Global Scientific JOURNALS

GSJ: Volume 10, Issue 7, July 2022, Online: ISSN 2320-9186

www.globalscientificjournal.com

DIGITAL TECHNOLOGY DISRUPTIONS AND INNOVATION IN FOOD INDUSTRIES DRIVEN BY COVID-19: A SYSTEMATIC REVIEW

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Abstract

Covid-19 caused economic and societal pressures and technological opportunities occasioned by the global lockdown. During this period, food manufacturers in various parts of the world experienced unprecedented inventions and occupational challenges, which arose from the pressure of being replaced by digital technologies. However, stakeholders in the food industries have not fully exploited the pandemic's vast innovation options. Accordingly, this paper seeks to understand the potential innovations in the manufacturing sector that can enhance productivity in the food industry (food security, food safety, and sustainability) in the Covid-19 era. A systematic review of the available literature is conducted to identify the suitability of various initiatives to improve and maintain productivity in food manufacturing. Incorporating information and communication technology in this initiative is explored and appreciated. The study identifies specific approaches to consuming food, such as laboratory-grown meat, governmental regulation of bio-resources, and incorporation of industry applications as some of the innovations with the highest potential for enhancing food security in this new era. The use of social media marketing is also identified as one of the avenues for understanding the perceptions, attitudes, and barriers that can impact consumers of the agro-food industries. The present study is relevant to developing countries, which struggle to cope with the unprecedented economic challenges due to the pandemic. The findings can bridge significant gaps in knowledge and decision-making and help policymakers in the manufacturing sector borrow ideas to adopt new norms in food industries.

Keywords: Technological innovation; Disruptions; Sustainability, Covid-19

INTRODUCTION

Adversity is the mother of all innovation, so they said. It is a fact that most advanced technologies respond to discrete events in humankind. In the present context, innovation is defined as creative responses that need the commitment of resources to enhance the development of a product or process. The announcement of the first case of the coronavirus disease in Wuhan, China, affected human life in ways that no one expected. The pandemic led to millions of infections and loss of lives worldwide (Mishra et al., 2021). The process altered what we observed as the norms impacting the healthcare system, businesses, society, and governmental policies. The food production sector is among the several industries that felt the impact of this disease outbreak. Specifically, the pandemic affected the food sector in three domains: food security, food safety, and sustainability (Guidi, 2021). Overcoming these obstacles requires strong leadership, ambition, and inspiration, leading to a paradigm shift in disruptive technologies and relevant innovations that can enhance food productivity and sustainability during and after the pandemic.

COVID-19 triggered societal and economic constraints, but paved the way for technological opportunities brought about by the global lockdown (Galanakis et al., 2021). During the period, food producers worldwide faced sustained inventions and occupational challenges that arose from the need to be substituted by digital technologies (Henry, 2020). Besides, the pandemic hit every aspect of life, and most companies did not anticipate its nature and impact (Han et al., 2021). Most firms were unable to predict and plan accordingly. Some of the emerging issues due to the pandemic were the food supply chain safety, which necessitated new precautionary measures to ensure the safety of consumables. The other challenge of the pandemic was the disruption of food production which manifested as clustering cases in food production, food processing firms, and slaughterhouses (Galanakis et al., 2021). Food is critical in ensuring and sustaining health, which also enhances the ability of individuals to survive pandemics and other considerations. Consumers have become more focused on securing healthy, sustainable, and organic foods (Guidi, 2021). However, gaps still exist in the food sector as companies and other stakeholders have not fully exploited the pandemic's significant innovation options. Accordingly, this paper seeks to comprehend the likely innovations in the manufacturing sector that can help improve productivity in the food industry, mainly food security, food safety, and sustainability in the COVID-19 era.

LITERATURE REVIEW

Various authors have studied the role of technology in enhancing food productivity. However, this paper is based on the existing knowledge regarding the three major categories: food security, food safety, and sustainability.

Food Security

Food security concerns the degree of food availability and the ability of persons to access the food. As such, adequate production, stable food supply, and affordability are critical factors in food security. Literature established that agricultural food productivity arise from various sources but availability of technology is essential to increase food security. Marinova and Bogueva (2022) examined how cities can exploit urban horticulture to ensure food security through and after the pandemic. Pulighe and Lupia's (2020) views align with those of Marinova and Bogueva (2022) by emphasizing that the rapid population growth threatens stable food supply, which calls for innovative approaches to expanding land under production of food. The pandemic affected

the food supply's sustainability features and disrupted prices and the supply chain (Mishra et al., 2021). Urban horticulture is touted as a solution to the threat and effects of the pandemic on food security.

Khan et al. (2020) draw attention to COVID-19 and other hazards and disasters that have increased the number of people at risk of hunger globally to 820 million persons, mainly due to disruptions in food supply chains. Sridhar et al. (2022) share the same view as Khan et al. (2020) by identifying urban food systems as the most affected. The global lockdown guidelines further worsened food insecurity by affecting every aspect of the food supply chain. Urban areas have faced food price inflation, a lack of supplies, and an increasing number of people unable to purchase food in urban areas (Galanakis et al., 2021). The poor people in urban areas are the most affected due to overall food imports and food export restrictions. There is bound to be food insecurity long after the worst effects of the pandemic have resolved.

O'Hara and Toussaint (2021) emphasize that integrating technology in urban horticulture, such as hydroponics, can help address the threat that food insecurity imposes in urban areas. The use of hydroponics implies cultivation that does not use soil but instead depends on water enriched with nutrients (Han et al., 2021). Plant roots are suspended in the solution or propped by growth media, usually clay or rocks. Lighting structures or sunlight supply light in an environment of managed temperature. Merchant (2021) also views hydroponics can ensure the food production minimizes the use of chemicals and that the food production is throughout the year. The technology is widely used to grow food during inclement weather such as winter. Information technology is integrated into the food production system to help manage ecological factors. The system requires less costly maintenance, which enhances the affordability of the food products produced.

Drescher et al. (2021) examined how aeroponics can help enhance food production and food security after the effects of the pandemic. The technology constitutes a vertical farm cultivation approach that uses only 10% of the water required in hydroponics. The technology can help grow fruits, vegetables, and flowers by applying mist in a chamber hosting the plant roots. Pulighe and Lupia (2020) and Drescher et al. (2021) highlight the benefits of aeroponics as foods grown under the system have enhanced nutritional quality because of the effective absorption of minerals. Urban spaces can benefit from aeroponics to improve their food safety as it allows the growing of large volumes of plants in a constrained area and limits the need for floor space.

Khan et al. (2020) focused on aquaponics, a technology that fuses aquaculture and hydroponics practices to produce food. Aquaponics helps create healthy plants and can also be used to farm fish distributed through local supply networks (Ekaputri et al., 2021). The technology helps save 98% of water in conventional agricultural methods by recycling most water. Kumar et al. (2020) further elaborated that the farmer minimizes harmful compounds and encourages beneficial bacteria in farming through aquaponics. The technology also contributes to sustainability in food production by reducing the use of water, minimizing toxic compounds, and promoting healthy bacteria in agriculture by encouraging reuse and recycles.

Oldani (2021) investigated how organoponics can help food security by expanding food production. The technology involves the growth of plants on substrates devoid of the need to use artificial compounds but applies a seedbed created by blending organic matter and soil. Canet-Martí et al. (2021) hold that organoponics can be applied with low fertility soils, making it appropriate for use in developing countries that struggle to procure fertilizers. The less impact of

the technology on the environment makes it applicable to urban farming (Lacombe et al., 2021). Cities can benefit from organoponics to reduce the threat of food insecurity due to the pandemic, which is grappling with increased food demand.

Food Safety

Some authors have delved into the need to incorporate technology to enhance food safety. Iftekhar and Cui (2021) examined how people can apply blockchain technology in food systems to enforce food safety and safeguard consumers from the effect the pandemic has on supply chains. Food safety concerns include preparing, handling, and storing consumables to eliminate foodborne illnesses. Han et al. (2021) reinforce the views of Iftekhar and Cui (2021) that the current issues with the traditional supply chain are the lack of adequate auditing and transparency features and opportunities, which expose the public to food safety issues. One approach to address food safety is the application of the Internet of Things to capture data and monitor the environment as a strategy for enhancing safety standards in the food value chain.

Lacombe et al. (2021) advocate cold chain management since it needs a large volume of reconciliations involving several departments. The use of tamper-proof and real-time trails of transactions affecting all departments in the food value chain can help enhance monitoring and intervention. Jawed et al. (2020) separately felt that one of the impacts of the pandemic is that it led to increased demand for food products which invites the risk of food safety issues as players in the market diversify sources of food products and inputs from the traditional partners. The short period needed to secure supplies may imply that new supplies can introduce food safety risks that conventional sources of supply had managed to address. The application of block chain technology in enforcing food safety can help establish transparency of regulations for everyone.

Guidi (2021) favors the application of technology in enforcing food safety mainly by enabling comprehensive data collection and managing that data to enhance the traceability and safety of food. Technology can also assist in certifying various aspects of the food value chain to improve food safety. Ma et al. (2021) emphasized that food safety relies on digital technology to facilitate data collection, analysis, and sharing. For instance, stakeholders in the system can acquire data about the conditions for planting, growing, harvesting, and processing of specific food products due to the application of information technology (Boyacı-Gündüz et al., 2021). Analytical tools and automation features enable digital technology to enforce food safety.

Dolgin (2020) called for enhanced surveillance of food safety status through technology. The application of digital technology in tracking food safety levels enables stakeholders to detect safety issues before the problem becomes widespread. Galanakis et al. (2021)’s position is shared by Dolgin (2020) who emphasize some of the interventions that can arise due to food safety surveillance and issues a public warning on recalling or banning the production of the affected products until food safety concerns are fully addressed. Food safety tracking is intended to improve pathogen detection before it can spread or ensure that its spread is promptly contained. The developing investigations about COVID-19 linked it to contaminated wet markets, suggesting gaps in food safety surveillance.

Sustainability

Efficient food production and consumption should consider the impact of the whole process on the environment. Rowan and Galanakis (2020) view a sustainable food system as including shared duty in food production, distribution, and consumption that promotes care for the

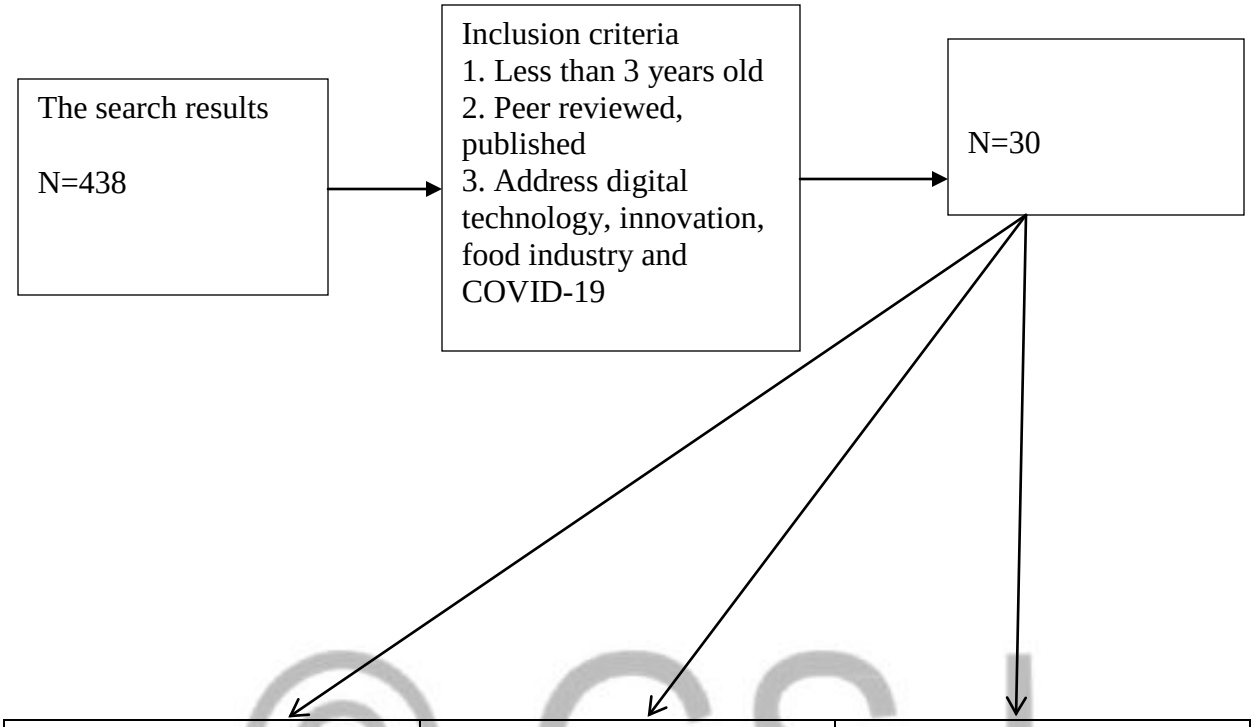
environment and ecosystem and assures continued generation and regeneration of ecosystem components. Technology such as wet peatland supports sustainable food systems by blending green innovations and agricultural systems. Boyacı-Gündüz et al. (2021) also observed that the advent of the pandemic showed the need for making maximum use of available resources because of the significant disruption of global supply chains. Palidiculture offers an interface between digital technology and agricultural innovations to ensure sustainable food production (Canet-Martí et al., 2021). The application of the technology can help minimize waste in food production and acknowledge the need to take climate action (Galanakis et al., 2021). The approach also advocates for the inclusion of the community in food production.

Overall, these authors offer significant information concerning the role of technology in the three facets of food security, safety, and sustainability. However, little information exists on the application of such technology to address the three areas at once. Therefore, the focus of this paper is the suitable innovation that can collectively bridge these gaps in food production.

METHODOLOGY

The research involved a systematic review of the available literature to determine the suitability of various interventions that enhance and maintain productivity in food manufacturing. The study conducted an online database search of reputable repositories using designed criteria for inclusion. The key search words were “digital technology,” “food industries and COVID-19”, “Information technology and food industries and COVID-19”, “Food security innovation COVID-19”, “Food safety technology and COVID-19”, and “Food sustainability information technology COVID-19”. The inclusion criteria included peer-reviewed articles, less than three years old, written in English, and showing depth in discussing digital technology innovation and disruptions in food industries occasioned by COVID-19. The search yielded 438 articles, of which the most relevant and quality journal articles were picked. Articles that addressed similar study subjects were reviewed to discover similarities and differences to help form synthesized arguments.

RESULTS



Food security Innovations in the COVID-19 context	Food safety innovations in the COVID-19 context	Food sustainability innovations in the COVID-19 context
N=12	N=11	N=7
Hydroponics, N=7	Blockchain application, N=3	Palidiculture, N=3
Aquaponics, N=5	Cold chain management, N=3	Hydroponics, N=7
Aeroponics, N=5	Data collection systems, N=3	
Organoponics, N=3	Surveillance systems, N=2	

Table 1: Selection of articles for the review

Nine of the articles discussed the use of hydroponics as an innovation to enhance food security. They included Marinova and Bogueva (2022), Pulighe and Lupia (2020), Mishra et al. (2021), Khan et al. (2020), Sridhar et al. (2022), Galanakis et al. (2021), O'Hara and Toussaint (2021), Han et al. (2021), and Merchant (2021). Other articles such as Drescher et al. (2021), Pulighe and Lupia (2020), and Drescher et al. (2021) dwelt on aeroponics as a disruptive technology in the agro-food industry that will boost food security. Khan et al. (2020), (Ekaputri et al., 2021), and Kumar et al. (2020) support the use of aquaponics, revolutionary technology to improve food security. Oldani (2021), Canet-Martí et al. (2021), and Lacombe et al. (2021) advocate for the use of organoponics to enhance food security.

Iftekhar and Cui (2021) and Han et al. (2021) identified blockchain applications in enhancing transparency in food systems. Lacombe et al. (2021), Jawed et al. (2020), and Predanócyová et al. (2021) support cold chain management technologies to improve food safety. Guidi (2021), Ma et al. (2021), and Boyacı-Gündüz et al. (2021) support comprehensive data collection to

enhance surveillance of food safety systems. Dolgin (2020) and Galanakis et al. (2021) push for intensive surveillance systems to improve food safety.

Articles such as Rowan and Galanakis (2020), Boyacı-Gündüz et al. (2021), Canet-Martí et al. (2021), and Galanakis et al. (2021) advocate for palidiculture and hydroponics technologies to enhance the sustainability of food systems.

ANALYSIS AND DISCUSSION

Innovative Approaches to Food Consumption

The finding of specific innovative approaches that change the way we consume food, such as laboratory-grown meat, aligns with the literature review that calls for new ways to adjust food production and consumption (Predanócyová et al., 2021). The disruption of supply chains and the global food market drew the attention of stakeholders to the threat of food insecurity, food safety concerns, and sustainability issues in the food system (Jairath et al., 2021). The food industry is guilty of accelerating the threat to food systems, but it also can play a critical role in resolving the identified issues. Whereas there has been progress in finding innovative ways to grow plant foods, there have been significant limitations in producing animal protein, a view shared by Predanócyová et al. (2021). Technology has enabled the growth and production of meat substitutes premised on vegetable protein. However, the successful culturing of animal meat in laboratory settings provides significant potential disruption in the food industry.

Some articles have discussed how developing countries such as Singapore have made significant progress in the growth of cultured meat for consumption which reinforces what the literature found on the same topic (Henry, 2020). Cultured beef will enhance food sustainability and improve nutritional security, benefiting developing countries lacking the resources and technology to scale up their food production while maintaining quality quickly. The other benefits of laboratory-grown meat are that it is free of pathogens, eco-friendly and ethical, unlike the conventional factory farming of animals for meat and meat products which reflects findings by Dolgin (2020). The technology can prove helpful due to disruptions of the supply chains, allowing countries to ramp up animal meat production without adverse impact on the environment and ecosystem.

Governmental Regulation of Bio-resources

Bio-resources are critical in the food industry and the agro-food sector because they affect food security, food safety, and sustainability, according to Saygun (2022), and align with a literature review on the same. The government approves allowable bio-resources through the food and drugs regulator, and the government regulations define how bio-resources can be exploited for food production. Bio-resources management helps ensure that the government expressly enforces sustainability of the sources, which is a critical factor in ensuring food security for the public, according to Eze et al. (2021) and is shared by the previous literature. Without the government's intervention, private businesses would exploit the resources and move to new markets leaving behind a country without adequate food production or food production that is not sustainable.

The other motivation for state regulation of bio-resources is enforcing food safety by enforcing food safety guidelines. The bio-resources used in food production constitute a significant source of contamination, according to Saygun (2022), which is also implied by Rowan and Galanakis (2020). The control of bio-resources helps enforce ethical practices in food industries. Government regulations can improve food security by provoking diversity and sustainability in

bio-resources. The rules can also encourage innovation, such as biotechnology applications that help improve the stock of bio-resources, according to Eze et al. (2021). Some of the rules dictate the maximum pesticide residues that can be found on plants harvested for food which help enhance food safety and, at the same time, motivate food industries to innovate less harmful ways to manage the health of crops grown and harvested.

Incorporation of Industry Applications

The industry has developed specific technologies that contribute to food security, especially those that enable farming without land or soil, which is consistent with the literature review, especially according to Canet-Martí et al. (2021). Hydroponics, in particular, allows urban horticulture, which addresses the threat of food insecurity. Hydroponics frees the food industry from the need for land and significant water resources to practice farming. The technology further frees the farmer from reliance on the sun, enabling agriculture irrespective of the weather or location (Khan et al., 2020). The disruption occasioned by the pandemic implies a need to rapidly expand farming beyond the available arable land or factory premises. The application of hydroponics offers food security solutions by allowing the all-year growing of food and expanding where food can be grown.

Hydroponics, aeroponics, and organoponics significantly lower the cost of food production, contributing to food security, reinforcing the literature review article by Pulighe and Lupia (2020). These applications are attractive and practical because they allow for integration with information technology, which allows for accurate diagnosis and control of ideal growing conditions for plant foods. The cost of food production is often passed down to the consumer, making food costly and inviting food insecurity, which is also shared in the literature review by Kumar et al. (2020). The technologies can be disruptive because they are revolutionary to the traditional way of growing food. Conventional food farming is often seasonal and labor-intensive, threatening food production and supply, but the new technologies address such challenges.

Social Media Marketing

The use of information technology also generates advantages, such as deploying social media marketing to understand the attitudes, perceptions, and barriers that can affect consumers of the agro-food industries, according to Naeem (2021). Food is one of the products that attract attention and almost immediate reaction by consumers, especially regarding food safety which is implied in the literature review by Boyacı-Gündüz et al. (2021). Consumers process food safety firstly by what the regulator and the producers indicate, such as quality certification, and secondly by perceptions about the food that need not have a scientific basis, according to Lahath et al. (2021). For instance, laboratory-grown meat is presumably safe and nutritious. Still, consumers' perceptions might disregard it as not secure and would affect its uptake and effectively the noble intentions behind cultured meat production, which reinforces the views of Gerritsen et al. (2021). Consumers' opinions are subjective, and deploying social media marketing is an effective and affordable way to understand consumers' trends and beliefs regarding new technologies for the production and consumption of food.

CONCLUSION AND RECOMMENDATION

Policymakers in the manufacturing sector will invoke some of the ideas discussed and align them with the new food industry norms. Before the pandemic, several countries were grappling with

hunger and malnutrition. The use of hydroponics, aquaponics, and laboratory-grown meat technologies can help developing nations address food insecurity and free resources. The freed resources can help enhance sustainable development to ensure further the local populations build more food resilience.

The other benefit of applying the new technologies in food production in developing nations is that it significantly moves them toward food-sufficient countries by expanding sites where food production can occur, including urban areas. Even within urban spaces, the space needed for food production and water required when using the technologies is significantly lower, allowing for cumulative large-scale food production. The increased food production will eventually lead to a drop in food prices due to market forces that can help free household incomes for investment and growth. The current study is relevant to developing nations that grapple with significant economic issues worsened by the pandemic. The findings of the study help address the gaps in decision-making and knowledge. By reducing food expenditure, while enhancing and improving the nutritional value of food, families can significantly tackle poverty in developing countries.

Food security should be a significant focus for the new technology because the lack of food security increases food safety risks. The high demand and prices may motivate unethical behavior by players in the industry. Future studies should conduct a descriptive analysis of how new technologies such as hydroponics that are also sustainable contribute to enhanced food production in developing. Emerging economies might not necessarily allow for optimum output and cost like developed economies. The study must be conducted in developing countries' environments to help determine the applicability of the new technologies in the industry.

There is a need to conduct survey research on consumers' perceptions, attitudes, and beliefs in developing countries regarding food grown through hydroponics, aquaponics, and aeroponics. Food is a critical cultural component, and previous studies have not addressed the issue of culture and adoption of food grown through such technologies. Most emerging economies have a restrictive approach to food that can be consumed, especially food they consider industrial food. Deploying emerging technologies in the agro-food industry without understanding or addressing culture's mediating and moderating impact would lead to a zero-sum game.

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