



Sustainability and Resilience: Integration of Sustainable Approaches to Achieve Resilience Food Security and Drug Safety after the Emergence of COVID-19

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Abstract

Following the COVID-19 pandemic, the food and pharmaceutical industries faced many challenges, increasing threats to food security and drug safety. This review mapped the published literature on sustainability and resilience in food security and drug safety. The papers were categorized based on their emphasis on reasons for food insecurity and drug safety, their public health impacts, strategies and actions needed, and their similarities and differences for sustainability and resilience. Systematic searches were conducted in PubMed, Google Scholar, Scopus, and Springer databases. Papers published from 2019 to 2022 targeting food security and drug safety threats following the pandemic were used. One hundred and five papers were retrieved, of which 37 met the inclusion criteria for further analysis. They were analyzed and categorized using thematic content analysis according to their focus on reasons, impacts, strategies, and similarities and differences. After examining all papers, this study proposed a framework for integrating sustainability and resilience in the food and drug sectors to enhance food security and drug safety to promote healthy lifestyles and public health. This framework will assist researchers in advancing studies related to sustainability and resilience in the food and pharmaceutical sectors and provide government agencies with ideas on implementing these approaches to build resilient food and drug supply chains.

Keywords: Resilience; food; drug; COVID-19; counterfeit; safety; supply chain; public health

Introduction

Over the last few years, scholars and practitioners have been attracted to the concept of sustainability. Sustainability incorporates the social, environmental, and economic-based performance of human lives within the framework of society, the environment, and the economy in the quest to generate benefits for a future generation. Researchers are finding opportunities to study the relationship between sustainability and resilience in food supply chains (FSCs) and drug supply chains (DSCs) because of their observed interchangeable influences. Both are regarded as critical components of supply chains. These two factors interact heavily and, as a result, significantly impact an organization's supply chain and performance [1].

The emergence of COVID-19 worldwide in December 2019 slowed international development by imposing financial consequences on business and global economies and creating a global health crisis [2] detrimental to public health and economic well-being [3]. For a supply chain to be sustainable after events like the COVID-19 pandemic, a framework has to be developed that combines technology and a sustainable network to increase market share, ecological responsiveness, and distinction. Approaches like being lean, green, and resilient and ensuring sustainability have been practiced supporting market requirements and prevent disturbances in supply and demand. The most recent and significant supply chain management model integrates sustainability and resilience.

Background and definition

Supply chain sustainability involves maintaining business continuity to reduce long-term risks. Whereas supply chain resilience essentially refers to the ability of a system to recover from a distorted state and return to an original or desired state after being disrupted. The concepts of sustainability and resilience are multi-dimensional and interrelated, with the convergence of their various aspects contributing to strategic decision-making. Public health is one of the most critical social sustainability factors and requires special attention. The development of models and decision-supporting tools can facilitate improved decision-making for resilient and sustainable supply chains. However, a lack of literature and limited research have hindered the development of frameworks for implementing resilient and sustainable production system decision-making processes. In previous literature, different frameworks have been presented, including resilience as a component of sustainability, sustainability as a component of resilience, and conflicts between them that may complicate their integration [4].

Effect of the COVID-19 pandemic on FSC

A significant amount of nutritious, safe food must be consumed to sustain life and maintain good health. A healthier lifestyle can only be achieved by attaining food sustainably, improving the global FSC, preventing food loss, and providing healthier food. The COVID-19 pandemic damaged lifestyles around the world. It adversely affected the FSC, from manufacturing to distribution, due to worker shortages, customer demand changes, cessation of food production, restrictive food trade policies, and financial pressure contributing to counterfeiting of food products. As a consequence, significant issues related to food safety and security arose. They included increased demand for functional foods by consumers for a healthy diet, increased attention toward food safety among producers, retailers, and consumers, and food sustainability and supply challenges [19]. Among the numerous challenges were a lack of flexibility, trust, government incentives, inadequate communication, security concerns associated with supply chains, and imbalances in supply and demand [5]. Given issues related to the food supply chain, reliable, robust, and sustainable tools are needed to trace food from the moment it is manufactured to its availability to the consumer to achieve transparency [6]. Implementing resilient strategies and understanding their impacts on sustainability's social-economic and environmental dimensions is required to respond and adapt to new market challenges [7]. The Food and Agriculture Organization (FAO) of the United Nations defines food security as follows: "Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life." Tragically in developing countries, the COVID-19 pandemic severely affected Sustainable Development Goals (SDGs) related to food security, especially during the lockdown period. COVID-19 negatively impacted food security's four main aspects: availability, stability, access, and utilization. Sufficient food delivery to the end-users depends mainly on land utilization, agricultural process-

es, architecture, transportation, farmers, and retailers. As the European Commission suggested, the food system needs to be more comprehensive, diverse, resilient, combative, and sustainable [8].

Effect of the COVID-19 pandemic on DSC

As part of COVID-19's aftermath, drug safety was compromised in various ways, among which was the panic buying of the public caused disruption of supply chains and an insufficient supply of medicines, an increase in health care costs, and the emergence of counterfeit products that contributed to the spread of infectious diseases and the use of addictive drugs. [9]. Due to the lack of technical and business solutions and inadequacies in traceability and derivative solutions, the counterfeiting of drug products affects all stakeholders in the DSC like manufacturers, wholesale distributors, hospitals, pharmacies, global public health programs, and regulatory authorities. It is also difficult to ensure product safety due to the easy availability of medicines through online pharmacies and unauthorized distribution channels. The only way to identify the originality and authenticity of drug products is through drug traceability systems. The US drug supply chain security act (DSCSA) requires implementation by 2023 to enhance the safety of drug products. Because food and drugs are directly linked to public health, all supply chain members are responsible for providing authentic and high-quality products. A lack of sustainability and resilience in the supply chain makes it difficult to ensure the safety of these products. The use of circumscribed third-party solutions is required to collect and validate information [5].

For the safety and security of drug products in the global supply chain after COVID-19, different technologies have been discussed in recent literature under the industry 4.0 revolution, like artificial intelligence (AI), big data analytics, blockchains, cloud computing, the Internet of Things (IOT), machine learning, smartphone, and 5G technologies. As a result of its accuracy in recording transactions, these technologies play a significant role in increasing trust among global partners. AI can play a vital role by providing sustainable business models. The DSC, blockchain, and IOT are considered more effective by ensuring traceability and providing predictions for future supply chains through integration [5].

Novelty of the study

A review of the literature published from the beginning of the COVID-19 pandemic until the present day found that no study covered both food security and drug safety, their impacts on public health, and sustainability and resilience. Few papers discussed sustainability in FSC, and few discussed sustainability and resilience in both sectors. [5]. examined the application of different technologies during the COVID-19 pandemic, investigated their impact on supply chain management, and suggested that if these technologies were correctly utilized, they could easily resolve supply chain issues [5]. [2]. examined the consequences of COVID-19 on the triple bottom line (TBL) of sustainability to define a future developmental agenda for sustainability. They provided five different research directions for sustainable development. In 2021, Golan et al. discussed the

resilient vaccine supply chain and identified the lack of a resilient supply chain for vaccines during the COVID-19 pandemic. The findings revealed that papers published in 2020 provided minimal data regarding resilient supply chains and were qualitative with rarely suggested measures [3].

Farooq Mu [3] determined different challenges and developed strategies for sustainability after exploring the epidemic's impacts on supply chains with the help of a structured literature review (SLR) approach [10]. defined the relevance between COVID-19 and the lack of sustainability and resilience in supply chain operations related to medications. They proposed different recommendations to prevent a possible medication shortage in the future.

[11] provided guidance for understanding the role of sustainability in supply chains during and after COVID-19. Various studies concluded that sustainability could be achieved for a short period, but long-term effects require further advanced research and new theoretical models. Nonetheless, many sustainability issues may arise in the future, which cannot be studied or covered through a single research paper [11]. [12]. discussed resilient strategies for managing the agri-food supply chain for perishable items during COVID-19 and future recommendations for the government and stakeholders. But this study lacks a discussion about sustainability in food security [13] investigated sustainability practices in the humanitarian medical supply chain and barriers to its implementation, but resilient strategies were not integrated along with it. The novelty of this study is discussing different issues related to food security and drug safety, their relationship between sustainability and resilience and how to adapt both of these factors in food and drug products supply chains, and future recommendations to maintain sustainability and resilience in food and drug products to ensure their safety and security by the integration of both.

Study objectives

This systematic review aimed to:

- a. Map publications on sustainability and resilience in food and drug products supply chains and their safety and security during and after COVID-19 crises;
- b. Identify the similarities and differences between the concepts; and
- c. Categorize papers according to their focus on the reasons for lack of sustainability and resilience in both sectors, their effects on public health, the strategy and actions they require, and provide a thematic analysis of their content.

Methodology

A systematic search was conducted using the most widely used databases, including Scopus, Elsevier, Google Scholar, PubMed, and Springer. From December 2019 to 2022, our focus was on papers published after the emergence of COVID-19, as food security and drug safety threats have increased since the pandemic started, which has affected public health. Only English-language publica-

tions were considered. In terms of keywords, this study considered sustainability, resilience, food security, drug safety, COVID-19, counterfeit, food and drug supply chain, public health, similarities, and differences.

Inclusion criteria for the selected publications:

- a) Papers published on sustainability and resilience in FSC and DSC to ensure food security and drug safety.
- b) Studies identify reasons for the lack of sustainability and resilience within FSC and DSC.
- c) Papers describing the impact of food and drug safety on supply chain sustainability and resilience to achieve public health.
- d) Papers comparing and contrasting the two areas in FSC and DSC
- e) Papers describing future directions for implementing and developing a sustainable and resilient supply chain to ensure food security, drug safety, and their effect on public health.
- f) Paper published in only the English language.
- g) Papers published during and after the emergence of the COVID-19 crisis (2019-2022).

Papers published on sustainability and resilience that did not concern food security and drug safety or the papers not identifying their relationships were excluded. In addition, editorials and letters were excluded. Papers that were not published in the English language or before the pandemic of COVID-19, i.e., before December 2019, were removed.

Data collection and analysis

The analysis was based on the main topic of the publication, reasons for the lack of sustainability and resilience in food security and drug safety, the impacts of these factors on public health, strategies/actions to adopt sustainability and resilience to ensure food security and drug safety, and similarities and differences between them. Thematic analysis identified key issues, strategies, and actions based on these categories. Table 1 shows each extracted theme along with a summary of its description. One hundred and five studies were retrieved for possible inclusion, of which 37 met the inclusion criteria, as illustrated in Figure 1. The remaining 62 papers were excluded from the systematic review since they did not meet inclusion criteria and had been published before COVID-19's emergence. Six papers were excluded from the systematic review but included in the discussion.

Data classification

Using the categories illustrated in Table 1, 37 publications were classified according to their focus on reasons, impacts, actions, strategies, and similarities and differences between sustainability and resilience.

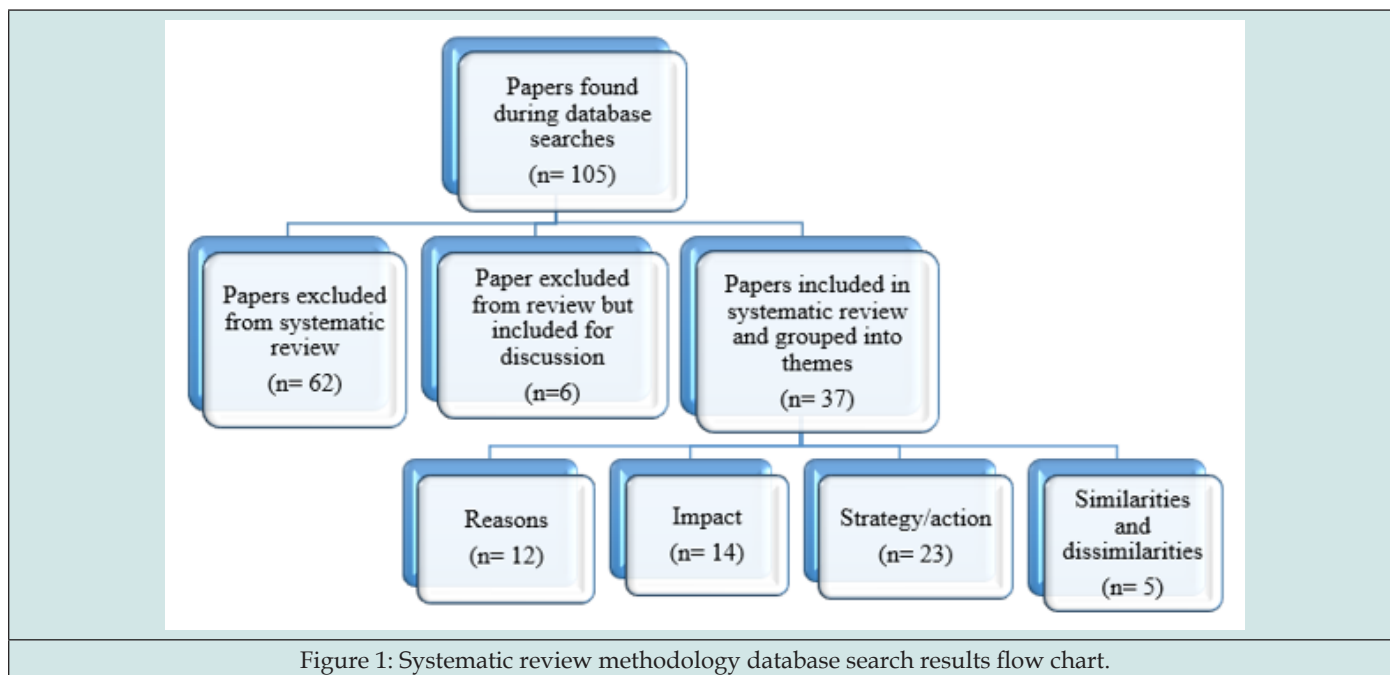


Figure 1: Systematic review methodology database search results flow chart.

Table 1: Characteristics of the included articles.

Category	Focus	Author, year
Relationship between sustainability and resilience	Conceptualization of a viable supply chain model spanning three perspectives, i.e., agility, resilience, sustainability, and discussion about adaptable networks that exhibit the features of legality, resilience against disruptions, and pandemic resistance	Dmitry Ivanov
Impacts/actions/strategies	Analysis of effects of COVID-19 on the triple bottom line (TBL) of sustainability to support the future sustainable development agenda	Meisam Ranjbari
Reasons	Resilience in vaccine and pharmaceutical supply chain (PSC) during and after COVID-19	Maureen S. Golan
Actions/strategies	Importance of sustainability in food and drug supply chain, use of blockchain technology to improve sustainability, and ensure food security and drug safety	Arim Park
Strategies	Adaptation of sustainability in food and drug sectors to ensure public health by using IOT, RFID, and blockchain technologies	Vincenzo Variabile
Strategies	Analysis of the impact of COVID-19 on sustainability in different health care sectors, how to maintain sustainability and resilience for the long term by utilizing modern approaches and technologies	Muhammad Umar Farooq
Reasons/impacts/strategies	Reasons for lack of sustainability in food security, its impact on public health, and future strategies to build sustainable food systems	Serafim Bakalis
Impacts/strategies	Impact of COVID-19 on food systems, public health, introduces one health strategy to achieve a sustainable food system and future recommendations to maintain sustainability in food sectors and SDGs of the United Nations and a "Planetary Health" perspective	Fernando O. Mardones
Actions/strategies	Role of community pharmacies to achieve a sustainable national healthcare system and ensure drug safety	BelénDerqui
Relationship between sustainability and resilience	Defines the relationship between sustainability and resilience and assessment of their performance in supply chains	Marta Negri
Reasons/impacts	Role of different enterprises in ensuring food and nutrition security during COVID-19, reasons for lack of sustainability in food security	Stella Nordhagen
Relationship between sustainability and resilience	Identifies the relationship between sustainability and resilience in the food production sector	Aly Owida
Impacts/strategies	Utilization of the integration of blockchain and IOT to ensure PSC and public health safety. Future directions are also discussed	Shashank Kumar
Impacts/strategies	Implementation of blockchain technology to prevent counterfeiting of medicines and to maintain a resilient supply chain	Anjum Khurshid

Strategies	Strategic plans to increase access to quality, affordable essential medicines and supplies that meet priority health objectives as well as effectively respond to health emergencies	Arush Lal
Impacts/strategies	Patient safety issues during COVID-19, policy actions to develop a sustainable health care system by ensuring drug and other medical safety	Sharda Narwal
Reasons/strategies	Role of blockchain technology in providing a secure supply of drug/medicines to the consumer and preventing counterfeiting of drugs after the emergence of COVID-19	Het Shah
Reasons/impacts/strategies	Prevalence of antibiotics resistance due to counterfeited drugs during COVID-19 and the role of pharmacists to adopt sustainable strategies to prevent antibiotics resistance and promote drug safety to ensure the public health	Wei Ping Khor
Strategies	Role of cloud computing-based technologies in combating counterfeiting of medicines and ensuring drug safety, and integration of two or more technologies in health care system	Yi Xie
Reasons	Reasons for lack of sustainability in the food supply chain	SanghaHan
Reasons/Strategies	Investigation of the role of digitalization on the resilience of the health care system, their functions to adapt resilience in drug safety	Leonardo Bertolin Furstenuau
Relationship between sustainability and resilience	Mainly focused on the impact of resilience on sustainability relationship between them in maintaining the social-economic performances of the organization.	Siddharth Shankar Rai
Impacts	Shortage of drug supply in Nigeria during COVID-19, impact on drug safety	Edward Faiva
Strategies	Safe supply of vaccines to the public during COVID-19 using a traceability approach.	Stephen Jarrett
Relationship between sustainability and resilience	Review of definitions, relationships between both approaches	S.Roostaie
Actions/strategies	Use of nano-technology in promoting sustainability in modern agriculture to ensure food safety	Hafeez Ur Rahim
Impacts	Impact of lack of sustainability on food systems during the COVID-19 crisis	Charis M. Galanakis
Impacts/strategies	One health approach for food safety, food security, and sustainable food production	Sara N. Garcia
Actions/strategies	Role of IOT in pharmaceutical manufacturing to ensure drug safety	Apoorva Sharma
Reasons/impacts/strategies	Tackling the blind spot of poor-quality medicines in Universal Health Coverage to provide a sustainable drug handling system to ensure drug safety	E. S. F. Orubu
Impacts/strategies	Outlook on current internationally harmonized strategies to combat pharmaceutical crime	Paola Bottoni
Reasons	Sustainability issues in PSC	Shaker AlHarthi
Reasons		Rachel Loopstra
Strategies	Innovations and technology disruptions in the food sector after the emergence of COVID-19	Charis M.Galanakis
Reasons/impacts	Impact of lockdown on food systems during COVID-19 in India	Vibhas Sukhwani
Strategies	Managing food safety, quality, and convenience, raise awareness of humanitarian food science and technology capabilities to support food security and resilience	DominiqueBounie
Reasons	Panic buying and hoarding behavior by the consumer during the COVID-19	C. Michael Hall

Literature Review

Based on the classifications of papers, this section defines and elaborates on the different themes' characteristics and explores their impacts on public health.

Reasons for lack of food security and drug safety

Various publications provide details regarding the lack of drug safety and food security. Table 2 summarizes and groups the factors under themes.

Table 2: Reasons for lack of food security and drug safety.

Themes	Descriptive terms
Lack of food security	
Disruptions in food production and logistics	Food security-related logistics and production mainly disrupted due to the restricted movement of labor and supplies, thus increasing the chances of food counterfeiting and food insecurity (Bakalis et al., 2020)
Food insecurity due to lockdown	Unemployment (Bakalis et al., 2020), loss of income, and loss of purchasing power (Sukhwani et al., 2020) due to the lockdown are the most common reasons for food and food insecurity and unavailability

Disruptions in access to the input, equipment, and services	Includes limitations in facilities, moving products, or sourcing inputs, equipment, and technicians affected the food system during and after the pandemic (Nordhagen et al., 2021)
Food security and agricultural disruptions	The food system usually consists of production, packaging, distribution, and storage, connecting the farm systems to the consumers directly. After the emergence of the pandemic, all species of FSCs greatly affected, i.e., fresh vegetables, fruit, bakery items, perishable goods, and food grains (Han et al., 2021)
Food insecurity due to economic crises	Food insecurity increased by double at the end of 2020 due to the economic crises after the emergence of COVID-19 (Han et al., 2021)
Panic behavior by the consumers	Dependent on different socio-economic factors and vicinity to the source of the risk (Hall et al., 2021), various food insecurity cases have been reported in India due to the panic behavior of consumers after the emergence of COVID-19 crises (Sukhwani et al., 2020)
Lack of drug safety	
Lack of resilient vaccine supply chain	Lack of resilience systems among the manufacturers and distributors may lead to a non-sustainable vaccine supply chain (Golan et al., 2021)
The emergence of counterfeit anti-microbial drugs	Due to the lockdown and travel restrictions, the cost of critical medications increases, leading to the increased supply of counterfeit anti-microbial medicines, thus affecting drug safety (Khor et al., 2020)
Stockout of critical drugs and supplies	Several weaknesses in the resilience of drug safety and the healthcare supply chain exposed after the emergence of COVID-19 related to the delays and stockouts of critical medicines (Bertolin Furstenau et al.)
Barriers to the quality assurance of medicines	Low political priority, weak regulatory system capacity, inadequate access to licensed facilities and outlets, challenges in the manufacturing and supply chain of medicines, and absence of public awareness may affect drug safety (Orubu et al., 2020)
Economic Environmental and Social sustainability issues	Lack of economic, environmental, and social sustainability in PSC dramatically impacts the safety of drugs and emergency pharmaceutical medicines, thus affecting public health (Alharthi et al., 2020).

Impact of lack of food security and drug safety on public health

Table 3: Impact of lack of food security and drug safety.

Themes	Descriptive terms
Lack of food security	
Socio-economic sustainability	690 million people were found to be hungry, and the effect of COVID-19 on the global economy makes it challenging to achieve resilience and sustainability in food safety and public health (Ranjbari et al., 2021).
Food shortage	Perishable food products have a short shelf life, and panic buying by the consumers during the COVID-19 pandemic makes it challenging to manage perishable items and their supply chain to fulfill the demands and the products shortages due to the lockdown and mobility restrictions (Ranjbari et al., 2021). The reports have revealed an evident change in consumer purchasing habits after the pandemic (Bakalis et al., 2020).
Broken food chain and food wastage	Reports of broken food chains and food wastage from the food producers due to food insecurity were reported (Bakalis et al., 2020).
Unemployment and loss of income	In different African countries, many informal markets that are useful for several low-income consumers and farmers have been shut down, which greatly affected the FSC and the essential needs of the consumers (Mardones et al., 2020). One report illustrated the impact of lockdown during the pandemic on food security, ultimately leading to the loss of income and purchasing power (Sukhwani et al., 2020).
Physical and mental health	To achieve SDGs and resilience to the disease, there is a significant role in nutrition and food security (Nordhagen et al., 2021). Inadequate nutrition, food insecurity, and poor quality diet directly impact physical and mental health (Mardones et al., 2020).
Economic loss	367 food systems in 17 different Asian and African countries were surveyed. Most firms had been greatly affected due to decreased sales and difficulty accessing inputs, equipment, and services, and an 80% decrease in the production volume was found (Nordhagen et al., 2021).
Food counterfeiting	Disruptions in the food security and supply chain increased food counterfeiting risks, leading to the critical situation to detect and identify the nutraceuticals and functional foods with real health benefits (Galanakis et al., 2021).
Environmental, social and economic threats	Environmental (climate change, marine debris, resource depletion), social (worker rights, consumer's awareness), and economic (market goods and services, competitiveness) threats were found (Galanakis et al., 2021).
Disrupted food availability and accessibility	The four main aspects of food security were severely affected, i.e., availability, accessibility, utilization, and stability (Sukhwani et al., 2020). Disruption in agriculture production, food availability, food utilization, and food stability due to the disasters, such as hurricanes, floods, tornadoes, wildfires, blizzards, emerging diseases, and earthquakes, directly impact food security and public health (Garcia et al., 2020).

Agricultural disaster	25% of agricultural commerce and manufacturing have been affected by a natural disaster, illustrated by a Food And Agricultural Organization survey from 2003-to 2013 (Garcia et al., 2020).
Lack of drug safety	
Disruption in logistics networks	After the emergence of the pandemic, restrictions in the movement greatly affected PSC and drug safety, directly impacting the logistics network, thus causing disruptions in the supply and increasing the demand for essential medicines (Kumar and Pundir, 2020).
Loss of trust due to drug counterfeiting	After the emergence of the pandemic, several reports were received regarding the counterfeiting of medicines and poor quality equipment, leading to the loss of trust in the operation of PSC (Khurshid, 2020). Patient safety has also been affected due to the irrational dispensing and usage of critical medications (Narwal and Jain, 2021). Drug counterfeiting can also lead to anti-microbial resistance (Orubu et al., 2020).
Anti-microbial resistance	The COVID-19 crisis significantly reduced drug safety because the misuse of antibiotics was highly seen during this pandemic, directly impacting public health by causing anti-microbial resistance (Khor et al., 2020). Severe consequences related to treatment failure, anti-microbial resistance, and adverse drug effects have been encountered by the prevalence of counterfeited drugs in public health, leading to loss of confidence and an increase in healthcare costs (Bottoni and Caroli, 2019).
Issues of availability, affordability, and rational use of medicines	Due to the lack of drug safety in many developing and developed countries, essential medicines were not easily accessible to most of the population. The few who had easy access could not take medicines correctly according to their health condition (Faiva et al., 2021).
Economic loss	Many affected countries have seen a significant economic loss from counterfeited antimalarials (Orubu et al., 2020).
Impact on low and middle-income countries	Easy availability of the medicines at low cost from unlicensed facilities also enhances the chances of supply of drugs having low quality and safety, compromising the health of the consumer (Orubu et al., 2020)

Several papers addressed a lack of food security and drug safety. They are categorized under the themes detailed in Table 3.

Strategies to adapt resilience and sustainability in food security and drug safety

Different strategies have been suggested in various papers to adopt sustainability and resilience in the food and drug sector according to the impact of food and drug insecurity on public health. These strategies are categorized under the following themes and summarised in Table 4.

Similarities, differences, and the relationship between

sustainability and resilience

Papers have been published discussing the similarities, differences, and relationships between sustainability and resilience in supply chain systems and their impacts on social, economic, and environmental factors. Still, no paper discussed the integration of both concepts in the context of food and drug safety and how to improve their impacts on public health by integrating these two concepts. Table 5 summarises the published papers on the similarities and differences between sustainability and resilience and their relationship.

Table 4: Summary of strategies to adapt resilience and sustainability in food security and drug safety

Themes	Descriptive terms
SDG 10 for socio-economic sustainability	Socio-economic sustainability and SDG 10 of the United Nations 2030 agenda for sustainable development can support healthcare systems, food, and nutritional needs with the help of dept suspension mechanisms (Ranjbari et al., 2021).
Utilization of blockchain technology	A novel technology named blockchain technology has been introduced that utilizes distributed and decentralized ledgers to trace the real-time movement of goods and services to adapt resilience in the food and drug supply chain and promote sustainable development. This technology could contribute to food safety, health, and nutrition along with the Wal-Mart FSC and promote waste management (Park and Li, 2021). Blockchain provides benefits in two ways: managing the supply chain system and determining the difference between the quality and counterfeited food or drug products (Khurshid, 2020). The resilient approach to utilizing blockchain technology for a sustainable vaccine supply includes different steps such as vaccine generation, safe delivery, inventory development, vaccine application, and patient monitoring after vaccination (Shah et al., 2021).
Integration of blockchain with other technologies	Integration of blockchain technology with RFID and IoT provides benefits in both economic and environmental ways by improving traceability and monitoring (Varriale et al., 2021). The government has adapted different digitalization techniques to provide medical facilities to ensure resilience and flexibility in systems (Farooq et al., 2021). Transparency, scalability, visibility, audibility, and immutability of PSC can also be enhanced by utilizing this approach (Kumar and Pundir, 2020). To achieve decentralization, autonomy, traceability, transparency, and credibility in PSC, blockchains have been integrated with modern technologies like AI, cloud computing, big data, wearable devices, IoT, and 5G (Xie et al., 2021).
Integrating resilient approach FSC	The study validated emergency planning, staff training and attendance, superfluity of food supply and suppliers, framework, location, service providers, assurance, and subsequent learning (Bakalis et al., 2020). Short and long-term goals like the movement of labor and ensuring transport and production to overcome the shortages with the interconnected support of human resources, transportation constraints, and regional policies (Farooq et al., 2021).

SDG to improve food systems	Global food systems should be accelerated and strengthened by providing support to the local production, rural producer communities in low middle-income countries, enhancing engagement with the producers and consumers, identifying consequences of interventions and policies related to food systems, improving food security by adopting risk-based approaches (Mardones et al., 2020).
Sustainable practices in community pharmacies	Pharmacies with sustainable approaches were more effective in implementing preventive measures than the ones without sustainable approaches (Derqui et al., 2021). Health system sustainability for drug and patient safety can be achieved by implementing the WHO Health Systems Building Blocks Framework (Narwal and Jain, 2021). Community pharmacists play a vital role in preventing anti-microbial resistance by promoting drug safety with the help of anti-microbial stewardship programs. In the light of COVID-19, community pharmacists can prevent anti-microbial resistance by adapting different approaches (Khor et al., 2020).
Pan American Health Organization (PAHO) strategic fund	The prevention of the supply of counterfeited drug products and optimization of drug safety can be done by PAHO by implementing WHO standards to promote public health concerns (Lal et al., 2022).
Resilient strategies in drug safety	The study examines the impacts of different digital technologies such as big data analytics, forecasting, and contract management systems, digital supplier systems, barcoding, enterprise resource planning system, RFID, electronic prescription, drug databases, automated drug dispensing cabinets, drug registration systems, advanced dispensing technology, etc. on main resilient features (anticipating, monitoring, responding and learning) (Bertolin Furstenau et al.). Government should implement policies to assure the quality of drug products and measure and strengthen regulatory capacity to ensure drug safety by utilizing modern technologies in promoting awareness among the public (Orubu et al., 2020). The role of chromatography-based techniques, often combined with mass spectrometry, colorimetry, infrared spectroscopy, and Raman spectroscopy in combating counterfeiting of drug products to ensure drug safety and increase public health, was discussed (Bottoni and Caroli, 2019).
Barcoding	WHO recommends barcoding on the primary packaging of vaccines and other drug products to prevent counterfeiting (Jarrett et al., 2020).
Nano-technology in food security	Food substances containing nano-additives should be commercialized to monitor, preserve, and protect food products (Ur Rahim et al., 2021).
One health approach	One health approach comprises of interconnection between the health of humans, animals, and the environment. It requires teamwork to improve public health, animals' health, and environmental resources to ensure food security. The article discussed the importance of food science and technology and their impacts on a humane food system (Bounie et al., 2020).

Table 5: Similarities, differences, and the relationship between sustainability and resilience.

Themes	Descriptive terms
Similarities between sustainability and resilience	Both factors are essential and critical for organizations (Negri et al., 2021). Organizations can quickly recover from any crisis by utilizing both approaches simultaneously without negatively impacting their sustainable value (Rai et al., 2021). Both are similar, and their integration would be technically possible, as illustrated by some theories (Roostaie et al., 2019).
Differences between sustainability and resilience	Sustainability can be categorized into concepts, implementation, performance and measurement, and future research goals in a supply chain. In contrast, resilience includes the adaptive capability to prepare, react and restore to any disruption and adaptation of new desirable conditions. It defines a system's ability to survive, adapt, and grow without negatively impacting its functionality (Negri et al., 2021). Many authors have categorized resilience into proactive resilience (preparedness for any disruption) and reactive resilience (recovery from the disruption). Sustainability includes the triple bottom line approach (environment, societal and economic) (Rai et al., 2021).
Relationship between sustainability and resilience	Resilience is a component of sustainability, and sustainability is a component of resilience. Resilient approaches exert variable influences on sustainability and complicated integration due to conflicts (Owida et al., 2022).

Discussion

Many papers have been published on sustainability and resilience in the last few years. Few papers illustrated that the terms are related, and a few represented them as different concepts. Some frameworks have also been discussed based on the similarities between these concepts positively impacting public health and the environment. Due to some similarities and potential for conflicts between these concepts, this paper proposed a framework for identifying similarities and differences between them and their integration in the food and drug sector to enhance public health. Both concepts are related to the system and can describe the system from

economic to mental or physical health. Integrating both concepts is possible because both can withstand any disturbances that any disruption in the supply chain causes. The main focus was on the disruptions in food security and drug safety after the emergence of the COVID-19 pandemic.

This paper identified different reasons and impacts of the pandemic on food and drug safety, directly affecting public health and the economy. Some strategies have also been studied and discussed. None of the literature integrated sustainability and resilience in the context of food security and drug safety. This paper integrated both concepts to seek direction for sustainable and resilient food and

drug systems to benefit the public economically, socially, and environmentally. For this purpose, a systematic literature review identified the concepts of sustainability and resilience and how these approaches could be integrated into the food and drug or pharmaceutical sectors with the help of thematic analysis. Integrating sustainability and resilience in a supply chain can make management and performance more effective. With the help of literature, we found that sustainability approaches consistent with resilient techniques could easily be developed. This study frames the most critical sustainability factors/techniques in the food and drug sector. It discusses their ability to withstand the disturbances during and after disasters and crises to provide food security and drug safety.

Integration of sustainability and resilience for food security

The emergence of COVID-19 revealed the lack of resilience and sustainability in FSC, resulting in disrupted food security and danger to public health. Due to this crisis, attention was directed to an increase in the need to integrate sustainability and the resiliency of food systems. This can be achieved by developing the decision-making framework. Because of the criticality and impact of food systems on public health and global economies after COVID-19, we integrated sustainability and resilience in food and agricultural systems to promote food security among the population. Developing new strategic tools and modifying existing sustainability features is essential in including resilience indicators to better understand related capabilities. After the emergence of COVID-19, the importance of food security increased due to the panic behavior of consumers and the disrupted production, supply, and transportation of essential food products.

The present study explored the reasons for food insecurity after COVID-19 and its impacts on public health with the help of a systematic literature review. It proposed a framework of sustainable strategies and actions to provide resilient FSC. Safety measures are the main element of social sustainability and are directly related to resilient business and economic growth, so having a direct positive effect on resilience and sustainability. So, resilience-building mainly depends on social sustainability. Digitalization also plays a vital role in detecting and controlling food products, positively impacting all three pillars of sustainability, thus providing resilient food systems. These modern technologies provide effective, resilient, and sustainable food systems by reducing the risks and promoting business continuity in terms of cost reduction, food security, and public health; thus, resilience in food systems can be achieved by adapting social, economic, and environmental sustainability.

Another sustainable approach is the utilization of nano-technology, which positively impacts food and agricultural systems with the help of nano-enzymes and innovative packaging, thus providing a safe and counterfeiting free, resilient food system with a balanced socio-economic environment. [14]. discussed FSC-related issues such as poor product traceability, disrupted product flow, food counterfeiting or contamination and its recall, and their impacts

on public health. They emphasized the need for future research to understand these issues better and solutions related to these issues. To prevent traceability-related issues, we have found the role of blockchain technology was beneficial, and this technology could be used as a primary factor for sustainable, resilient food systems. Blockchain technology seems to be the most effective sustainable approach to providing social, economic, and environmental sustainability to achieve resilient FSC. It helps detect and prevent counterfeited products, thus promoting food security economically and socially. This technology plays a vital role in the supply chain from the farm to production to distributing food products to consumers. Blockchain technology can also be integrated with other industry 4.0 technologies like IOT and RFID to enhance traceability, authenticity, and legality of the food product, thus providing resilient FSC systems in terms of cybercrime and counterfeiting prevention and security of data sharing. [15]. discussed the importance of traceability and identified and compared traceability systems for food safety, minerals, pharmaceuticals, and financial transactions and their positive and negative impacts.

The literature also shows that hunger, malnutrition, and lack of institutional capacities were the primary reasons for food insecurity after the COVID-19 crisis, directly impacting public health and thus required a sustainable approach that provided humanitarian assistance. Thus we considered the role of food and science technology as a sustainable approach to resilient food systems. This approach can provide sustainable recovery from any external shock and help maintain a resilient and sustainable food system in response to any disruption. Food and science technology can promote food security and positively impact health and the economy, thus securing public health. This technology can assist in preventing disruption and can anticipate, absorb, recover and adapt sustainably, thus strengthening resilience. This technology promotes long-term sustainability and resilience, economic feasibility, and partnerships among the stakeholders, thus providing resilient FSC socially, economically, and environmentally. [16]. addressed the importance of food science and technology in humanitarian response and consumers' requirements for local food systems. Implementing technologies can promote food security, increase employment, and enhance the local economy. They suggested future research in the same context with longer-term support for sustainable livelihoods and resilience.

Another sustainable approach to building a resilient food system includes assessing life cycle sustainability, social life cycles, and costing life cycles. This can be achieved by adapting short and long-term sustainable strategies like ensuring labor movement, assessing policies related to resilience and survivability in inventory, manufacturing, and transport and production to overcome the shortages with the interconnected support of human resources and transportation constraints and regional policies. We also found the positive impacts of SDGs and a health approach on public health. This approach comprises interconnections between the health of humans, animals, and the environment. It requires teamwork to

improve public health, animals' health, and environmental resources to ensure food security. This approach aims to prevent diseases, assure food security, and secure environmental quality, thus promoting resilient food systems. Figure 2 illustrates the framework

for integrating sustainability critical factors to achieve resilient food security. It mainly represents the role and impact of sustainable strategies in promoting resilient food systems to ensure food security and enhance public health.

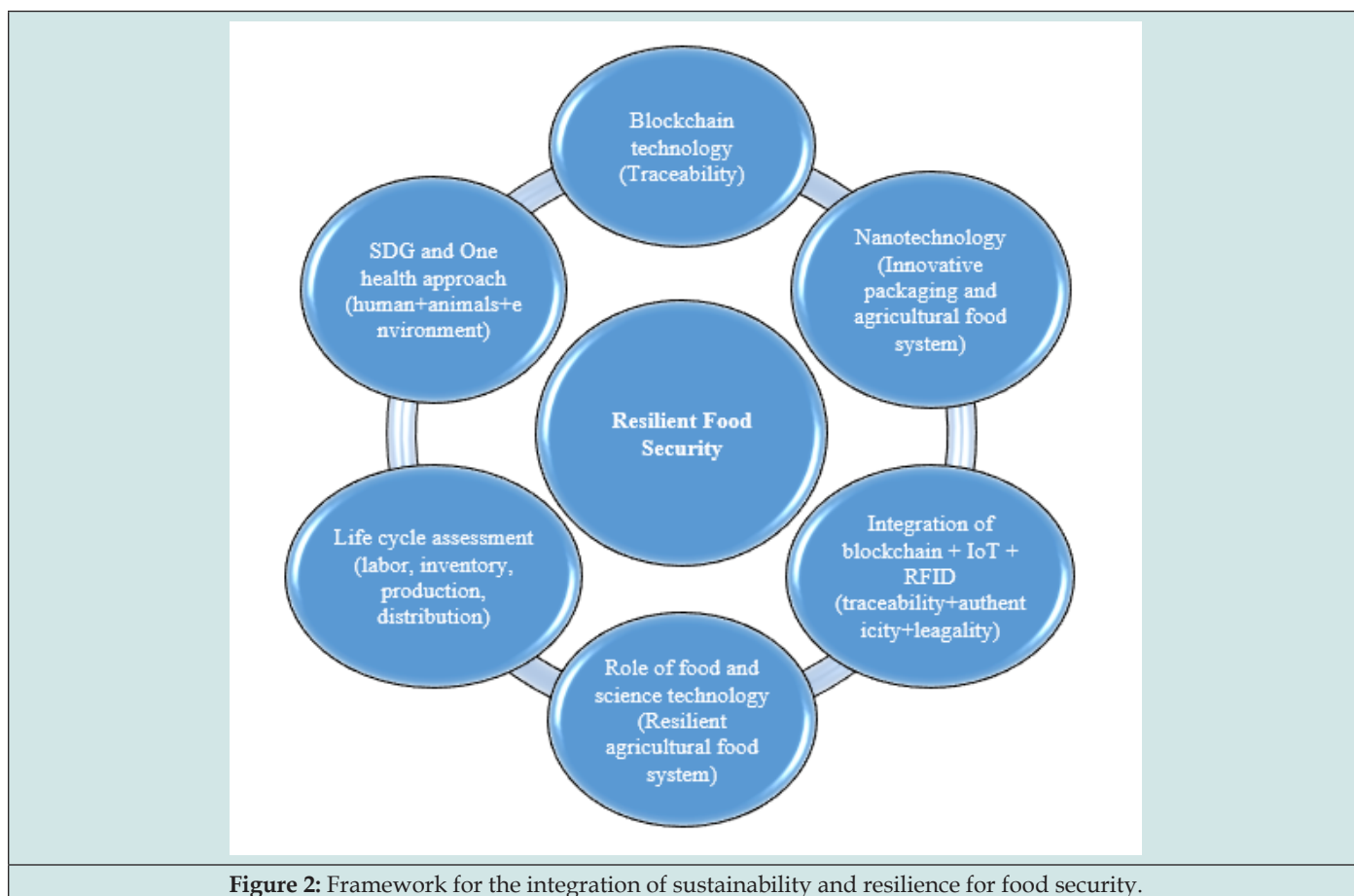


Figure 2: Framework for the integration of sustainability and resilience for food security.

Integration of sustainability and resilience in drug safety

After the emergence of COVID-19, the second most severely affected supply chain system was the PSC, which experienced the absence of sustainability and resilient strategies to enhance public health. With the help of a literature review, we identified different factors that impacted drug safety during and after COVID-19 and determined different sustainable strategies that can be utilized to build resilient pharmaceutical systems to ensure drug safety and public health. Healthcare systems should marshal their resources and capacities to achieve sustainability in PSC and medical services. Five important areas in PSC that should be focused on to become sustainable were identified in the literature: risk management, optimization of supply chain planning, probabilistic theory analysis, life-cycle analysis of sustainability, and strategies related to drug distribution to build resilient drug systems. After the COVID-19 pandemic, vaccine manufacturing and distribution disruptions increased due to manufacturer defects and logistics and distribution

maintenance failures. To develop a resilient vaccine supply chain, nano-supply chains based on sustainable strategies should be adopted, including standardization, network science, big data analytics, and a decision-making framework [17]. introduced the concept of localization, agility, and digitization (LAD) to provide more resilient and sustainable supply chain systems through blockchain technology. Blockchain technology enables tracking, tracing, and responsiveness through the active participation of all stakeholders, government, and community.

Using the literature, this paper discussed different sustainable strategies having direct and positive impacts on resilient PSC to ensure drug safety and indicated the possibility of integration of sustainability and resilience in the drug sector; these include: SDG 10, blockchain technology, integration of blockchain with other technologies like IoT, RFID, AI, cloud computing, 5G and big data analytics, anti-microbial stewardship programs to prevent anti-microbial resistance resulted due to drug counterfeiting, PAHO strategic fund reduces the cost and prevents drug counterfeiting thus

promoting drug safety socially and economically. Utilizing analytical techniques like chromatography and spectrophotometry (calorimetry, IR, and Raman spectrophotometry) to detect and prevent counterfeited drug products ensures drug safety. It promotes public health, as does a barcoding system on the primary packaging of products. We have found that using all these sustainable strategies in the respective areas could make the system more sustainable and resilient against future disruptions by preserving its sustainable characteristics.

Blockchain technology can improve supply chain management in many ways, including reducing or eliminating fraud and errors, reducing delays from paperwork, improving inventory management, identifying issues more rapidly, minimizing courier costs, and increasing consumer and partner trust and the integration of this technology with AI can make it more robust and flexible [18]. Along with pharmaceutical manufacturers, community pharma-

cists, distributors, and healthcare providers must adopt sustainable strategies to make the drug supply system more secure and resilient. [20]. identified the barriers to PSC and investigated the importance of utilizing modern Industry 4.0 technologies in developing a sustainable drug system. Other sustainable strategies to build resilient and ensure drug safety include public awareness through healthcare promotion programs, implementing government strategies and policies, active participation of community pharmacists, reducing purchasing on online outlets by providing knowledge to the consumers regarding the hazards of purchasing drug products from unlicensed medical store and enforcing governmental policies on these online pharmacies and websites to control them better. Figure 3 illustrates the framework for integrating sustainability and resilience critical factors to achieve drug safety. This figure mainly represents the role and impact of sustainable strategies in promoting resilient PSC systems to ensure drug safety and enhance public health.

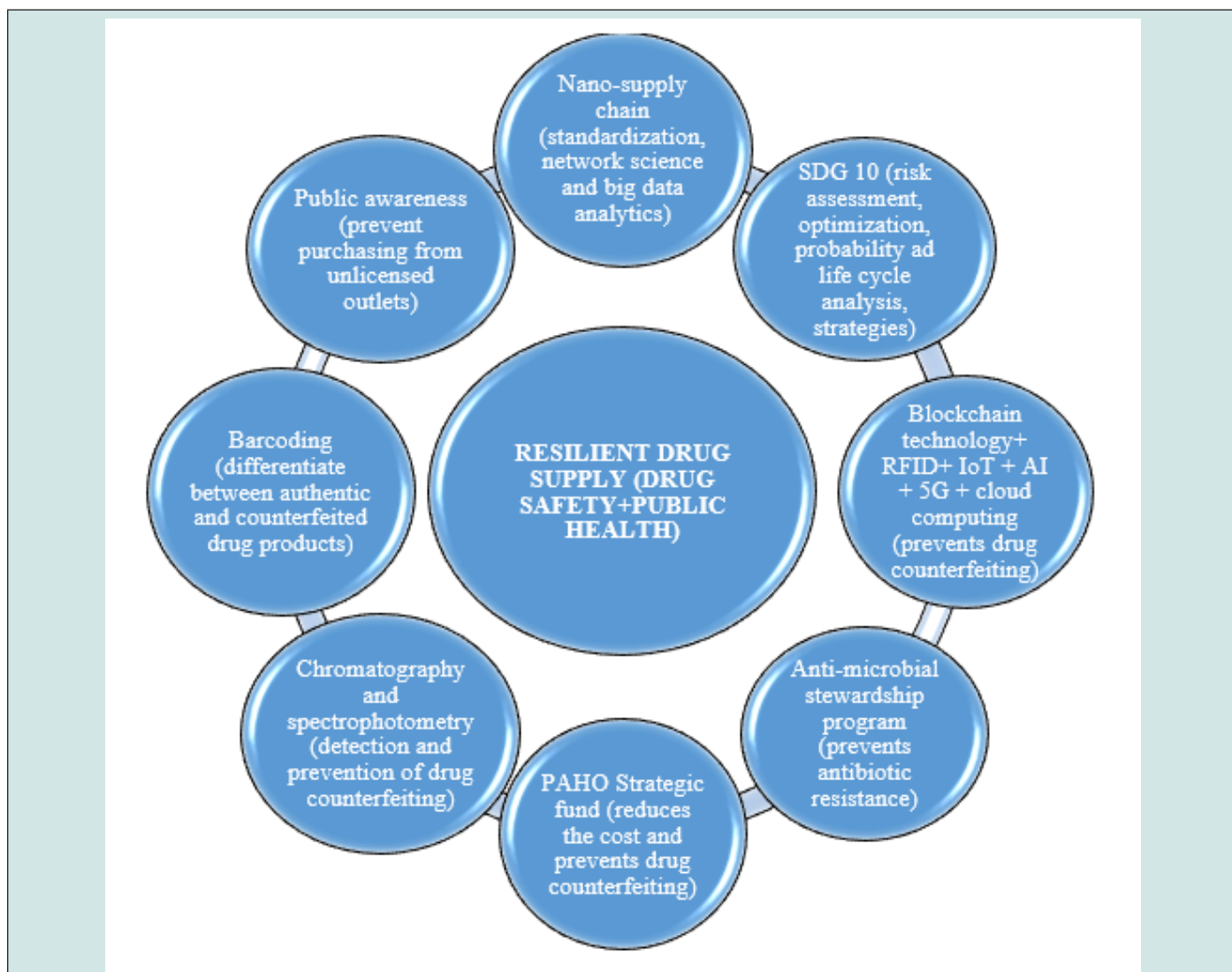


Figure 3: Framework for the integration of sustainability and resilience for drug safety.

Integration of sustainability and resilience in food and drug supply chains

During and after the COVID-19 pandemic, most issues people faced were related to the demand, production capacity, distribution, and storage of food and drug products. These were due to the lack of transparency, visibility, and sustainability in food-agricultural and healthcare systems. These issues increase the need for real-time data, monitoring, and tracking in these sectors. Demand increases and lower supplies boost the chances of counterfeiting food and drug products, thus, threatening public health. These issues increased the significance of utilizing and integrating modern digital technologies with transparency in the food and drug sectors. Digitalization and visualization are commonly used in the food and healthcare industries because they improve tracking and traceability. The present study identified different sustainable strategies in both sectors and their performance in building resilient food and drug systems. We found many similarities in strategies that can contribute to the integration of sustainability and resilience in the food and drug sectors. Those sustainable strategies are as follows: Nano-technology, blockchain technology, SDG 10 of 2030, life cycle assessment, blockchain integration with other technologies like IOT, RFID, etc. These technologies can be utilized as a sustainable approach to building socially, economically, and environmentally resilient food and drug systems, thus promoting food security and drug safety. Figure 4 illustrates the framework under which sustainability and resilience can be integrated into the food and drug sectors to ensure food security and drug safety.

Conclusion

The sudden emergence of COVID-19 revealed the lack of sustainability and resilience in the most common sectors directly related to public health, i.e., the food and drug sectors. A high-quality health system should have the capability to achieve optimal health outcomes sustainably to ensure a beneficial and resilient health system for future generations. A sustainable health system is also resilient and can recover from disruptions and prepare for future disasters while preserving its resilient features. Societies could play a vital role in managing their health systems to achieve a sustainable and resilient health system. Both food security and drug safety contribute to a high-quality health system. This can only be achieved by integrating sustainability and resilience in the food and drug sectors to promote food security and drug safety among the population [21-54]. Mechanisms or modern technologies should be adapted to involve stakeholders in decision-making to meet a population's needs. It has been revealed by the findings that the utilization of digitalization and visualization techniques in food and healthcare systems can promote food security and drug safety, ensuring resilient food and drug systems. Researchers concentrating on the recovery and resiliency of sustainable supply chains should further explore the relationship between sustainability and resilience in the food and drug sectors and possibly implement these strategies in both sectors. This study will assist all stakeholders, and researchers understand the current literature on sustainability

and resilience and the importance of their integration in the food and drug sectors during and after the COVID-19 pandemic and identify areas that require advanced research for future studies.

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