVID-19 pandemic: Insights from Bangladesh towards effective response. *Food Secur.* 12, 761–768. doi: 10.1007/s12571-020-01083-2

Bakalis, S., Valdramidis, V. P., Argyropoulos, D., Ahrne, L., Chen, J., Cullen, P. J., et al. (2020). Perspectives from CO+RE: how COVID-19 changed our food systems and food security paradigms. *Curr. Res. Food Sci.* 3, 166–172. doi: 10.1016/j.crfs.2020.05.003

Banco de Alimentos Perú (2021). *Cada año, en nuestro país se desperdician 12,8 millones de toneladas de alimentos, el 47,6% del total con que cuenta el perú. Solo en frutas y vegetales se pierden 5,6 millones*. Available online at: https://bancodealimentosperu.org/en-el-peru-la-mitad-de-los-alimentos-termina-en-la-basura/ (accessed February 26, 2022).

Banco Mundial (2020). *Infografía: Migrantes y Refugiados Venezolanos en El Perú: El Impacto de la Crisis de la Covid-19 (#Coronavirus)*. Available online at: https://www.bancomundial.org/es/news/infographic/2020/07/22/infografia-migrantes-y-refugiados-venezolanos-en-el-peru-el-impacto-de-la-crisis-de-la-covid-19-coronavirus#:$\sim$:text=En el Perú hay 1,de migrantes y refugiados venezolanos (accessed February 26, 2022).

Barman, A., Das, R., and De, P. K. (2021). Impact of COVID-19 in food supply chain: disruptions and recovery strategy. *Curr. Res. Behav. Sci.* 2, 100017. doi: 10.1016/j.crbeha.2021.100017

Bassett, H. R., Lau, J., Giordano, C., Suri, S. K., Advani, S., and Sharan, S. (2021). Preliminary lessons from COVID-19 disruptions of small-scale fishery supply chains. *World Dev.* 143, 105473. doi: 10.1016/j.worlddev.2021.105473

Bedoya-Perales, N. S., and Dal' Magro, G. P. (2021). Quantification of food losses and waste in peru: a mass flow analysis along the food supply chain. *Sustain.* 13, 2807. doi: 10.3390/su13052807

Benítez, M. A., Velasco, C., Sequeira, A. R., Henríquez, J., Menezes, F. M., and Paolucci, F. (2020). Responses to COVID-19 in five Latin American countries. *Heal. Policy Technol.* 9, 525–559. doi: 10.1016/j.hlpt.2020.08.014

Binder, N. and Vogl, C. R. (2018). Participatory guarantee systems in Peru : two case studies in lima and apur í mac and the role of capacity building in the food chain. *Sustainability* 10, 4644. doi: 10.3390/su10124644

Blazy, J. M., Causeret, F., and Guyader, S. (2021). Immediate impacts of COVID-19 crisis on agricultural and food systems in the Caribbean. *Agric. Syst.* 190, 103106. doi: 10.1016/j.agsy.2021.103106

Briceño-Garmendia, C., Guasch, J. L., Díaz, L., Rozenberg, J., and Bozanigo, L. (2016a). *Análisis Integral de la Logística en el Perú: 5 Cadenas de Exportación. Producto Cacao*. Available online at: https://www.mincetur.gob.pe/wp-content/uploads/documentos/comercio_exterior/facilitacion_comercio_exterior/P_Cacao.pdf (accessed February 26, 2022).

Briceño-Garmendia, C., Guasch, J. L., Díaz, L., Rozenberg, J., and Bozanigo, L. (2016b). *Análisis Integral de la Logística en el Perú: 5 Cadenas de Exportación. Producto Café*. Available online at: https://www.mincetur.gob.pe/wp-content/uploads/documentos/comercio_exterior/facilitacion_comercio_exterior/Anexo2_Producto_Cafe_Final.pdf (accessed February 26, 2022).

Briceño-Garmendia, C., Guasch, J. L., Díaz, L., Rozenberg, J., and Bozanigo, L. (2016c). *Análisis Integral de la Logística en el Perú: 5 Cadenas de Exportación. Producto Quinua*. Available online at: https://cdn.http://www.gob.pe/uploads/document/file/ (accessed February 26, 2022).

Briceño-Garmendia, C., Guasch, J. L., Díaz, L., Rozenberg, J., and Bozanigo, L. (2016d). *Análisis Integral de la Logística en el Perú: 5 Cadenas de Exportación*. Available online at: https://www.mincetur.gob.pe/wp-content/uploads/documentos/comercio_exterior/facilitacion_comercio_exterior/Analisis_Integral_Logistica_Peru.pdf (accessed February 26, 2022).

Bunclark, L. and Barcellos-paula, L. (2021). Sustainability reporting for sustainable supply chain management in. *Sustain. Prod. Consum.* 27, 1458–1472. doi: 10.1016/j.spc.2021.03.013

Burlea-Schiopoiu, A., Ogarca, R. F., Barbu, C. M., Craciun, L., Baloi, I. C., and Mihai, L. S. (2021). The impact of COVID-19 pandemic on food waste behaviour of young people. *J. Clean. Prod.* 294, 126333. doi: 10.1016/j.jclepro.2021.126333

Cable, J., Jaykus, L. A., Hoelzer, K., Newton, J., and Torero, M. (2021). The impact of COVID-19 on food systems, safety, and security—a symposium report. *Ann. N. Y. Acad. Sci.* 1484, 3–8. doi: 10.1111/nyas.14482

Cañari-Casaño, J. L., Elorreaga, E. A., Cochachin-Henostroza, O., Huaman-Gil, S., Dolores-Maldonado, G., Aquino-Ramírez, A., et al. (2021). Social predictors of food insecurity during the stay-at-home order due to the COVID-19 pandemic in Peru. *medRxiv [Preprint]*. doi: 10.1101/2021.02.06.21251221

Castro, J. and Chirinos, D. (2015). Impact of a comprehensive intervention on food security in poor families of central highlands of Peru. *Food Public Heal.* 5, 213–219. doi: 10.5923/j.fph.20150506.02

Castro-Bedriñana, J., Chirinos-Peinado, D., and De La Cruz-Calderón, G. (2021). Predictive model of stunting in the Central Andean region of Peru based on socioeconomic and agri-food determinants. *Public Heal. Pract.* 2, 100112. doi: 10.1016/j.puhip.2021.100112

Cequea, M. M., Neyra, J. M. V., Schmitt, V. G. H., and Ferasso, M. (2021). Household food consumption and wastage during the covid-19 pandemic outbreak: a comparison between peru and brazil. *Sustainability* 13, 7583. doi: 10.3390/su13147583

Chenarides, L., Manfredo, M., and Richards, T. J. (2021). COVID-19 and food supply chains. *Appl. Econ. Perspect. Policy* 43, 270–279. doi: 10.1002/aepp.13085

Chitrakar, B., Zhang, M., and Bhandari, B. (2021). Improvement strategies of food supply chain through novel food processing technologies during COVID-19 pandemic. *Food Control* 125, 108010. doi: 10.1016/j.foodcont.2021.108010

Coletto, D., Jaber, L., and Vanhellemont, L. (2021). Street vendors in Lima in the time of COVID-19: guilty or oppressed? *Can. Geogr.* 65, 435–447. doi: 10.1111/cag.12712

Contreras, B. E. M. (2018). *Análisis y propuesta de mejora de la cadena de distribución de alimentos no perecederos entre las empresas de industrias alimentarias y los supermercados en el Perú (master's thesis)*. Universidad Politécnica de Cataluña, Barcelona, Spain. Available online at: https://upcommons.upc.edu/handle/2117/117480?show=full

Cordova-Buiza, F., Paucar-Caceres, A., Quispe-Prieto, S. C., Rivera-Garr,é, A. P., Huerta-Tantalean, L. N., Valle-Paucar, J. E., et al. (2022). Strengthening collaborative food waste prevention in Peru: towards responsible consumption and production. *Sustainability* 14, 1050. doi: 10.3390/su14031050

Cuenca Jaque, C. R., Osorio Tarrillo, M. L., Pastor Ramos, J. L., Peña Pasapera, G. del P., and Torres Vásquez, L. E. (2020). Economic and health aspects in times of quarantine for COVID 19 in the Peruvian population, year 2020. *Rev. la Fac. Med. Humana* 20, 630–639. doi: 10.25176/RFMH.v20i4.3067

Cullen, M. T. (2020). *COVID-19 and the Risk to Food Supply Chains: How to Respond*. Rome: Publication of the FAO. Available online at: https://www.fao.org/documents/card/es/c/ca8388en/

Curi-Quinto, K., Sánchez, A., Lago-Berrocal, N., Penny, M. E., Murray, C., Nunes, R., et al. (2021). Role of government financial support and vulnerability characteristics associated with food insecurity during the covid-19 pandemic among young peruvians. *Nutrients* 13, 3546. doi: 10.3390/nu13103546

Delgado, L., Schuster, M., and Torero, M. (2021). Quantity and quality food losses across the value chain: a comparative analysis. *Food Policy* 98, 101958. doi: 10.1016/j.foodpol.2020.101958

Enfoque Derecho (2020). *Los precios y el coronavirus:? Intervención o empatía?* Available online at: https://www.enfoquederecho.com/2020/04/10/los-precios-y-el-coronavirus-intervencion-o-empatia/ (accessed February 26, 2022).

Erokhin, V. and Gao, T. (2020). Impacts of COVID-19 on trade and economic aspects of food security: evidence from 45 developing countries. *Int. J. Environ. Res. Public Health* 17, 1–28. doi: 10.3390/ijerph17165775

FAO (2020a). *Adjusting Business Models to Sustain Agri-food Enterprises during COVID-19*. Available at: http://www.fao.org/3/ca8996en/CA8996EN.pdf (accessed February 26, 2022).

FAO (2020b). *Urban Food Systems and COVID-19: The Role of Cities and Local Governments in Responding to the Emergency*. Available online at: http://www.fao.org/3/ca8600en/CA8600EN.pdf (accessed February 26, 2022).

FAOSTAT (2021). *Suite of Food Security Indicators*. Available online at: https://www.fao.org/faostat/en/#data/FS (accessed November 25, 2021).

Galanakis, C. M. (2020). The food systems in the era of the coronavirus (COVID-19) pandemic crisis. *Foods* 9, 523. doi: 10.3390/foods9040523

García, L., Veneros, J., and Tineo, D. (2020). Severe acute respiratory syndrome (SARS-CoV-2): a national public health emergency and its impact on food security in Peru. *Sci. Agropecu.* 11, 241–245. doi: 10.17268/sci.agropecu.2020.02.12

Gemmill-Herren, B. (2020). Closing the circle: an agroecological response to covid-19. *Agric. Human Values* 37, 613–614. doi: 10.1007/s10460-020-10097-7

Godoy, D., Gonzales, J., Roque, R., Fernández, M., Gamarra, S., Hidalgo, V., et al. (2021). Use of unconventional agro-industrial by-products for supplementation of grazing dairy cattle in the Peruvian Amazon region. *Trop. Anim. Health Prod.* 53, 294. doi: 10.1007/s11250-021-02718-y

Grillo-Núñez, J., Mendo, T., Gozzer-Wuest, R., and Mendo, J. (2021). Impacts of COVID-19 on the value chain of the hake small scale fishery in northern Peru. *Mar. Policy* 134, 104808. doi: 10.1016/j.marpol.2021.104808

Han, S., Roy, P. K., Hossain, M. I., Byun, K. H., Choi, C., and Ha, S. (2021). COVID-19 pandemic crisis and food safety: implications and inactivation strategies. *Trends Food Sci. Technol.* 109, 25–36. doi: 10.1016/j.tifs.2021.01.004

Hashem, N. M., González-Bulnes, A., and Rodriguez-Morales, A. J. (2020). Animal welfare and livestock supply chain sustainability under the COVID-19 outbreak: an overview. *Front. Vet. Sci.* 7, 582528. doi: 10.3389/fvets.2020.582528

Hecht, A. A., Biehl, E., Barnett, D. J., and Neff, R. A. (2019). Urban food supply chain resilience for crises threatening food security: a qualitative study. *J. Acad. Nutr. Diet.* 119, 211–224. doi: 10.1016/j.jand.2018.09.001

Hobbs, J. E. (2020). Food supply chains during the COVID-19 pandemic. *Can. J. Agric. Econ.* 68, 171–176. doi: 10.1111/cjag.12237

INEI (2021). *Avance Coyuntural de la Actividad Económica N° 02 - Febrero 2022*. Available online at: https://m.inei.gob.pe/media/MenuRecursivo/boletines/02-informe-tecnico-avance-coyuntural-dic-2021.pdf (accessed February 26, 2021).

IoT.nxt (2020). *IoT.nxt Develops Solution to Manage Social Distancing for Retailers, Offices*. Available online at: https://www.itweb.co.za/content/xA9POvNZy6Vvo4J8 (accessed July 31, 2022).

Kerr, W. A. (2020). The COVID-19 pandemic and agriculture: short- and long-run implications for international trade relations. *Can. J. Agric. Econ.* 68, 225–229. doi: 10.1111/cjag.12230

Kumar, A., Mangla, S. K., Kumar, P., and Song, M. (2021). Mitigate risks in perishable food supply chains: learning from COVID-19. *Technol. Forecast. Soc. Change* 166, 120643. doi: 10.1016/j.techfore.2021.120643

Lal, R. (2020). Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic. *Food Secur.* 12, 871–876. doi: 10.1007/s12571-020-01058-3

Lanza, L. A. R., and Narváez, C. A. S. (2020). Emergencia, gestión, vulnerabilidad y respuestas frente al impacto de la pandemia COVID-19 en el Perú. *ScIELOPreprints* 1, 1–16. Available online at: https://preprints.scielo.org/index.php/scielo/preprint/view/94/version/99

Lazo, M. L. (1984). Food supply in Peru monopolies. *Food Policy* 9, 68–82. doi: 10.1016/0306-9192(84)90034-4

Luckstead, J., Nayga Jr, R. M., and Snell, H. A. (2020). Labor Issues in the Food Supply Chain Amid the COVID-19 Pandemic. *Appl. Econ. Perspect. Policy* 43, 382–400. doi: 10.1002/aepp.13090

Mahajan, K. and Tomar, S. (2021). COVID-19 and supply chain disruption: evidence from food markets in India†. *Am. J. Agric. Econ.* 103, 35–52. doi: 10.1111/ajae.12158

Malone, A., Cabana, Y. D. C., and Zegarra, A. T. (2021). Informal food systems and differential mobility during the COVID-19 pandemic in Arequipa, Peru. *Town Plan. Rev.* 92, 187–193. doi: 10.3828/tpr.2020.61

Marco, D. G. (2020). *Coronavirus: qué dice sobre la economía (y el gobierno) de Perú que el país prepare el mayor plan de estímulo de América Latina contra el covid-19 - BBC News Mundo*. Available online at: https://www.bbc.com/mundo/noticias-america-latina-52104166 (accessed February 13, 2022).

Mariutti, L. R. B., Rebelo, K. S., Bisconsin-Junior, A., de Morais, J. S., Magnani, M., Maldonade, I. R., et al. (2021). The use of alternative food sources to improve health and guarantee access and food intake. *Food Res. Int.* 149, 110709. doi: 10.1016/j.foodres.2021.110709

Marusak, A., Sadeghiamirshahidi, N., Krejci, C. C., Mittal, A., Beckwith, S., Cantu, J., et al. (2021). Resilient regional food supply chains and rethinking the way forward: key takeaways from the COVID-19 pandemic. *Agric. Syst.* 190, 103101. doi: 10.1016/j.agsy.2021.103101

Memon, S. U. R., Pawase, V. R., Soomro, M. A., and Pavase, T. R. (2021). Investigation of covid-19 impact on the food and beverages industry: China and India perspective. *Foods* 10, 1069. doi: 10.3390/foods10051069

Mercado, W. and Ubillus, K. (2017). Characterization of producers and quinoa supply chains in the Peruvian regions of Puno and Junin. *Sci. Agropecu.* 8, 251–265. doi: 10.17268/sci.agropecu.2017.03.08

MINAGRI (2020). *Perspectivas del Comercio Exterior Agrario en el Marco de la Declaración de Emergencia Nacional COVID-19*. Available online at: https://repositorio.midagri.gob.pe/handle/MIDAGRI/784 (accessed February 26, 2022).

Mukhamedjanova, K. (2020). The impact of the Covid-19 pandemic on the supply chain of agricultural products. *Asian J. Technol. Manag. Res.* 10, 49–52. Available online at: http://www.ajtmr.com/papers/Vol10Issue1/Vol10Iss1_P7.pdf

O'Hara, S. and Toussaint, E. C. (2021). Food access in crisis: food security and COVID-19. *Ecol. Econ.* 180, 106859. doi: 10.1016/j.ecolecon.2020.106859

Padulosi, S., Amaya, K., Jäger, M., Gotor, E., Rojas, W., and Valdivia, R. (2014). A holistic approach to enhance the use of neglected and underutilized species: the case of andean grains in Bolivia and Peru. *Sustain.* 6, 1283–1312. doi: 10.3390/su6031283

Parkhill, M. (2022). *Amid strict lockdown, Shanghai firefighters deliver necessities via drone*. Available online at: https://www.ctvnews.ca/health/coronavirus/amid-strict-lockdown-shanghai-firefighters-deliver-necessities-via-drone-1.5859753 (accessed July 31, 2022).

Parlamento Andino (2022). *Alternative Venting in Steam Retorts-An Approach to Energy Savings in Thermal Processing*. Available online at: https://www.parlamentoandino.org/images/actualidad/informes-covid/Peru/Principales-medidas-adoptadas-por-el-gobierno-peruano.pdf (accessed July 31, 2022).

Rahimi, P., Islam, M. S., Duarte, P. M., Tazerji, S. S., Sobur, M. A., El Zowalaty, M. E., et al. (2021). Impact of the COVID-19 pandemic on food production and animal health. *Trends Food Sci. Technol.* 121, 105–113. doi: 10.1016/j.tifs.2021.12.003

Ramirez-Hernandez, A., Galagarza, O. A., Álvarez Rodriguez, M. V., Pachari Vera, E., Valdez Ortiz, M. del C., Deering, A. J., et al. (2020). Food safety in Peru: a review of fresh produce production and challenges in the public health system. *Compr. Rev. Food Sci. Food Saf.* 19, 3323–3342. doi: 10.1111/1541-4337.12647

Ramos, E., Coles, P. S., Chavez, M., and Hazen, B. (2021). Measuring agri-food supply chain performance: insights from the Peruvian kiwicha industry. *Benchmarking An Int. J.* 29, 1484—1512. doi: 10.1108/BIJ-10-2020-0544

Ramos, E., Espichan, K., Rodriguez, K., Lo, W. S., and Wu, Z. (2018). Blueberry supply chain in Peru: planning, integration and execution. *Int. J. Supply Chain Manag.* 7, 1–12. Available online at: https://core.ac.uk/download/pdf/230751452.pdf

Requena-Sanchez, N., Carbonel-Ramos, D., Moonsammy, S., Klaus, R., Punil, L. S., and Ng, K. T. W. (2022). Virtual methodology for household waste characterization during the pandemic in an urban district of Peru: citizen science for waste management. *Environ. Manage.* 69, 1078–1090. doi: 10.1007/s00267-022-01610-1

Rizou, M., Galanakis, I. M., Aldawoud, T. M. S., and Galanakis, C. M. (2020). Safety of foods, food supply chain and environment within the COVID-19 pandemic. *Trends Food Sci. Technol.* 102, 293–299. doi: 10.1016/j.tifs.2020.06.008

Romero, T. H. and Reys, A. (2020). Empobrecimiento de los Hogares y Cambios en el Abastecimiento de Alimentos por la COVID-19 en Lima, Perú. *Ar@cne* 24, 243. doi: 10.1344/ara2020.243.31627

Sanchez, A., Cueto, S., and Penny, M. (2020). *Listening to young lives at work in Peru: first call*. Available online at: https://www.younglives.org.uk/sites/default/files/migrated/YOL-Peru-Headlines-FirstPhoneSurvey-Aug20_0.pdf (accessed February 26, 2022).

Sharma, M. (2020). Conceptualizing the nexus of migration and food security during COVID-19. *J. Agric. Food Syst. Community Dev.* 9, 1–5. doi: 10.5304/jafscd.2020.094.036

Shen, Z. M. and Sun, Y. (2021). Strengthening supply chain resilience during COVID-19: a case study of JD.com. *J. Oper. Manag.* doi: 10.1002/joom.1161

Shrestha, N., Shad, M. Y., Ulvi, O., Khan, M. H., Karamehic-Muratovic, A., Nguyen, U. S. D. T., et al. (2020). The impact of COVID-19 on globalization. One *Heal.* 11, 100180. doi: 10.1016/j.onehlt.2020.100180

Siche, R. (2020). What is the impact of COVID-19 disease on agriculture? *Sci. Agropecu.* 11, 3–9. doi: 10.17268/sci.agropecu.2020.01.00

Singh, M., Sadat, A., Abdi, R., Colaruotolo, L. A., Francavilla, A., Petker, K., et al. (2021). Detection of SARS-CoV-2 on surfaces in food retailers in Ontario. *Curr. Res. Food Sci.* 4, 598–602. doi: 10.1016/j.crfs.2021.08.009

Singh, S., Kumar, R., Panchal, R., and Tiwari, M. K. (2021). Impact of COVID-19 on logistics systems and disruptions in food supply chain. *Int. J. Prod. Res.* 59, 1993–2008. doi: 10.1080/00207543.2020.1792000

STATISTA (2021). *Revenue of the Food Market Worldwide Between 2012 to 2025(in Billion U.S. Dollars)*. Available online at: 15daafde01110eb1faa7d35784d76 (accessed February 26, 2022).

Súmar, H. E. D. (2004). *Plantas Alimenticias del Perú*. Available online at: file:///C:/Users/user/Documents/2017/Referencias de TESIS ETNOBOTANICA/UNALM-Etnobotánica-Chota.pdf (accessed February 26, 2022).

Thilmany, D., Canales, E., Low, S. A., and Boys, K. (2021). Local food supply chain dynamics and resilience during COVID-19. *Appl. Econ. Perspect. Policy* 43, 86–104. doi: 10.1002/aepp.13121

Tittonell, P., Fernandez, M., El Mujtar, V. E., Preiss, P. V., Sarapura, S., Laborda, L., et al. (2021). Emerging responses to the COVID-19 crisis from family farming and the agroecology movement in Latin America – a rediscovery of food, farmers and collective action. *Agric. Syst.* 190, 103098. doi: 10.1016/j.agsy.2021.103098

UNICEF (2019). *Estado Mundial de la Infancia 2019 incluye a Perú entre las experiencias exitosas de lucha contra la desnutrición crónica infantil*. Available online at: https://www.unicef.org/peru/nota-de-prensa/estado-mundial-infancia-nutricion-alimentos-derechos-peru-experiencias-exitosas-desnutricion-cronica-infantil-reporte (accessed February 26, 2022).

Useche, P. and Twyman, J. (2016). Sugar, fat, or protein: are all food insecure households eating the same? The case of small rice producers in Peru. *Front. Econ. Glob.* 16, 115–132. doi: 10.1108/S1574-871520150000016005

Vaio, A. D., Boccia, F., Landriani, L., and Palladino, R. (2020). Artificial intelligence in the agri-food system: rethinking sustainable business models in the COVID-19 scenario. *Sustainability* 12, 4851. doi: 10.3390/su12124851

van der Ploeg, J. D. (2020). From biomedical to politico-economic crisis: the food system in times of Covid-19. *J. Peasant Stud.* 47, 944–972. doi: 10.1080/03066150.2020.1794843

Vargas, R., Fonseca, C., Hareau, G., Ordinola, M., Pradel, W., Robiglio, V., et al. (2021). Health crisis and quarantine measures in Peru: Effects on livelihoods of coffee and potato farmers. *Agric. Syst.* 187, 103033. doi: 10.1016/j.agsy.2020.103033

Varona, L. and Gonzales, J. R. (2021). Dynamics of the impact of COVID-19 on the economic activity of Peru. *PLoS ONE* 16, e0244920. doi: 10.1371/journal.pone.0244920

Vázquez-Rowe, I., and Gandolfi, A. (2020). Peruvian efforts to contain COVID-19 fail to protect vulnerable population groups. *Public Heal. Pract.* 1, 13–15. doi: 10.1016/j.puhip.2020.100020

Velásquez-Quispe, L. S., Ortiz-Meza, C. A., Calizaya-Mamani, U. G., Zapana-Calderón, A. A., and Chire-Fajardo, G. C. (2021). Energética nutricional en tiempos de pos COVID-19 en el Perú. *Enfoque UTE* 12, 1–28. doi: 10.29019/enfoqueute.761

Villena-Tejada, M., Vera-Ferchau, I., Cardona-Rivero, A., Zamalloa-Cornejo, R., Quispe-Flórez, M. M., Frisancho-Triveño, Z., et al. (2021). Plantas medicinales y alimentos funcionales usados como recursos contra Covid-19 en una población andina del Perú. *Ambient. Comport. y Soc.* 4, 62–81. doi: 10.51343/racs.v4i1.819

WHO (2022). *WHO Coronavirus (COVID-19) Dashboard*. Available online at: https://covid19.who.int/ (accessed July 31, 2022).

Worldometer (2022). *COVID-19 Coronavirus Pandemic*. Available online at: https://www.worldometers.info/coronavirus/?utm_campaign=homeAdvegas1#countries (accessed July 31, 2022).

Zimmerer, K. S. and de Haan, S. (2020). Informal food chains and agrobiodiversity need strengthening—not weakening—to address food security amidst the COVID-19 crisis in South America. *Food Secur.* 12, 891–894. doi: 10.1007/s12571-020-01088-x