COVID-19 PANDEMIC-INDUCED DISRUPTIONS IN THE FOOD SYSTEM AND THEIR IMPLICATIONS FOR DIETARY PATTERNS AND NUTRITIONAL OUTCOMES: A SYSTEMATIC REVIEW

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ABSTRACT

The COVID-19 pandemic disrupted food systems globally, impacting diets and nutrition. This review explored the challenges in food systems during the COVID-19 pandemic and their effects on diets and nutrition. It analyzed 23 studies from 11,398 references using PRISMA guidelines to identify the pandemic's impact on food production, supply chains, and dietary patterns. Agricultural output was reduced due to labour shortages, lack of buyers, transportation constraints, and import delays. Food supply disruptions affected the availability of healthy foods, disproportionately impacting children, the elderly, and those with chronic conditions. Stockpiling and inadequate storage increased food waste, particularly bakery items, fruits, and vegetables. Only 8.3% of food hygiene practices met acceptable standards. Negative dietary changes, such as higher consumption of sugary, salty, and processed foods, led to weight gain, particularly among overweight individuals. Stunting and undernutrition increased in low-income nations, while higher-income countries experienced weight gain. The study highlighted the need for strategies to mitigate food system challenges during crises.

KEYWORDS

Covid-19 pandemic, Challenges, Food System, Food production, Supply chain, Dietary patterns

1. INTRODUCTION

Since late 2019, the COVID-19 pandemic has significantly disrupted global food systems, primarily due to containment measures such as lockdowns and social distancing. While these interventions were effective in mitigating virus transmission [1,2], they also had unintended consequences, including disruptions in food production, transportation, and supply chains. These challenges contributed to supply-demand imbalances, rising food prices, and decreased access to nutritious food [3].

Food systems, which encompassed production to consumption and disposal, vary significantly across regions and between urban and rural areas [4,5]. Urban food supply chains are more prone to disruptions, whereas rural systems face fewer challenges due to proximity to production sites. The pandemic significantly changed food-buying behaviors and consumption patterns. Online

food ordering increased as people avoided physical stores [6]. Healthier eating patterns were found in middle-aged adults, while obese individuals consumed more junk foods and sugary drinks, increasing the risk of obesity-related diseases like hypertension and type 2 diabetes [7.8]. Lockdown measures also led to reduced availability and accessibility of food, particularly for low-income populations. Families with children, elderly members, or chronic illnesses faced higher risks of food insecurity due to limited income and increased dependency [9.10]. Food waste became a significant issue, especially in producing perishable foods, due to the closure of food industries and markets [11]. On the other hand, domestic food waste declined during the pandemic [12].

Food safety emerged as another critical challenge. Although the likelihood of COVID-19 transmission through food was minimal, concerns over contamination underscored the critical need for stringent hygiene practices. Emphasis was placed on proper food handling, thorough cleaning of materials, and maintaining personal hygiene among food industry workers to mitigate potential risks [13.14]. The virus's survival on surfaces and presence in stool emphasized the need to restrict symptomatic workers from food processing roles. Nutritional imbalances became obvious as the pandemic reduced access to fresh, healthy foods, pushing people toward preserved and less nutritious options. Rising prices of fruits and vegetables further worsened the shift, contributing to micronutrient deficiencies, malnutrition, and weight gain [15]. This review aimed to identify COVID-19-induced challenges in food production, supply chains, availability, waste management, hygiene, and accessibility while examining variations in consumer behaviours and their impacts on nutrition. It emphasized the need for strategies to ensure food security and improve nutritional outcomes during crises. Interventions should include promoting healthy eating, stabilizing food prices, enhancing food safety measures, and addressing the specific needs of vulnerable populations. By addressing these challenges, governments and stakeholders can mitigate the negative impacts on food systems and ensure healthier societies. This research offers valuable insights for policymakers and raises public awareness of sustainable dietary practices during pandemic.

2. MATERIAL AND METHOD

To comprehensively analyze the impact of the COVID-19 pandemic on food systems and nutrition, a systematic review methodology was employed. The following subsections detail research design, the eligible criteria, data sources, search strategy, data extraction, critical appraisal and data synthesis.

2.1. Research Design

This systematic review was designed to synthesize the best available evidence regarding the challenges induced by the COVID-19 pandemic on the global food system. The primary objective was not to produce new knowledge but rather to compile and synthesize existing research to address the distinct challenges that food systems encountered across various countries during the pandemic. Given the constraints of time, budget, and logistics—particularly under pandemic-related restrictions—conducting large-scale primary research was not feasible. As a result, a systematic review approach was selected as a structured and effective method for gathering, analyzing, and integrating data from multiple studies. This approach enabled the researcher to present comprehensive and impartial insights from diverse settings. By consolidating evidence from numerous primary studies into a single analysis, the systematic review ensured the development of well-founded and reliable conclusions

2.2. Eligibility Criteria

A set of well-defined eligibility criteria was systematically formulated to regulate the inclusion and exclusion of studies, providing a fundamental framework for the systematic review process. Two types of eligibility criteria were applied: fixed and changeable. Fixed inclusion criteria included studies published in English to avoid translation issues that might compromise content validity. Only full-text, downloadable, non-purchased studies published in peer-reviewed journals during the pandemic (2019-2022) were included to ensure access to quality and relevant evidence. The studies focused on challenges in food production, supply chain systems, food availability, marketing policies, food waste management, food hygiene, and their effects on nutritional indicators. Another essential component was the research methodology, which needs precise documentation of the research design, study population, sample size, and data collection and analysis techniques. To uphold methodological rigor, studies with non-response rates exceeding 20% or citing fewer than 20 references were excluded. Moreover, the inclusion criteria were designed to be flexible, allowing for variations in study designs, such as cross-sectional descriptive, longitudinal, case-control, and experimental studies. Peer-reviewed journals were prioritized to ensure scientific validity. Studies from developed and developing countries were included to overview pandemic-induced challenges comprehensively. Nutritional indicators such as Body Mass Index (BMI), waist circumference, and waist-to-hip ratio were considered for inclusion to ensure relevance to the research objectives. Even when studies met the predefined inclusion criteria, they were excluded if they lacked clear methodologies, were published prior to the pandemic, or could not be accessed due to language barriers or incomplete data. Additionally, non-research-based reports, theses, and dissertations were excluded from the review.

2.3. Information Sources and Search Strategies

Information sources were carefully selected to optimize the comprehensiveness and relevance of the review. The databases considered included Web of Science, Science Direct, PubMed, Google Scholar, and Hinari, as they provided access to a wide range of high-quality, peer-reviewed articles. Other databases, such as Cochrane Library, Scopus, CINAHL, and ProQuest, were excluded due to their focus on controlled trials or overlap with the selected databases. The search strategy incorporated Boolean operators ("AND" and "OR") and modifiers to combine keywords effectively. Core keywords included "COVID-19 pandemic," "challenges," and "food system," with synonyms and related terms such as "novel coronavirus pandemic," "food production," and "nutritional security" included to broaden the search scope.

2.4. Paper Selection

The paper selection process involved several stages, including title and abstract screening, full-text assessment, and final study inclusion. Both fixed and changeable eligibility criteria were applied at each stage to ensure alignment with the research objectives. Studies that failed to meet the eligibility criteria or exhibited additional characteristics that compromised their relevance, such as lack of methodology or focus, were excluded. Collaboration with a second reviewer and consultation with a supervisor ensured reliability and minimized bias during the selection process.

2.5. Data Extraction

Data extraction was performed using a pre-designed data extraction sheet, which was piloted for reliability and validity. Key information, including study objectives, methods, population characteristics, and outcome measures, was systematically extracted. The extracted data focused

on pandemic-induced challenges in food production, supply chain systems, food availability, and their effects on nutritional indicators. Variations in food consumption and diet quality were also documented. To ensure accuracy, the data extraction process was conducted independently by two reviewers, with discrepancies resolved through discussion or consultation with the supervisor.

2.6. Critical Appraisal

Critical appraisal was conducted to assess the methodological quality of the included studies. Key aspects evaluated included research design, sample size, data collection methods, and analytical rigor. To ensure the review's credibility, studies with methodological shortcomings, including unclear research designs or excessive non-response rates, were excluded. A standardized appraisal tool was employed to ensure consistency and objectivity in evaluating the quality of evidence. Collaboration with experienced researchers further enhanced the appraisal process, ensuring robust and credible outcomes.

2.7. Data Synthesis

Data synthesis involved a qualitative and thematic analysis of the extracted information. Challenges related to food production, supply chain systems, food availability, marketing policies, food hygiene, and food waste management were categorized and analyzed. Variations in food consumption patterns and their impact on nutritional indicators were examined to identify trends and correlations. By consolidating evidence from various contexts, the review offered a thorough understanding of the pandemic's complex effects on food systems. The results were systematically presented to emphasize key findings and guide the development of effective strategies to address similar challenges in the future.

3. RESULTS

The findings of this review highlight the multifaceted challenges posed by the pandemic, including disruptions in food supply chains and affordability issues. The following subsections present the key results in this review.

3.1. PRISMA's Step-by-step Selection Process

The PRISMA selection process comprised three steps: identification, screening, and selection. In the identification phase, 11,398 records were retrieved, of which 5,945 remained after removing 3,876 duplicates and 488 inaccessible records. During the screening, 1,037 records were excluded based on inconsistencies with review objectives and criteria, leaving 544 full-text papers. Further exclusions reduced this to 23 papers. In the final selection phase, two reviewers and supervisors conducted detailed evaluations, cross-checks, and pilot-testing for data extraction, confirming the inclusion of the 23 most relevant studies. This systematic approach ensured the selection of high-quality, pertinent research for the review.

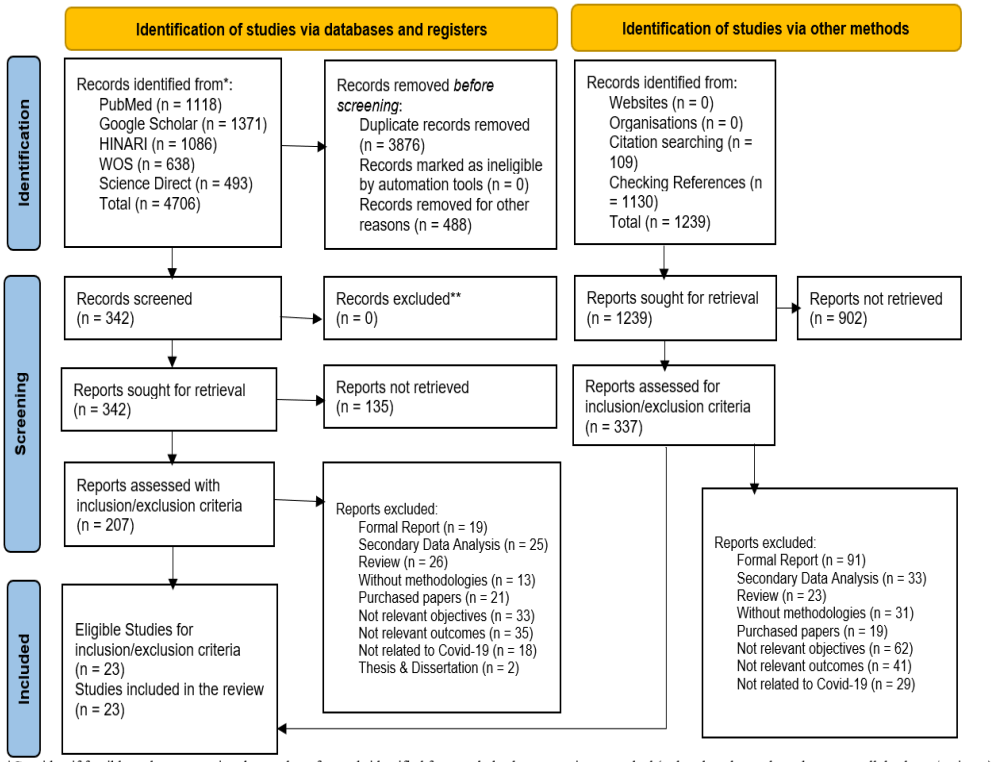

Figure 1. PRISMA's Step-by-step Selection Process

3.2. Summary of the Selected Papers' Characteristics

The 23 studies included in the review, published between 2020 and 2022, represented 102 countries, with most studies from India. Of these, 21 (91.3%) used cross-sectional designs, while 2 (8.7%) employed cohort designs. About half used simple random sampling, while others applied purposive sampling. The total sample size was 24,076. Response rates varied, with three studies at 60%-70%, two at 70%-80%, one at 80%-90%, and seventeen at 90%-100%. Each study utilized appropriate statistical analysis tools.

3.3. Challenges in Food System

The COVID-19 pandemic triggered significant challenges across food systems globally, influencing food production, supply chains, food waste management, food hygiene, and the accessibility of healthy foods. During the initial phase of the pandemic, restrictions on the movement of workers resulted in a decline in food production. Many respondents reported having to skip harvests, experiencing labor shortages, and encountering market closures (Jaacks et al., 2021). A reduction in agricultural output was noted, with maize yields dropping significantly compared to pre-pandemic levels (Mthembu et al., 2022). Food production was further hindered by low prices, lack of buyers, transportation issues, and import shortages (Harris et al., 2020). The pandemic also exacerbated food security concerns, with large portions of the population experiencing food insecurity, particularly low-income households, housewives, and those with reduced income due to lockdowns (Rezaul Karim & Tasnim, 2022). As the crisis evolved, disruptions in supply chains, food shortages, and rising prices of nutrient-rich foods, including meats, dairy products, legumes, fruits, and vegetables, became prevalent (Jafri et al., 2021). Additionally, the COVID-19 pandemic had a significant impact on food waste management, as

increased stockpiling behaviors led to higher food disposal rates (Cosgrove et al., 2021), while excessive cooking contributed further to wastage (Jribi et al., 2020). Furthermore, food hygiene practices became a primary concern, with more people taking precautions such as handwashing and disinfecting food packages (Finger et al., 2021; Faour-Klingbeil et al., 2021). In addition to these challenges, significant changes in consumer behavior were observed, such as a reduced diversity in food choices and an increased dependence on less preferred food items. (Jafri et al., 2021), as well as changes in diet quality and eating habits (Błaszczyk-Bębenek et al., 2020; Ruiz-Roso et al., 2020). Many households adopted various coping strategies to navigate food shortages, including consuming less-preferred foods, skipping meals, and depending on external assistance (Rezaul Karim & Tasnim, 2022). Such disruptions in food systems had profound impacts on nutrition and health, with particularly severe consequences for vulnerable populations.

3.3.1. Challenges in Food Production

The COVID-19 pandemic posed significant challenges to food production, profoundly affecting global food systems. Restrictions on worker mobility led to reduced productivity, while lockdown measures exacerbated labor shortages and forced market closures, further straining agricultural workers. Research indicates that many respondents reported skipping harvest activities, primarily due to lockdown restrictions and adverse weather conditions (Jaacks et al., 2021). Additionally, shifts in food trade policies, changing consumer demand, and worsening financial constraints further disrupted the sector. Studies highlighted a marked decline in agricultural output, with maize yields dropping considerably during the pandemic compared to pre-pandemic levels (Mthembu et al., 2022). Contributing factors such as declining prices, a lack of buyers, and import shortages further hindered food production, as farmers and suppliers faced significant barriers in accessing essential resources (Harris et al., 2020).

3.3.2. Challenges in Supply Chain System and Food Availability

The COVID-19 pandemic caused major disruptions in food supply chains, reducing food availability and exacerbating widespread food insecurity. In India, the closure of key wholesale markets led to confusion and restricted access to essential food items, making it more challenging to obtain nutritious foods (Sukhwani et al., 2020). Globally, supply chain breakdowns left many people, particularly in East and Southern Africa, struggling to secure sufficient food. Vulnerable groups, including individuals with chronic illnesses, the elderly, and children, were disproportionately affected by these shortages (Jafri et al., 2021). Additionally, the prices of staple foods and nutrient-rich items such as meat, dairy, legumes, and fruits surged during the pandemic, intensifying food insecurity, especially among low-income households (Rezaul Karim & Tasnim, 2022). A considerable segment of the population, particularly those in financially disadvantaged households, faced severe food insecurity due to income losses and restricted food access (Rezaul Karim & Tasnim, 2022).

3.3.3. Challenges in Food Waste Management

The COVID-19 pandemic heightened concerns over food waste management, as shifts in consumer behavior contributed to increased wastage. While some individuals reported discarding minimal amounts of food, others disposed of significantly larger quantities. Key factors driving food waste included stockpiling, overcooking, and extended storage, particularly of perishable items such as fruits and bakery products (Cosgrove et al., 2021; Jribi et al., 2020). However, certain studies indicated a decline in food waste, with respondents demonstrating greater awareness and adopting improved food management practices during the pandemic (Cosgrove et al., 2021). Despite these positive changes, stockpiling behaviors persisted as a major contributor to food wastage (Cosgrove et al., 2021).

3.3.4. Challenges in Food Hygiene

Food hygiene emerged as a major concern during the COVID-19 pandemic, prompting individuals to adopt precautionary measures to reduce contamination risks and ensure safe food handling. Many respondents reported disinfecting food packaging with alcohol-based sanitizers, washing hands before and after handling food, and exercising caution when receiving food deliveries (Finger et al., 2021; Faour-Klingbeil et al., 2021). However, studies identified discrepancies between self-reported hygiene behaviors and expert evaluations, revealing that only a small proportion of participants consistently followed proper food safety protocols during meal preparation (Limon, 2021). Research conducted in food establishments further highlighted that food handlers equipped with personal protective equipment (PPE) and access to adequate sanitation facilities were more likely to maintain proper hygiene standards (Alamneh et al., 2022).

3.3.5. Challenges in Accessibility of Preferred and Healthy Food

The COVID-19 pandemic brought significant changes to food consumption patterns, limiting access to preferred and nutritious foods. Many respondents reported a decline in dietary variety, with an increased reliance on less desirable food options during the crisis (Jafri et al., 2021). Disruptions in food supply chains, coupled with shifts in consumer purchasing power, made fresh and healthy food choices less accessible. Additionally, income reductions and rising food prices further restricted access to nutritious foods, forcing numerous individuals and households to depend on more affordable yet less nutritious alternatives.

3.3.6. Variation in Consumer Behaviours, Food Consumption, and Diet Quality

The COVID-19 pandemic brought considerable changes in consumer behavior, particularly in food consumption patterns and dietary quality. Many individuals reported reducing portion sizes and meal frequency, while others experienced an increase in the intake of unhealthy foods, such as fried snacks and sugary beverages (Błaszczyk-Bębenek et al., 2020; Ruiz-Roso et al., 2020). Notably, some respondents incorporated more fruits and vegetables into their diets, reflecting a positive dietary shift in certain groups (Tan et al., 2022). However, these improvements were often counterbalanced by a heightened consumption of unhealthy foods, including fried items and sugary snacks. These dietary changes were primarily influenced by emotional responses to the pandemic and lifestyle modifications resulting from lockdown restrictions. While some individuals adopted healthier eating habits, the overall effect on diet quality remained inconsistent.

3.4. Effects of Food System-related Challenges on Nutritional Indicators

The disruptions to food systems during the COVID-19 pandemic had significant consequences on nutritional outcomes, leading to poorer dietary quality and heightened food insecurity for many populations. Limited access to a variety of nutritious foods resulted in dietary shifts, with many individuals opting for lower-quality and more affordable alternatives. This change in food consumption patterns adversely impacted nutritional intake, particularly among vulnerable groups, including low-income households, children, the elderly, and those with pre-existing health conditions. The rise in food insecurity had serious public health implications, contributing to increased malnutrition, micronutrient deficiencies, and other nutrition-related health issues (Jafri et al., 2021; Rezaul Karim & Tasnim, 2022). Furthermore, reduced food availability and escalating food prices aggravated the struggles of those already facing challenges in meeting their nutritional needs. As a result, numerous households resorted to coping mechanisms, such as eating less-preferred foods, skipping meals, and depending on external food assistance (Rezaul

Karim & Tasnim, 2022). Although some individuals adopted healthier eating habits during the pandemic, these improvements were not enough to counterbalance the wider negative effects of food system disruptions on nutritional outcomes (Madan et al., 2021; Kriaucioniene et al., 2020). The effects of these challenges on nutrition emphasize the critical need for strategic approaches to bolster food security, enhance access to nutritious foods, and fortify public health resilience in anticipation of future crises.

Table 1. Changes in food production, food hygiene practice, Consumer Behaviours and Nutritional Indicators Due to Covid-19

References	variables	Before the COVID-19	During the COVID-19	Differences
Ruiz-Roso et al., 2020	4 servings of legumes per week	6.5%	7.7%	1.2%
	daily consumption of vegetables	34%	42.4%	8.4%
	daily consumption of fruits	25.3%	33.1%	7.8%
	consuming fast food, no more than once per week	44%	65%	21%
	daily consumption of fried foods	2.1%	3.2%	1.1%
	daily consumption of sweet foods	13.4%	20.6%	7.4%
	daily consumption of processed meats	6.8%	8.4%	1.6%
	daily consumption of sugar-sweetened beverages	8.7%	9.4%	0.7%
Błaszczyk-Bębenek et al., 2020	underweight adult	2.1%	2.3%	0.2%(P=0.7213)
	normal weight adult	53.3%	50.8%	-2.5%(P=0.7213)
	overweight adult	32.5%	33.6%	1.1%(P=0.7213)
	obese adult	12.1%	13.3%	1.2%(P=0.7213)
	Eating outside or ordering takeaway food(never)	15.7%	51.6%	35.9%(P<0.0001)
	Eating outside or ordering takeaway food (1-3 times per month)	45.5%	34.6%	-10.9%(P<0.0001)
	Eating outside or ordering takeaway food (1 time per week)	17%	9%	-8%(P<0.0001)
	Eating outside or ordering takeaway food (few times a week)	17.3%	3.5%	-13.8%(P<0.0001)
	Eating outside or ordering takeaway food (1 time per day)	3.5%	1.3%	-2.2%(P<0.0001)
	Eating outside or ordering take-away food (few times per day)	0.6%	0.0%	-0.6(P<0.0001)
	5 meals per day	19.9%	31.1%	11.2%(P<0.0001)
	4 meals per day	40.7%	40.4%	-0.3%(P<0.0001)
	3 meals per day	32.1%	23.1%	-9%(P<0.0001)
	2meals per day	7.1%	4.8%	-2.3%(P<0.0001)
	1meal per day	0.6%	0.3%	-

			0.3%(P<0.0001)
consumption of egg (never)	2.6%	1.6%	-1%(P=0.0022)
consumption of egg (1-3 times per month)	9.6%	7.4%	-2.2%(P=0.0022)
consumption of egg (once a week)	26.3%	24.0%	-2.3%(P=0.0022)
consumption of egg (few times a week)	54.2%	55.8%	1.8%(P=0.0022)
consumption of egg (once a day)	5.4%	9.6%	4.2%(P=0.0022)
consumption of egg (few times a day)	1.9%	1.6%	-0.3%(P=0.0022)
consumption of potatoes (never)	4.8%	5.1%	0.3%(P=0.0004)
consumption of potatoes (1-3 times per month)	18.6%	10.3%	-8.3%(P=0.0004)
consumption of potatoes (once a week)	26.9%	26.6%	-0.3%(P=0.0004)
consumption of potatoes (few times a week)	44.2%	51.6%	7.4%(P=0.0004)
consumption of potatoes (once a day)	4.5%	6.1%	1.6%(P=0.0004)
consumption of potatoes (few times a day)	1.0%	0.3%	-0.7%(P=0.0004)
consumption of fast foods(never)	25.6%	41.7%	16.1%(P=0.0001)
consumption of fast foods (1-3 times per month)	57.40%	42%	-15.4%(P=0.0001)
consumption of fast foods (once a week)	10.6%	11.5%	0.9%(P=0.0001)
consumption of fast foods (few times a week)	6.1%	4.2%	-1.9%(P=0.0001)
consumption of fast foods (once a day)	0.0%	0.6%	0.6%(P=0.0001)
consumption of fast foods (few times a day)	0.3%	0.0%	-0.3%(P=0.0001)
consumption of sweets (never)	5.4%	7.4%	2%(P=0.0241)
consumption of sweets (1-3 times per month)	19.9%	16%	3.9%(P=0.0241)
consumption of sweets (once a week)	16.7%	15.4%	-1.3%(P=0.0241)
consumption of sweets (few times a week)	38.1%	34.0%	-4.1%(P=0.0241)

consumption of sweets (once a day)	13.8%	16.0%	2.2%(P=0.0241)
consumption of sweets (few times a day)	6.1%	11.2%	5.1%(P=0.0241)
consumption of instant soup (never)	74.7%	78.2%	3.5%(P=0.0247)
consumption of instant soup (1-3 times per month)	16.0%	15.1%	-0.9%(P=0.0247)
consumption of instant soup (once a week)	5.1%	3.8%	-1.3%(P=0.0247)
consumption of instant soup (few times a week)	2.6%	2.6%	0%(P=0.0247)
consumption of instant soup (once a day)	1.3%	0.3%	-1%(P=0.0247)
consumption of instant soup (few times a day)	0.3%	0.0%	-0.3%(P=0.0247)
consumption of tinned meat (never)	73.1%	68.3%	4.8%(P=0.0004)
consumption of tinned meat (1-3 times per month)	20.2%	19.2%	-1%(P=0.0004)
consumption of tinned meat (once a week)	5.1%	9.3%	4.2%(P=0.0004)
consumption of tinned meat (few times a week)	1.0%	2.6%	1.6%(P=0.0004)
consumption of tinned meat (once a day)	0.3%	0.6%	0.3%(P=0.0004)
consumption of tinned meat (few times a day)	0.3%	0.0%	-0.3%(P=0.0004)
consumption of energy drink (never)	78.5%	85.3%	6.8%(p=0.0150)
consumption of energy drinks (1-3 times per month)	14.7%	8.3%	-6.4%(p=0.0150)
consumption of energy drinks (once a week)	1.6%	3.2%	1.6%(p=0.0150)
consumption of energy drinks (few times a week)	4.2%	1.9%	-2.3%(p=0.0150)
consumption of energy drinks (once a day)	0.3%	0.6%	0.3%(p=0.0150)
consumption of energy drinks (few times a day)	0.6%	0.6%	0.0%(p=0.0150)
consumption of alcohol (never)	21.8%	25.6%	3.8%(P=0.0031)
consumption of alcohol (1-3 times per month)	37.8%	26.0%	-11.8%(P=0.0031)
consumption of alcohol (once a week)	19.6%	19.9%	0.3%(P=0.0031)
consumption of alcohol (few times a week)	16.0%	22.2%	6.2%(P=0.0031)
consumption of alcohol (once a day)	3.8%	5.4%	1.6%(P=0.0031)
consumption of alcohol (few times a day)	1.0%	1.0%	0%(P=0.0031)

portion size of white bread per day (0 serving)	7.4%	6.4%	-1%(P=0.0400)
portion size of white bread per day (0.5 serving)	28.8%	34.9%	6.1%(P=0.0400)
portion size of white bread per day (1 serving)	23.4%	23.4%	0%(P=0.0400)
portion size of white bread per day (2 servings)	17.6%	13.8%	-3.8%(P=0.0400)
portion size of white bread per day (3 servings)	1.9%	4.2%	2.3%(P=0.0400)
portion size of white bread per day (4 servings)	10.9%	7.1%	-3.8%(P=0.0400)
portion size of white bread per day (5 servings)	9.9%	10.3%	0.4%(P=0.0400)
portion size of red meat per day (0 serving)	13.1%	18.6%	5.5%(P=0.0199)
portion size of red meat per day (0.5 serving)	74.0%	68.9%	-5.1%(P=0.0199)
portion size of red meat per day (1 serving)	11.5%	11.5%	0%(P=0.0199)
portion size of red meat per day (2 servings)	0.6%	1.0%	0.4%(P=0.0199)
portion size of red meat per day (3 servings)	0.3%	0.0%	-0.3%(P=0.0199)
portion size of red meat per day (4 servings)	0.3%	0.0%	-0.3%(P=0.0199)
portion size of red meat per day (5 servings)	0.0%	0.0%	0%(P=0.0199)
portion size of fast foods per day (0 serving)	26.0%	41.7%	15.7%(P<0.0001)
portion size of fast foods per day (0.5 serving)	67.6%	54.8%	-12.8%(P<0.0001)
portion size of fast foods per day (1 serving)	6.1%	2.9%	-3.2%(P<0.0001)
portion size of fast foods per day (2 servings)	0.3%	0.3%	0%(P<0.0001)
portion size of fast foods per day (3 servings)	0.0%	0.3%	0.3%(P<0.0001)
portion size of fast foods per day (4 servings)	0.0%	0.0%	0%(P<0.0001)
portion size of fast foods per day (5 servings)	0.0%	0.0%	0%(P<0.0001)
portion size of sweets per day (0 serving)	5.8%	7.4%	1.6%(P=0.0029)
portion size of sweets per day (0.5 serving)	66.0%	58.0%	-8%(P=0.0029)
portion size of sweets per day (1 serving)	19.2%	18.9%	-0.3%(P=0.0029)
portion size of sweets per day (2 servings)	4.5%	7.7%	3.2%(P=0.0029)
portion size of sweets per day (3 servings)	1.0%	1.0%	0%(P=0.0029)
portion size of sweets per day (4 servings)	1.6%	3.5%	1.9%(P=0.0029)
portion size of sweets per day (5 servings)	1.9%	3.5%	1.6%(P=0.002

	portion size of instant soup per day (0 serving)	74.7%	78.2%	9) 3.5%(P=0.0283)
	portion size of instant soup per day (0.5 serving)	23.4%	20.8%	-2.6%(P=0.0283)
	portion size of instant soup per day (1 serving)	1.0%	1.0%	0%(P=0.0283)
	portion size of instant soup per day (2 servings)	0.6%	0.0%	-0.6%(P=0.0283)
	portion size of instant soup per day (3 servings)	0.3%	0.0%	-0.3%(P=0.0283)
	portion size of instant soup per day (4 servings)	0.0%	0.0%	0%(P=0.0283)
	portion size of instant soup per day (5 servings)	0.0%	0.0%	0%(P=0.0283)
	portion size of tinned meats per day (0 serving)	73.1%	68.6%	-4.5%(P=0.0390)
	portion size of tinned meats per day (0.5 serving)	23.4%	20.8%	-2.6%(P=0.0390)
	portion size of tinned meats per day (1 serving)	1.0%	1.0%	0%(P=0.0390)
	portion size of tinned meats per day (2 servings)	0.6%	0.0%	-0.6%(P=0.0390)
	portion size of tinned meats per day (3 servings)	0.3%	0.0%	-0.3%(P=0.0390)
	portion size of tinned meats per day (4 servings)	0.0%	0.0%	0%(P=0.0390)
	portion size of tinned meats per day (5 servings)	0.0%	0.0%	0%(P=0.0390)
	portion size of energy drinks per day (0 serving)	78.5%	85.3%	6.8%(P=0.0008)
	portion size of energy drinks per day (0.5 serving)	18.3%	13.5%	-4.8%(P=0.0008)
	portion size of energy drinks per day (1 serving)	2.2%	0.3%	-1.9(P=0.0008)
	portion size of energy drinks per day (2 servings)	0.3%	0.0%	-0.3%(P=0.0008)
	portion size of energy drinks per day (3 servings)	0.0%	0.0%	0%(P=0.0008)
	portion size of energy drinks per day (4 servings)	0.0%	0.6%	0.6%(P=0.0008)
	portion size of energy drinks per day (5 servings)	0.6%	0.3%	-0.3%(P=0.0008)
Mthembu et al., 2022	average maize grain yield	2.2 t ha−1	1.4 t ha−1	-0.8t ha−1(P=0.002)
	average dry bean yield	1.1t ha−1	1.0 t ha−1	-0.1t ha−1(P=0.829)
	average soybeans yield	0.95t ha−1	0.88 t ha−1	-0.7t ha−1(P=0.732)
Amare et al.,	skipping a meal	0.26%	0.73%	0.47%(P=0.01)

2021				0.32%(P=0.01
	having a food shortage	0.25%	0.57%	)
	went a whole day without eating	0.05%	0.24%	0.2%(P=0.01)
Faour-Klingbeil et al., 2021	dispose of shopping bags for food (never)	19.60%	7%	-12.60%
	dispose of shopping bags for food (rarely)	26.40%	7.70%	-18.70%
	dispose of shopping bags for foods(sometimes)	27.80%	19.20%	-8.60%
	dispose of shopping bags for food (often)	16.20%	31.10%	14.9%
	dispose of shopping bags for food (always)	10%	32.00%	22%
	dispose of all food containers, packages and coverings(never)	17.20%	4.30%	-12.90%
	dispose of all food containers, packages and coverings(rarely)	24.30%	7.60%	-16.70%
	dispose of all food containers, packages and coverings(sometimes)	24.50%	17.30%	-7.20%
	dispose of all food containers, packages and coverings(often)	19.90%	34.00%	14.1%
	dispose of all food containers, packages and coverings(always)	14.10%	36.80%	22.7%
	sterilization of food packages prior to storage at home(never)	31.60%	6.90%	-24.70%
	sterilization of food packages prior to storage at home(rarely)	26.80%	7.90%	-18.90%
	sterilization of food packages prior to storage at home(sometimes)	18.50%	15.50%	-3.00%
	sterilization of food packages prior to storage at home(often)	13.00%	28.60%	15.6%
	sterilization of food packages prior to storage at home(always)	10.10%	41.10%	31%
	hand washing after handling food packages(never)	11.00%	2.00%	-9.00%
	hand washing after handling food packages(rarely)	16.90%	3.20%	-13.70%
	hand washing after handling food packages(sometimes)	23.40%	7.70%	-15.70%
	hand washing after handling food packages(often)	23.60%	29.80%	6.2%
	hand washing after handling food packages(always)	25.10%	57.30%	32.2%
	hand washing after getting home(never)	4.30%	1.80%	-2.50%
	hand washing after getting home(rarely)	9.80%	1.70%	-8.10%
	hand washing after getting home(sometimes)	17.30%	6.10%	-11.20%
	hand washing after getting home(often)	31.50%	29.20%	-2.30%
	hand washing after getting home(always)	37.10%	61.20%	24.1%
	hand washing prior to food preparation(never)	3.00%	2.20%	-0.80%
	hand washing prior to food preparation(rarely)	4.70%	1.60%	-3.10%
	hand washing prior to food preparation(sometimes)	11.50%	6.90%	-4.60%
	hand washing prior to food preparation(often)	31.50%	28.80%	-2.70%
	hand washing prior to food preparation(always)	49.30%	60.50%	11.2%
(Kang et al., 2021)	children with obesity	14.60%	18.60%	4%
	children with overweight	9.30%	12.80%	3.5%
	children with normal weight	69.90%	62.80%	-7.10%
	children with underweight	6.20%	5.80%	-0.40%
	25OHD, mg/dL (calcidiol)	23.8%mg /dL	18.9mg/dL	-4.9mg/dL

4. DISCUSSION

This review found that the COVID-19 pandemic disrupted food systems, affecting both food availability and nutrition. Agricultural production declined due to labor shortages, transport

restrictions, and delays in imports, leading to limited access to healthy foods. These disruptions had a greater impact on vulnerable groups, such as children, the elderly, and people with chronic diseases. Dietary habits also changed, with increased consumption of processed, sugary, and salty foods, which contributed to weight gain, especially in higher-income countries. Meanwhile, undernutrition and stunting became more common in low-income nations, showing the unequal impact of the pandemic on global nutrition.

This systematic review aimed to reveal the challenges occurred in the food system during Covid-19 pandemic and their impact on the healthy diet and nutritional status of the population. This review showed that disruption of the food system especially in food production and food supply chain. The prevalence of undernourishment and food production is strongly associated. Mughal& Fontan Sers (2020) showed that the number of people suffering from undernourishment decreased by 0.2 percent when cereal production rose by 1 percent. In this review, a study in South Africa declared that the production of maize was significantly reduced during COVID-19(Mthembu et al., 2022). It may cause nutrient deficiency in the population depending on maize as a staple crop because maize can provide certain amounts of macronutrients and micronutrients(K, 2016). During Covid-19, a study included in this review showed that 11% of farmers in India skipped harvesting because of weather, lockdown and its consequences such as market closure and shortages of workers. Increasing the prices of inputs (34%), unavailability of employee (22%), unobtainable fertilizer and seed (20%) and high labor costs were the most complained reasons(Jaacks et al., 2021).Moreover, a study in this review conducted by Sukhwani et al (2020) showed the disruption of the food supply chain because of the interruption of the routes for transportation and closing of the markets for sanitation. These findings are compatible with a previous study conducted by Pu & Zhong (2020) in China that aimed to explore the production of agricultural products impacted by the Covid-19 pandemic showing that unreasonable interventions caused the disruption of food production process and reduction in food production. If these problems are not resolved properly, the population in countries that depend on farming will face the food insecurity. Therefore, the policy makers in each nation should consider the preventive interventions which cannot interfere the migration of workers, transportation of agricultural products and inputs including seeds and fertilizers. And then, the authorized persons should try to develop digital marketing for agricultural products to promote the trading of the agricultural products.

This review found that lockdown strategies undertaken during pandemic disrupted the global food system and changed availability and accessibility of healthy foods. Malnutrition and noncommunicable diseases can be prevented by consuming healthy diets containing balanced and diverse foods(FGO, 2020). In a study included in this review, half of the population who are living in urban area declared that availability of nutrient dense foods declined because of a reduction in the number of markets and frequent moving of markets(Sukhwani et al., 2020). Another reason for difficulties in availability of food explored by this review is inclining of the food prices especially nutrient dense foods. Furthermore, more than 50% of respondents in multi-country survey faced a reduction in variety of food consumed and nearly 50% were dependent on the less preferred foods(Jafri et al., 2021). Low-income level and unemployment are the challenges encountered during COVID-19 pandemic to access the enough foods(Rezaul Karim & Tasnim, 2022). These results are congruent with previous reviews conducted by Louie et al (2022) and Éliás & Jámbor (2021). According to the findings of this review, increasing food prices, low-income level, unemployment and instability of food markets are the issues for the availability and accessibility of nutritious foods. Therefore, Governments and all authorized persons should pay attention to develop strategies to cope with these issues during COVID-19 and unexpected pandemics.

According to the findings explored by this review, there have been positive changes regarding food waste. For example, a study included in this review conducted by Jribi et al (2020) showed

that people with higher education and senior adults had more aware of food waste prevention. In this review, Cosgrove et al (2021) also identified that there has been a 10% drop in food waste when compared to the time before COVID-19. These findings are being supported by the systematic review conducted by Iranmanesh et al (2022) showing that there was a reduction of food waste during COVID-19 pandemic and older adults and people with higher education were less likely to waste food. Moreover, the review explored that overcooking, storage in a freezer for longer than required and stockpiling of foods were the leading causes of food waste. And then, the most wasted foods were vegetables, fruits and frozen foods(Cosgrove et al., 2021; Jribi, Ben Ismail, et al., 2020). The review of Everitt et al (2023) also showed that fruits and vegetables were the most wasted food. Controlling food waste is important for the maintenance of food security because food waste is one of the things that threatens the food security(Shabanali Fami et al., 2021). In 2012, there were 1216.5 calories, 32.8 grams of protein, 36.7 grams of good fats, 5.9 grams of dietary fiber, 880 milligrams of potassium, 1.7 milligrams of vitamins, and 286 milligrams of calcium in the daily wasted food of each person at the level of consumers and stores in the US(Spiker et al., 2017). Therefore, the useful food waste behavior observed during COVID-19 should be maintained. The social media should be used to provide information about purchasing strategies to prevent stockpiling, proper storage of perishable foods, proper processing, and consumption of all food prepared.

This review also explored the issues concerning food hygiene that occurred during the COVID-19 pandemic. In this review, a study in Philippines showed that nearly 50% of the food handlers practiced their personal hygiene (Limon, 2021). This finding is similar to the result of the other systematic review in Ethiopia which revealed that only half of the food handlers followed good hygiene practices(Zenbaba et al., 2022). Moreover, the significant difference was occurred between self-reported practice and observed food hygiene, and only 8.3% of food handlers met the standard criteria for food hygiene by observing(Limon, 2021). This finding was also supported by the preview review conducted by (Insfran-Rivarola et al., 2020) showing there were disparities between self-reported and actual practices. This review also found that food handlers who were supported with a supervisor, PPEs, piped water in the kitchen, and separate changing rooms for dressing had a higher chance of following food hygiene than those without facilities(Alamneh et al., 2022). This result is consistent with the results of the studies conducted by Derso et al., (2017), Legesse et al., (2017) and Tessema et al., (2014). Although poor food hygiene practices cannot directly impact the nutritional status of consumers, environmental enteropathy due to the ingestion of fecal bacteria can cause malnutrition in children living in poor hygiene environments(Humphrey, 2009). According to the findings of this review, the percentage of food handlers who followed good standards for food hygiene was relatively low. Therefore, the training program for food safety practice should be developed for both the owners of food businesses and food handlers because training for food safety is the most suitable technique for improving good standards for food hygiene(Medeiros et al., 2011). And then, the authorized persons should regularly check the kitchens and food establishments for the presence of facilities necessary for food hygiene practices.

Consumer' behaviors, food consumption, and diet patterns are vital for the development of a robust food system. Because, the dietary choices of consumers have many consequences for food production, food marketing, food trading, and professionals in the food industry(Nestle, 2000). During the COVID-19 pandemic, both positive and negative changes in food consumption and diet patterns were found among consumers, according to the findings of this review. For example, increasing vegetable (42.4%) and fruit (33.1%) consumption(Ruiz-Roso et al., 2020), choosing fruits as snacks (64.7%) (Błaszczyk-Bębenek et al., 2020), eating more fruits (45.3%), and more leafy greens (36.6%) (Tan et al., 2022) were found to be positive findings in the reviews. Similarly, the reviews of Mignogna et al (2022), Brakspear et al (2022) and Johnson et al (2023)also showed that there were increases in consumption of fruits and vegetables in the

COVID-19 period. Moreover, one study in this review explored healthy eating practices such as increasing overall nutrient intake (79%), eating more nutritious foods (85%), eating more home-cooked meals (89%), keeping track of daily food consumption (74%), frequently making meals at home (84%)(Madan et al., 2021). In the previous scoping review by Bennett et al (2021) also found that there was an upward trend in cooking at home during the COVID-19 pandemic.

On the other hand, negative changes such as increases in consumption of fried foods were also occurred in the studies of Ruiz-Roso et al (2020), Błaszczyk-Bębenek et al (2020) and Kriaucioniene et al (2020). And then there was an increased consumption of alcohol and salty foods during the COVID-19 pandemic compared to pre-pandemic(Błaszczyk-Bębenek et al., 2020). Furthermore, eating sugary and sweet foods were more common During the COVID-19 period(Tan et al., 2022). These findings are being supported by the results in the reviews of Bennett et al (2021), González-Monroy et al (2021)and Alamri (2021).

In the present review, deterioration in the food system during the pandemic have many negative impacts on the nutritional status of the population. Firstly, A study in Bangladesh showed that the prevalence of stunting was the highest among the children between the ages of one to two years (69.6%) followed by the age groups between 6 to 11 months. It was obvious that the rate of stunting was directly related to the low level of mothers' education, unemployment, households with low income, families with severe food insecurity and low "Household dietary diversity score (HDDS)". The prevalence of wasting and underweight was also associated with low "Household dietary diversity score (HDDS)" and low-income level(Rezaul Karim & Tasnim, 2022). A study in Indonesia also showed that low-income level was strongly associated childhood stunting(Yanti & Fauziah, 2021).The results are similar to Chandrasekhar et al (2017) who found that stunting, underweight and wasting were common in children from extremely food insecure families because they were unable to achieve a minimal diet diversification. On the other hand, the studies in the USA and Korea found that there were increases in the BMI of children during the pandemic when compared to the pre-pandemic period(Kang et al., 2021; Knapp et al., 2022). In this review, it is interesting to note that children in low- and middle-income countries stunted, while those in developed countries had more opportunities to gain weight.

In addition, the majority of the studies included in this review reported that most of the adult people who gained weight were greater than those who lost weight and remained unchanged in weight during the COVID-19 period. In this review, increases in BMI were occurred in the studies of Błaszczyk-Bębenek et al (2020), Tan et al (2022) A diet pattern such as "Emotionally-driven pattern (ED-P)" was highly associated with weight gain because the people who followed this diet pattern were more likely to eat unhealthy foods and the foods they preferred (Bühlmeier et al., 2022). According to the studies in Poland and Lithuania in this review, the participants who were already overweight and obese prior to the pandemic experienced weight gain, and the participants who ate fewer fruits and vegetables gained weight during the pandemic (Drywień et al., 2020; Kriaucioniene et al., 2020). Regarding this review, drinking less water and high intake of unhealthy foods such as sweets, processed meat, salty and sugary foods were the factors that caused the weight gain during the COVID-19 period (Kriaucioniene et al., 2020; Tan et al., 2022). These findings are in line with the previous scoping review of Chew & Lopez (2021) showing that factors such as emotional eating, unhealthy food choice, inadequate water intake and higher BMI were associated with weight gain during the COVID-19 pandemic. Gaining more weight than necessary is associated with cardiovascular diseases, endocrine disorders, osteoarthritis and some kinds of malignancies(Aballay et al., 2013). Therefore, health information about disadvantages of inappropriate weight gain and nutritional counselling about balanced diet should be given to the public.

5. CONCLUSION

The COVID-19 pandemic disrupted the food system by reducing food production and disrupting the food supply chain. And then, lockdown strategies undertaken during the pandemic disrupted the global food system and changed the availability and accessibility of healthy foods. During the pandemic, there have been positive changes regarding food waste and the percentage of food handlers who followed good standards for food hygiene was relatively low. This review identified that both positive and negative changes in food consumption and diet patterns were found among consumers during the COVID-19 pandemic. This review emphasized how the nutritional status of consumers was directly impacted by changes in the availability and accessibility of nutritious food as well as detrimental changes in food consumption and dietary habits throughout the epidemic. The findings of this study will assist decision-makers, representatives of each nation's government, and experts in the food sector in addressing issues that have arisen in the food system as a result of the COVID-19 epidemic and an upcoming unplanned disaster.

6. LIMITATION

There are some limitations in this review. For example, this review identified a decrease in agricultural food production during the COVID-19 pandemic, however, meat and dairy production could not be identified. In this review, data were collected by phone-based surveys, online surveys and self-administered questionnaires in most of the studies. The population who did not have access to the Internet were unable to participate in the online surveys. Inaccuracy, incomplete responses, and recall bias are all issues that can arise from conducting surveys online due to the nature of the self-reported data. And then, Separating the impact of the pandemic from the influence of annual and seasonal changes in dietary diversity may be challenging in the absence of substantial longitudinal data collected before to the outbreak. Changes of nutritional indicators such as BMI, weight gain, weight loss, stunting and wasting during COVID-19 were observed in this review but other laboratory data regarding nutritional indicators could not be identified. Therefore, more primary research on changes in nutritional indicators during the COVID-19 pandemic will be needed in the future. Moreover, more information is required from other nations and vulnerable groups such as pregnant women, elderly persons and people who are suffering from chronic illness or non-communicable diseases.

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