American Journal of Public Health Research, 2025, Vol. 13, No. 4, 152-164
Available online at http://pubs.sciepub.com/ajphr/13/4/2
Published by Science and Education Publishing
DOI:10.12691/ajphr-13-4-2

Impact of Socioeconomic Factors on Post-COVID-19 Dietary Changes: Analysis Across Income and Education Levels

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Received June 14, 2025; Revised July 16, 2025; Accepted July 23, 2025

Abstract The coronavirus disease 2019 (COVID-19) pandemic has led to significant shifts in dietary behaviors worldwide, influenced by socioeconomic factors such as income and education. This study examines the impact of these factors on dietary changes in urban middle-aged and older adults in the United States during the pandemic. A cross-sectional survey was conducted with 10,050 participants aged 40–100 years who were stratified by income and education levels. Dietary habits were assessed using the 25-item Dietary Screening Tool (DST), with scores being calculated pre- and post-pandemic. Nutritional risk was evaluated based on the DST scores, and binary logistic regression models were used to assess associations between socioeconomic factors and changes in food consumption. During the pandemic, lower-income individuals were more likely to reduce their consumption of nutrient-dense foods, including fruits, vegetables, and lean proteins, while processed meat intake showed mixed trends across income levels. Interestingly, individuals with higher education levels demonstrated increased nutritional vulnerability, potentially due to stress-related changes and disrupted access to preferred foods. Educational level was a stronger predictor of nutritional risk than income level, with higher education being unexpectedly associated with greater vulnerability to dietary disruption. These findings highlight the need for public health interventions that address nutritional challenges across all socioeconomic levels during crises, rather than focusing solely on income or educational disparities. By improving food access, promoting affordable healthy options, and addressing stress-related eating, future policies can better support equitable dietary resilience. This study's insights can inform strategies for mitigating nutritional risk and promoting dietary stability in future public health emergencies.

Keywords: *COVID-19 pandemic, dietary change, socioeconomic disparities, nutritional vulnerability, public health nutrition, income and education level*

Cite This Article: Lillie Monroe-Lord, Azam Ardakani, Xuejing Duan, Elmira Asongwed, Tia Jeffery, and Phronie Jackson, "Impact of Socioeconomic Factors on Post-COVID-19 Dietary Changes: Analysis Across Income and Education Levels." *American Journal of Public Health Research*, vol. 13, no. 4 (2025): 152-164. doi: 10.12691/ajphr-13-4-2.

1. Introduction

The emergence of the coronavirus disease 2019 (COVID-19) and the subsequent implementation of lockdowns and other pandemic-related restrictions forced many individuals to alter their food consumption patterns [1,2,3]. Numerous studies documented notable shifts in dietary behaviors, with some individuals increasing their reliance on home-cooked meals due to restaurant closures, while others turned to processed foods as a response to stress or to ensure access to longer-lasting pantry items [4-16].The findings from these studies present a complex picture; some groups reported healthier eating patterns during lockdown, while others indicated a decline in dietary quality [15] [17-23]. This divergence highlights the intricate and varied effects of the pandemic on global food consumption habits.

Socioeconomic inequalities in health are well documented [22,24]. The COVID-19 pandemic has exacerbated these inequalities, disproportionately affecting individuals from lower socioeconomic backgrounds. In particular, these individuals are more likely to experience food insecurity and have limited access to healthy food options [25,26]. While previous research has primarily examined dietary behaviors among younger adults or specific populations, less attention has been given to the unique vulnerabilities of middle-aged and older adults, who may face distinct health risks and dietary challenges. Middle-aged and older adults are at greater risk of developing chronic conditions and may experience higher rates of food insecurity due to fixed incomes or limited mobility, making them particularly susceptible to dietary shifts during crises [27].

Individuals with higher education levels generally have better access to information about healthy eating and resources to maintain a balanced diet. Conversely, those with lower education and income levels face significant obstacles, such as food insecurity and limited access to nutritious foods [26,27]. Higher education levels are associated with better dietary habits and greater resilience in the face of disruptions. For instance, people with higher education are more likely to have the knowledge and resources to adapt their diets in response to changing circumstances, such as varying food availability or the need to prepare meals at home [28,29]. In contrast, those with lower education levels often lacked the necessary skills and information to make healthy dietary choices during the pandemic, which further exacerbated health disparities [30].

In the United States, pandemic-induced income loss has led to increased food insecurity, with a notable rise in both moderate and high food insecurity [31]. Paradoxically, some households reported improved dietary healthfulness, which was attributed to more home-cooked meals and increased health awareness, suggesting a complex relationship between income loss and dietary behaviors. Similarly, in Ecuador, low-income groups reported an increase in unhealthy eating habits, whereas higher-income groups reported improved eating practices thanks to their continued access to supermarkets and grocery stores [32]

In this context, where the COVID-19 pandemic has brought into sharp focus the significant disparities in dietary behaviors influenced by socioeconomic factors, we use the social determinants of health (SDH) framework to better understand how these disparities are shaped by income and education levels. The SDH framework posits that economic stability, education, and the social environment are critical factors influencing health outcomes [33]. Higher income levels afford individuals better access to nutritious food options, while populations with lower incomes often face food insecurity and are compelled to rely on cheaper, less healthy options [25,27]. Similarly, higher education levels equip individuals with the knowledge and skills necessary to make healthier dietary choices and adapt their eating habits in response to challenges such as those posed by the pandemic [28,29]. Conversely, those with lower education levels may lack the necessary nutritional literacy, exacerbating their vulnerability to poor dietary outcomes during crises [30]. The SDH framework highlights the intersection of socioeconomic status and dietary behaviors, emphasizing the need for targeted public health interventions that address these social determinants to mitigate nutritional inequalities heightened by the pandemic [23,26].

Previous studies on dietary habits during the COVID-19 pandemic have predominantly focused on one or two food groups, usually fruits and vegetables or healthy and unhealthy snacks. This limited scope leaves a gap in understanding the comprehensive and multidimensional changes in dietary habits that have taken place. In this study, we address this gap by considering seven different food groups: fruits; vegetables; grains; lean proteins; dairy; fats, sugars, and sweets (FSSs); and processed meats. By doing so, we provide a more holistic examination of dietary habit changes since the onset of the COVID-19 pandemic. Moreover, previous research has not sufficiently explored the relationship between dietary changes during the pandemic and different levels of household income and education. This study specifically examines how socio-demographic factors influence dietary patterns among American middle-aged and older adults, thereby determining nutritional vulnerability. By analyzing the eating patterns of individuals across various income and education levels in the US, this research highlights the significant influence of these factors on post-pandemic dietary habits. Understanding these dynamics is crucial for developing targeted public health interventions, especially for vulnerable populations navigating the unique nutritional challenges posed by the pandemic. The insights gained from this study are essential for informing future nutritional guidelines and policies, ensuring that they are tailored to the needs of diverse groups during global health crises and contributing to more equitable health outcomes.

2. Methods

2.1. Design, Participants, and Procedure

Focusing on the impacts of COVID-19 on dietary changes, this cross-sectional study targeted vulnerable urban populations with varying household incomes and education levels. The research protocol was approved by the Institutional Review Board at the University of the District of Columbia (Approval Number: 1380607-5, dated 23 July 2020). The study included 10,050 participants aged 40 to 100 years who were recruited between 9 August and 15 September 2020. To ensure diverse representation from urban areas across all four census regions of the United States, we conducted recruitment through Qualtrics (2020) using an online survey panel. Urban populations were specifically chosen due to their higher risk of severe COVID-19 symptoms and complications [34]. According to the United States Census Bureau [35], urban cities are defined as areas with populations exceeding 50,000 residents.

2.2. Demographic Characteristics

We collected demographic information from participants, including gender (male, female), race (White, Asian, Black, Hispanic), and ethnicity (Hispanic, non-Hispanic). We grouped participants based on annual household income into three categories: less than USD 50,000 (less than USD 50k), between USD 50,000 and USD 100,000 (USD 50–100k), and greater than USD 100,000 (>USD 100k). Additionally, we divided education levels into three categories: less than high school and High school diploma (≤HS), some college without a degree (Some college), and at least a college degree (≥College).

2.3. Dietary Assessment

To assess participants' nutritional status, we used the 25-item Dietary Screening Tool (DST). This tool is specifically developed and validated for use in older and middle-aged populations. The DST includes a variety of response options covering different food groups and dietary behaviors, with each question scoring between 0 and 8 points. The total DST score ranges from 0 to 100, with higher scores indicating a healthier diet. For example, a question in the DST might ask, "How often do you eat carrots, sweet potatoes, broccoli, or spinach?," with response options ranging from "Never" (0 points) to "Three or more times a week" (8 points).

The DST was administered twice retrospectively—covering periods before and since the onset of the COVID-19 pandemic—which allowed for the measurement of nutritional changes over time. The DST questions were consolidated into seven food groups, including all MyPlate food items (fruits, grains, vegetables, lean proteins, and dairy) along with FSSs and processed meats. MyPlate is a visual guide created by the United States Department of Agriculture [36] to help Americans understand the recommended proportions of different food groups in their meals, emphasizing the inclusion of all five food groups as part of a healthy eating pattern.

Additionally, we included FSSs and processed meats to capture dietary components that are commonly associated with increased health risks when consumed in excess. While FSSs can be part of a healthy diet in moderation, they are often overconsumed, leading to unhealthy dietary patterns. This categorization simplifies and quantifies the consumption of these items, providing insights into dietary habits that may contribute to nutritional vulnerabilities or chronic health conditions [37]. The separate inclusion of processed meats addresses evidence linking their consumption to adverse health outcomes such as heart disease and certain cancers, offering a more comprehensive assessment of dietary risks [38].

In the first analytical stage, we calculated the mean and standard deviation of each food group's consumption, along with the mean percentage change, for the periods before and since the COVID-19 pandemic. In the second stage, we grouped participants based on changes in their food intake since the pandemic into the following categories: decreased consumption, no change in consumption, and increased consumption [38-40]. Furthermore, each participant was assigned a total DST score. Based on these scores, we classified participants into three groups: at risk (scores lower than 60), possibly at risk (scores between 60 and 75), and not at risk (scores above 75). This classification serves as a valuable indicator of the participants' nutritional status, allowing a validated and detailed analysis of their levels of dietary risk [39,41].

2.4. Statistical Analysis

Data analysis was conducted using the SAS 9.4 software (SAS Institute, Cary, NC, USA). Descriptive statistics were calculated with means and standard deviations (SDs) for continuous variables and with frequencies and percentages for categorical variables. Paired-sample *t*-tests were used to compare food item consumption before and after the COVID-19 pandemic. Associations between categorical variables were analyzed using the chi-square test. Binary logistic regression models were applied, with MyPlate food items serving as the response variables and Fisher's scoring optimization being used for modeling. These models predicted the likelihood of decreased food consumption since the pandemic—taking into account explanatory variables such as gender, race, age, income, and education—and provided odds ratio (OR) estimates. Another set of binary logistic regression models predicted the probability of participants being classified as having higher nutritional risk since the onset of COVID-19. The response variable was categorized into two groups: participants without nutritional risk and nutritionally vulnerable participants. Nutritional vulnerability was assessed based on whether participants shifted from being at possible risk to being at risk since COVID-19. Participants who remained at risk both before and after the pandemic were not classified as nutritionally vulnerable, whereas those who moved from at possible risk to at risk were considered nutritionally vulnerable. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Demographic Characteristics

Table 1. Demographic and Socioeconomic Characteristics of the Study Participants

Characteristic	Category	Frequency (N)	Percentage (%)
Gender	Male	4283	42.62%
	Female	5767	57.38%
Age (years)	40–60	3866	38.52%
	61–80	5908	58.86%
	81–100	263	2.62%
	Missing	13	0.13%
Ethnicity/race	White	7390	74.55%
	African American	1393	14.05%
	Asian	701	7.07%
	Hispanic	429	4.33%
	Missing	137	1.36%
Education	<HS	1634	16.28%
	Some college	3210	31.99%
	≥College	5191	51.73%
	Missing	15	0.15%
Annual income (USD)	Less than USD 25,000	1551	16.09%
	USD 25,000–49,999	2243	23.27%
	USD 50,000–99,999	3281	34.03%
	USD 100,000 or more	2566	26.62%
	Missing	409	4.07%

Table 1 presents a comprehensive breakdown of the demographic and socioeconomic profiles of the participants. In terms of gender distribution, the sample skews towards females, who constitute 57.38% (N = 5767), compared with males at 42.62% (N = 4283). Age-wise, the majority of participants fall within the 61–80 age group, representing 58.86% (N = 5908), followed by the 40–60 age group at 38.52% (N = 3866) and the 81–100 age group at 2.62% (N = 263). A significant majority, 74.55% (N = 7390), identify as White, followed by African American at 14.05% (N = 1393), Asian at 7.07% (N = 701), and Hispanic at 4.33% (N = 429). Educational attainment varies, with 51.73% (N = 5191) having a college degree or higher, 31.99% (N = 3210) having some college education, and 16.28% (N = 1634) having a high school education or less. In terms of annual income, the largest group falls within the USD 50,000–99,999 range (34.03%, N = 3281), followed by those earning USD 25,000–49,999 (23.27%, N = 2243), those earning over USD 100,000 (26.62%, N = 2566), and those earning less than USD 25,000 (16.09%, N = 1551).

3.2. Change in Dietary Consumption by Income and Education Level

Table 2 presents an overview of different food consumption patterns, which were stratified by education and income level since the pandemic. The results showed a significant downward shift in the DST score of fruit and grain consumption for all three levels of income, with the largest decrease being seen for the lowest income level (<USD 50k) at 5.1% for fruits and 8.04% for grains, followed by the middle-income level (USD 50–100k) at 4% for fruits and 7.63% for grains, and the smallest decrease was found for the highest income level (>USD 100k) at 3.3% for fruits and 6.45% for grains; all had *p*-values <0.001. Lean protein consumption showed a significant decline only for the lowest income levels, by 2.6% (p <0.001), while the changes in the middle- and higher-income groups were not statistically significant. Vegetable consumption changes were not statistically significant for any income level. Dairy consumption decreased slightly but was only statistically significant for the lowest income level by 2%. The mean score of FSSs increased across all income levels (p <0.001), which means that FSS consumption was reduced since the pandemic, with the largest reduction being for the <USD 50k level by 4.4%, followed by the USD 50–100k level (3.8%) and then the >USD 100k level (3.2%). Processed meat consumption did not change significantly in most groups, with a slight and statistically significant decrease only for the highest income bracket by 1.2% ($p = 0.018$).

Regarding education levels, fruit consumption declined by 4.35% for individuals with less than a high school education, 4.88% for those with some college education, and 3.81% for those with a college degree or higher (p <0.001 for all). Grain consumption decreased by 7.95% for individuals with less than a high school education, 8.31% for those with some college education, and 6.79% for those with a college degree or higher (p <0.001 for all). Changes in vegetable consumption were not statistically significant for any education level. Lean protein consumption decreased by 1.81% for those with less than a high school education ($p = 0.044$), 1.58% for some college education ($p = 0.009$), and 1.19% for college-educated or higher ($p = 0.023$). For those with less than a high school education, dairy intake dropped by 1.08%, although this change was not statistically significant. Dairy consumption for those with some college education decreased by 2.1%; for college graduates or above, it declined by 1.04% (p <0.001 and $p = 0.012$, respectively). The mean score of FSS consumption increased for all education levels, with 4.01% for less than high school, 4.22% for some college education, and 3.19% for college degree or higher (p <0.001 for all). Processed meat consumption changes were not statistically significant for any education level.

Table 3 details the analysis of dietary changes across different income and education levels. The results show significant disparities in the consumption patterns of various food items except grains. Notably, fruits (p <0.001), vegetables (p <0.001), lean proteins ($p = 0.010$), dairy (p <0.001), FSSs ($p = 0.029$), and processed meats ($p = 0.001$) all displayed significant differences in consumption based on income.

Specifically, individuals with an annual income of less than USD 50k reported the highest decrease in the consumption of fruits (33.37%), vegetables (19.66%), lean proteins (19.24%), dairy products (16.53%), and processed meat (16.42%). Interestingly, the consumption of FSSs decreased the most for the same income group (41.20%).

Differences in food consumption changes were observed in four different food groups out of seven when stratified by educational level. Significant differences were detected in fruit ($p = 0.020$), grain ($p = 0.001$), vegetable ($p = 0.027$), and dairy ($p = 0.001$) consumption. Those with less than a high school education had a higher percentage of decreased consumption of fruits (33.23%), grains (33.72%), vegetables (19.83%), and dairy (18.18%) compared with individuals with some college education or higher. All of these food groups decreased the least among those with at least a college education.

3.3. Nutritional Risk Assessment in Different Income and Education Level

Before COVID-19, 5.01% of individuals earning less than USD 50k were categorized as not at risk, which marginally increased to 5.06% since the pandemic. In the USD 50–100k income bracket, 7.62% were not at risk before, with a slight decrease to 7.47% since the pandemic. The individuals in the >USD 100k group showed a slight decrease from 8.61% to 8.57%. The possible risk category showed a decrease in all income brackets since COVID-19. For the <USD 50k group, it decreased from 30.97% to 28.47%. The USD 50–100k group showed a decrease from 38.04% to 36.64%, and the >USD 100k group showed a decrease from 42.28% to 40.80%. Individuals at risk increased since COVID-19 in all income categories. The <USD 50k group showed an increase from 64.02% to 66.47%, the USD 50–100k group showed an increase from 53.98% to 55.90%, and the >USD 100k group showed an increase from 49.10% to 50.62%.

Before COVID-19, 4.47% of individuals with less than a high school education were not at risk, which slightly decreased to 4.41% since the pandemic. Among those with some college education, individuals not at risk were at 5.61% before and saw a minor increase to 5.70% since. In the college-educated or above group, there was a decrease from 8.38% to 8.23%. The possible risk category showed a decline in all education levels since the pandemic. The group with less than a high school education saw a decrease from 26.19% to 23.93%, the group with some college education decreased from 34.36% to 32.31%, and the group who was college-educated or above decreased from 41.32% to 39.49%. Conversely, the at-risk category reflected an increase across educational levels. For the group with less than a high school education, the increase was from 69.34% to 71.66%; for the group with some college education, the increase was from 60.03% to 61.99%, and for the group who was college-educated or above, the increase was from 50.30% to 52.28%.

In this series of analyses, the p-values were less than 0.001 for all statuses of nutritional risk both before and since the pandemic with stratified education and income levels. The analysis reveals a statistically significant relationship between education level and risk status, with the risk decreasing as the education level increases. Table 4 presents the detailed results of this analysis.

Table 2. Changes in Mean Scores for the Consumption of Different Food Items since the COVID-19 Pandemic across Different Income and Education Levels

Food Item	Income/Education Status	Before	Since	MPC3	p-Value
		Mean (SD)	Mean (SD)	(%)	
Fruits	<USD 50k	7.82 (3.8)	7.42 (3.91)	−5.17	<0.001
	USD 50–100k	8.75 (3.62)	8.39 (3.78)	−4.05	<0.001
	>USD 100k	9.15 (3.53)	8.85 (3.68)	−3.31	<0.001
	<HS1	7.66 (3.86)	7.33 (3.92)	−4.35	<0.001
	Some college	8.18 (3.7)	7.78 (3.89)	−4.88	<0.001
	≥College2	8.95 (3.58)	8.61 (3.72)	−3.81	<0.001
Grains	<USD 50k	6.97 (4.46)	6.41 (4.51)	−8.04	<0.001
	USD 50–100k	7.66 (4.51)	7.07 (4.53)	−7.63	<0.001
	>USD 100k	8.13 (4.51)	7.61 (4.61)	−6.45	<0.001
	<HS1	6.66 (3.86)	6.13 (4.38)	−7.95	<0.001
	Some college	7.11 (4.49)	6.52 (4.49)	−8.31	<0.001
	≥College2	8.02 (4.52)	7.47 (4.62)	−6.79	<0.001
Vegetables	<USD 50k	7.63 (4.25)	7.62 (4.36)	−0.17	0.75
	USD 50–100k	8.56 (4.02)	8.57 (4.09)	0.20	0.68
	>USD 100k	8.9 (3.9)	9.01 (4.01)	1.22	0.036
	<HS1	7.39 (4.17)	7.35 (4.27)	−0.51	0.92
	Some college	8.09 (4.18)	8.12 (4.27)	0.26	0.24
	≥College2	8.71 (4.02)	8.75 (4.11)	0.48	0.10
Lean proteins	<USD 50k	4.82 (2.52)	4.69 (2.54)	−2.65	<0.001
	USD 50–100k	5.28 (2.32)	5.26 (2.41)	−0.42	0.392
	>USD 100k	5.70 (2.4)	5.66 (2.51)	−0.72	0.18
	<HS1	4.56 (2.49)	4.48 (2.51)	−1.81	0.044
	Some college	5.09 (2.14)	5.01 (2.46)	−1.58	0.009
	≥College2	5.49 (2.42)	5.43 (2.51)	−1.19	0.023
Dairy	<USD 50k	4.37 (2.6)	4.28 (2.62)	−2.07	<0.001
	USD 50–100k	5.28 (2.32)	5.26 (2.41)	−0.42	0.03
	>USD 100k	4.67 (2.6)	4.64 (2.61)	−0.77	0.20
	<HS1	4.38 (2.62)	4.33 (2.63)	−1.08	0.213
	Some college	4.45 (2.55)	4.35 (2.56)	−2.10	<0.001
	≥College2	4.57 (2.58)	4.53 (2.61)	−1.04	0.012
Fat, sugar, sweets	<USD 50k	13.82 (4.35)	14.43 (4.7)	4.414	<0.001
	USD 50–100k	13.57 (4.33)	14.09 (4.54)	3.806	<0.001
	>USD 100k	13.47 (4.53)	13.81 (4.79)	2.523	<0.001
	<HS1	13.53 (4.66)	14.08 (4.76)	4.01	<0.001
	Some college	13.7 (4.21)	14.27 (4.46)	4.22	<0.001
	≥College2	13.69 (4.55)	14.13 (4.77)	3.19	<0.001
Processed meats	<USD 50k	7.04 (2.73)	7.07 (2.69)	0.39	0.37
	USD 50–100k	7.3 (2.62)	7.28 (2.57)	−0.29	0.42
	>USD 100k	7.19 (2.74)	7.11 (2.72)	−1.17	0.018
	<HS 1	6.9 (2.77)	6.94 (2.69)	0.60	0.48
	Some college	7.07 (2.7)	7.06 (2.66)	−0.14	0.56
	≥College2	8.14 (2.3)	8.17 (2.28)	0.352	0.10

[1]Less than high school
[2]At least a college degree
[3]Mean percentage change

Table 3. Variations in Food Item Consumption Changes Based on Income and Educational Levels since the COVID-19 Pandemic

Food Item		Decreased Consumption	No Change	Increased Consumption	*p*-Value
		N (%)	N (%)	N (%)	
Fruits	<USD 50k	1266 (33.37)	1796 (47.34)	732 (19.29)	
	USD 50–100k	1004 (30.60)	1747 (53.25)	530 (16.15)	
	>USD 100k	761 (29.66)	1326 (51.68)	479 (18.67)	
					<0.001
	≤HS [1]	543 (33.23)	776 (47.49)	315 (19.28)	
	Some college	1024 (31.90)	1604 (49.97)	582 (18.13)	
	≥College[2]	1572 (30.28)	2704 (52.09)	915 (17.63)	
					0.020
Grains	<USD 50k	1248 (32.89)	1921 (50.63)	625 (16.47)	
	USD 50–100k	1067 (32.52)	1723 (52.51)	491 (14.96)	
	>USD 100k	799 (31.14)	1375 (53.59)	392 (15.28)	
					0.13
	≤HS [1]	551 (33.72)	791 (48.41)	292 (17.87)	
	Some college	1048 (32.65)	1655 (51.56)	507 (15.79)	
	≥College[2]	1625 (31.30)	2800 (53.94)	766 (14.76)	
					0.001
Vegetables	<USD 50k	747 (19.66)	2259 (59.54)	789 (20.80)	
	USD 50–100k	547 (16.67)	2145 (65.38)	589 (17.95)	
	>USD 100k	438 (17.07)	1600 (62.35)	528 (20.58)	
					<0.001
	≤HS [1]	324 (19.83)	961 (58.81)	349 (21.36)	
	Some college	570 (17.76)	2020 (62.93)	620 (19.31)	
	≥College[2]	906 (17.45)	3281 (63.21)	1004 (19.34)	
					0.027
Lean proteins	<USD 50k	730 (19.24)	2499 (65.87)	565 (14.89)	
	USD 50–100k	533 (16.25)	2260 (68.88)	488 (14.87)	
	>USD 100k	434 (16.91)	1728 (67.34)	404 (15.74)	
					0.010
	≤HS [1]	314 (19.22)	1058 (64.75)	262 (16.03)	
	Some college	585 (18.22)	2148 (66.92)	477 (14.86)	
	≥College[2]	872 (16.80)	3555 (68.48)	764 (14.52)	
					0.056
Dairy	<USD 50k	1594 (16.53)	6577 (68.22)	608 (16.03)	
	USD 50–100k	479 (14.60)	2339 (71.09)	463 (14.11)	
	>USD 100k	397 (15.47)	1770 (68.98)	399 (15.55)	
					<0.001
	≤HS [1]	297 (18.18)	1057 (64.69)	280 (17.14)	
	Some college	544 (16.95)	2212 (68.91)	454 (14.14)	
	≥College[2]	802 (15.45)	3600 (69.35)	789 (15.20)	
					0.001
Fat, sugar, sweets	<USD 50k	1563 (41.20)	1384 (36.48)	847 (22.32)	
	USD 50–100k	1299 (39.59)	1218 (37.12)	764 (23.29)	
	>USD 100k	953 (37.14)	991 (38.62)	622 (24.24)	
					0.029
	≤HS [1]	656 (40.15)	601 (36.78)	377 (23.07)	
	Some college	1297 (40.40)	1198 (37.32)	715 (22.27)	
	≥College[2]	2010 (38.72)	1946 (37.49)	1235 (23.79)	
					0.436
Processed meats	<USD 50k	623 (16.42)	2555 (67.34)	616 (16.24)	
	USD 50–100k	460 (14.02)	2323 (70.80)	498 (15.18)	
	>USD 100k	343 (13.37)	1784 (69.52)	439 (17.11)	
					0.001
	≤HS [1]	259 (15.85)	1116 (68.30)	259 (15.85)	
	Some college	481 (14.98)	2205 (68.69)	524 (16.32)	
	≥College[2]	728 (14.02)	3639 (70.10)	824 (15.87)	
					0.353

[1]Less than high school
[2]At least a college degree

Table 4. Comparisons of Nutritional Risk Status based on Income and Educational Levels Before and since the COVID-19 Pandemic

		<USD 50k	**USD 50–100k**	**>USD 100k**	**≤HS[1]**	**Some College**	**≥College[2]**
		N (%)	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Not at risk	Before	190 (5.01)	250 (7.62)	221 (8.61)	73 (4.47)	180 (5.61)	435 (8.38)
	Since	192 (5.06)	245 (7.47)	220 (8.57)	72 (4.41)	183 (5.70)	427 (8.23)
Possible risk	Before	1175 (30.97)	1260 (38.04)	1085 (42.28)	428 (26.19)	1103 (34.36)	2145 (41.32)
	Since	1080 (28.47)	1202 (36.64)	1047 (40.80)	391 (23.93)	1037 (32.31)	2050 (39.49)
At risk	Before	2429 (64.02)	1771 (53.98)	1260 (49.10)	1133 (69.34)	1927 (60.03)	2611 (50.30)
	Since	2522 (66.47)	1834 (55.90)	1299 (50.62)	1171 (71.66)	1990 (61.99)	2714 (52.28)

[1]Less than high school
[2]At least a college degree

Table 5. Binary Logistic Regression Analysis of Odds Ratios (OR) for Changes in Food Group Consumption by Income and Education Levels since the COVID-19 Pandemic

	OR	95% CI[3]	*p*-Value
Fruits			
			0.1081
<USD 50k vs. >USD 100k	1.133	1.001–1.282	0.0475
USD 50–100k vs. >USD 100k	1.036	0.921–1.165	0.5577
<USD 50k vs. USD 50–100k	1.094	0.984–1.216	0.0965
			0.8673
≤HS[1] vs. ≥College[3]	1.031	0.902–1.178	0.6581
Some college vs. ≥College[3]	0.995	0.895–1.106	0.9275
≤HS[1] vs. Some college	1.036	0.907–1.182	0.6028
Grains			
			0.8887
<USD 50k vs. >USD 100k	1.023	0.904–1.156	0.7218
USD 50–100k vs. >USD 100k	1.029	0.916–1.155	0.6316
<USD 50k vs. USD 50–100k	0.994	0.895–1.104	0.9100
			0.3434
≤HS[1] vs. ≥College[3]	1.097	0.960–1.253	0.1728
Some college vs. ≥College[3]	1.057	0.952–1.173	0.2985
≤HS[1] vs. Some college	1.038	0.910–1.183	0.5797
Vegetables			
			0.0092
<USD 50k vs. >USD 100k	1.213	1.044–1.410	0.0118
USD 50–100k vs. >USD 100k	1.013	0.877–1.171	0.8577
<USD 50k vs. USD 50–100k	1.197	1.052–1.362	0.0064
			0.3896
≤HS[1] vs. ≥College[3]	1.057	0.900–1.240	0.4994
Some college vs. ≥College[3]	0.948	0.833–1.080	0.4230
≤HS[1] vs. Some college	1.114	0.951–1.306	0.1800
Lean proteins			
			0.0631
<USD 50k vs. >USD 100k	1.124	0.966–1.307	0.1294
USD 50–100k vs. >USD 100k	0.964	0.834–1.116	0.6264
<USD 50k vs. USD 50–100k	1.165	1.023–1.328	0.0215
			0.7550
≤HS[1] vs. ≥College[3]	1.064	0.904–1.251	0.4578
Some college vs. ≥College[3]	1.027	0.902–1.170	0.6831
≤HS[1] vs. Some college	1.035	0.883–1.214	0.6710
Dairy			
			0.0005
<USD 50k vs. >USD 100k	1.234	1.057–1.4442	0.0079
USD 50–100k vs. >USD 100k	0.952	0.818–1.107	0.5203
<USD 50k vs. USD 50–100k	1.297	1.134–1.484	0.0002
			0.6926
≤HS[1] vs. ≥College[3]	1.075	0.910–1.270	0.3958
Some college vs. ≥College[3]	1.033	0.903–1.180	0.6387
≤HS[1] vs. Some college	1.041	0.885–1.225	0.6292
Fat, sugar, sweets			

			0.0205
<USD 50k vs. >USD 100k	1.182	1.051–1.329	0.0054
USD 50–00k vs. >USD 100k	1.110	0.994–1.241	0.0648
<USD 50k vs. USD 50–100k	1.064	0.962–1.177	0.2271
			0.9172
≤HS [1] vs. ≥College[3]	1.003	0.882–1.139	0.9690
Some college vs. ≥College[3]	1.020	0.923–1.128	0.6934
≤HS [1] vs. Some college	0.983	0.866–1.115	0.7853
Processed meats			
			0.0024
<USD 50k vs. >USD 100k	1.321	1.121–1.556	0.0009
USD 50–100k vs. >USD 100k	1.110	0.947–1.300	0.1972
<USD 50k vs. USD 50–100k	1.190	1.035–1.368	0.0145
			0.8602
≤HS [1] vs. ≥College[3]	0.973	0.817–1.160	0.9218
Some college vs. ≥College[3]	0.962	0.837–1.106	0.7068
≤HS [1] vs. Some college	0.984	0.885–1.139	0.8903

[1]Less than high school
[2]At least a college degree
[3]Confident interval

3.4. Income and Education Disparities in Food Consumption: Binary Logistic Regression Analysis

The results of the binary logistic regression model are reported in Table 5. The findings indicate that lower income is associated with a greater likelihood of consuming less of certain food groups, including vegetables (*p* = 0.0092), dairy (*p* = 0.0005), FSSs (*p* = 0.0205), and processed meats (*p* = 0.0024), while education levels did not exhibit a significant correlation with any food group consumption changes ($p > 0.05$).

Regarding income levels, individuals earning less than USD 50k showed a statistically significant tendency towards reduced consumption in several food categories when compared with those earning above USD 100k. Specifically, the odds of decreased intake were higher for fruits (OR = 1.13, *p* = 0.0475), vegetables (OR = 1.21, *p* = 0.0118), dairy (OR = 1.23, *p* = 0.0079), FSSs (OR = 1.23, *p* = 0.0054), and processed meat (OR = 1.32, *p* = 0.0009). Furthermore, when comparing individuals earning less than USD 50k with those with incomes between USD 50k and USD 100k there was a statistically significant likelihood of lower consumption of vegetables (OR = 1.20, *p* = 0.0064), lean protein (OR = 1.16, *p* = 0.215), dairy (OR = 1.30, *p* = 0.0002), and processed meat (OR = 1.19, *p* = 0.0145).

3.5. Binary Logistic Regression Analysis of Nutritional Vulnerability by Income and Education Levels

Table 6 presents the results of the binary logistic regression for increased nutritional vulnerability stratified by income and education levels since the COVID-19 pandemic. None of the income comparisons yielded statistically significant differences in nutritional vulnerability, indicating that income level was not a significant predictor of nutritional vulnerability in this sample. In contrast, education level has been a significant factor in determining nutritional vulnerability since the COVID-19 pandemic (p = 0.0009). Individuals with less than a high school education have significantly lower odds (24%) of being more nutritionally vulnerable than those with a college degree or higher (OR = 0.759, p = 0.0145). In addition, the odds of being more nutritionally vulnerable are 20% lower for individuals with some college education than for those with a college degree or higher (OR = 0.800, 95%, p = 0.0099). However, no significant difference was observed between those with less than a high school education and those with some college education (OR = 0.948, p = 0.6388). These findings highlight the critical role of educational attainment in reducing the risk of being classified as more nutritionally vulnerable during the pandemic.

Table 6. Comparative OR for Increased Nutritional Vulnerability Across Different Income and Education Levels since the COVID-19 Pandemic

	OR	95% CI[1]	*p*-Value
More Nutritionally Vulnerable			
			0.6697
<USD 50k vs. >USD 100k	0.915	0.753–1.112	0.3726
USD 50–100k vs. >USD 100k	0.958	0.799–1.149	0.6473
<USD 50k vs. USD 50–100k	0.955	0.805–1.133	0.5969
			0.0009
≤HS [1] vs. ≥College[3]	0.759	0.608–0.947	0.0145
Some college vs. ≥College[3]	0.800	0.676–0.948	0.0099
≤HS [1] vs. Some college	0.948	0.758–1.186	0.6388

[1]Less than high school
[2]At least a college degree
[3]Confident interval

4. Discussion

The COVID-19 pandemic has profoundly affected daily life, notably altering dietary habits and nutritional intake. This study investigates dietary changes among adults of various income and education levels during the pandemic by comprehensively examining all MyPlate food categories along with FSSs and processed meats. This study reveals the pandemic's impact on nutritional risk, particularly the rise in individuals becoming at risk. These results highlight the critical need for focused attention on specific food groups during future health crises to safeguard vulnerable populations from potential harm.

Our analysis of dietary choices during the COVID-19 pandemic reveals that lower-income individuals are significantly less likely to consume healthy food groups such as fruits, vegetables, lean proteins, and dairy products than higher-income individuals are. This finding aligns with existing research showing that economic barriers and food insecurity, which are exacerbated by the pandemic, significantly impact dietary habits [28,42,43,44,45]

The findings of this study show that, during the COVID-19 pandemic, income significantly impacted fruit consumption, with lower-income individuals reducing their intake by 13%. This might be explained by financial constraints and limited access. Pechey et al. [46] highlighted that lower socioeconomic status is linked to decreased fruit consumption, a trend that worsened during the pandemic as incomes dropped and food insecurity rose. Similarly, Lin et al. [47] found that lower-income households are more price-sensitive when it comes to fruit, particularly organic options. This aligns with the current study, where individuals earning less than USD 50k showed significantly lower fruit consumption than those earning over USD 100k, reflecting the impact of financial stress on healthy food choices during the pandemic [46,47,48].

This study found no significant differences in grain consumption across income levels. This might be because grains are affordable and widely accessible staples, leading to consistent consumption across different income levels even during economic hardship. Hui [49] remain a critical part of the diet for lower-income households, as their affordability makes them essential even as rising prices affect purchasing power. Similarly, Lu and Yu [50] noted that poor families tend to maintain grain consumption during economic downturns because of the staple's low cost and accessibility.

The impact of income on vegetable consumption during the COVID-19 pandemic was particularly significant for lower-income households. Studies by Aruga et al. [51] found that the pandemic reduced vegetable demand and consumption, with lower-income households being disproportionately affected due to price sensitivity and reduced access to fresh produce. Similarly, Revoredo-Giha et al. [52] noted that, while overall vegetable consumption increased for at-home meals, the expected rise was lower among lower-income groups, who often opted for cheaper processed alternatives. The current study aligns with these findings, showing that individuals earning less than USD 50k had significantly reduced vegetable consumption compared with higher-income groups, while income differences were not significant for middle- and higher-income levels.

The analysis of lean protein consumption during the COVID-19 pandemic suggests that income plays a notable role, particularly for lower-income groups. The current study indicates that individuals earning less than USD 50k were 16% more likely to reduce their lean protein consumption than those earning USD 50–100k. This finding aligns with research showing that protein consumption is sensitive to income fluctuations, especially during periods of economic downturn. According to Yang et al. [53], lower-income households show limited flexibility in adjusting their protein consumption due to financial constraints during economic recessions. Similarly, Andreoli et al. [54] found that increasing income generally leads to higher animal protein consumption, but the relationship is more complex for wealthier groups, where high incomes may lead to a shift in dietary preferences away from animal protein. These findings underscore the importance of income in shaping dietary behaviors, particularly when it comes to higher-cost food items such as lean proteins.

Since the COVID-19 pandemic, dairy consumption was significantly lowered among lower-income households, as individuals earning less than USD 50k were more likely to reduce their intake compared with higher-income groups. This reduction was likely due to financial constraints and limited access to dairy products, which were exacerbated by the economic challenges posed by the pandemic. Research shows that lower-income households face difficulties in affording nutrient-dense foods such as dairy, which often results in decreased consumption during periods of economic hardship [42,43] The study's findings align with research showing that food insecurity, particularly during the pandemic, disproportionately impacted lower-income groups, leading to reduced consumption of essential food groups, including dairy [55].

During the COVID-19 pandemic, lower-income individuals (<USD 5 k) significantly reduced their consumption of foods high in fat, sugar, and sweets compared with higher-income groups. This aligns with the findings by Tan et al. [56] and Sidor and Rzymski [8], who also reported that lower-income households reduced their intake of FSSs due to financial constraints and limited access to these food items during the pandemic. The economic strain forced many lower-income households to prioritize affordable staples over less essential processed foods that are rich in sugar and fats. However, our findings contrast with the results from Park et al. [57], who observed increased consumption of unhealthy snacks and sugar-sweetened beverages among lower-income US adults during the pandemic. This contradiction could be explained by differences in stress-induced eating patterns and the widespread availability of ultra-processed foods in the US, which may have been more affordable and accessible than healthier alternatives. Moreover, cultural and geographical variations, as well as the degree of access to food assistance programs, may have influenced these differing consumption patterns. Thus, our results highlight the need to consider both economic and psychological factors when evaluating dietary behaviors, particularly during crises such as the COVID-19 pandemic.

The study's findings on reduced processed meat consumption among lower-income groups during the COVID-19 pandemic align with other research showing that financial constraints influenced dietary adjustments. Niles et al. [58] observed that lower-income individuals often cut back on higher-cost food items, including meat, due to economic insecurity; Revoredo-Giha et al. [52] found similar reductions in processed meat purchases in the UK, with lower-income households prioritizing affordable staples. In contrast, Bennett et al. [2] reported increased processed food reliance among some lower-income groups in the US, possibly due to stress-induced eating and a preference for shelf-stable items. These differences highlight the complex interplay of economic pressures and coping mechanisms in shaping dietary choices during the pandemic.

The analysis in Table 5 reveals that education level was not a significant predictor of changes in the consumption of various food groups during the COVID-19 pandemic, suggesting a uniform impact on dietary choices across educational backgrounds. This result contrasts with the general expectation that higher educational attainment correlates with healthier dietary habits, as more educated individuals typically have greater nutritional knowledge and access to resources [28]. Rather, the widespread disruptions caused by the pandemic—including food supply chain issues, economic constraints, and increased stress—may have affected individuals similarly across educational levels, diminishing typical disparities in food consumption patterns. The research by Béné [59] and Dubowitz et al. [60] supports this idea, indicating that public health crises can equalize dietary behaviors across socioeconomic lines due to pervasive impacts on food access and availability. These findings highlight the importance of considering broader social and economic factors that influence food choices, especially during public health emergencies, and they suggest that interventions during such crises should target the entire population rather than focusing solely on education-based disparities.

The findings indicate a surprising pattern: individuals with lower education levels were less likely to be classified as nutritionally vulnerable than those with higher education levels during the COVID-19 pandemic. This observation challenges conventional expectations, as higher education is typically associated with healthier dietary habits due to better access to nutritional information and resources. The pandemic, however, appears to have disrupted these usual patterns, likely due to stress-induced changes in dietary routines, shifts in food availability, and economic constraints that affected people across all educational backgrounds. For instance, individuals with higher education levels may have experienced a sudden lack of access to their usual food choices, particularly fresh or specialty items, leading them to shift toward processed or less diverse diets. Conversely, individuals with lower education levels were accustomed to constraints in food access and intake before the COVID-19 pandemic. The research by Niles et al. [58] reinforces this perspective, showing that even those with higher socioeconomic and educational levels faced food insecurity and altered dietary choices under pandemic pressures. This unexpected trend underscores the need for crisis-responsive public health strategies that ensure stable access to nutritious foods for all groups rather than relying solely on traditional education-based strategies. In future crises, recognizing and addressing the shared vulnerabilities across education levels will be essential for promoting food security and equitable health outcomes for all.

One of the primary strengths of this study is its comprehensive examination of dietary changes across different socioeconomic groups, specifically focusing on education and income levels. By analyzing a large sample and employing a robust statistical approach, the study provides detailed insights into how the COVID-19 pandemic influenced dietary habits in diverse demographic groups. The use of the DST allowed for a nuanced view of food group consumption, offering valuable data on multiple food categories rather than focusing narrowly on a few items. Additionally, the study design includes both pre- and post-pandemic dietary assessments, which enables a direct comparison and highlights specific changes influenced by the pandemic. By addressing multiple socioeconomic factors in tandem, the study also contributes to understanding the intersections of income, education, and dietary behaviors during public health crises, offering guidance for targeted public health interventions.

In addition, this study has several limitations. First, as a cross-sectional study, it captures associations but cannot establish causal relationships, limiting the ability to infer whether socioeconomic factors directly led to changes in dietary habits. Second, relying on self-reported dietary data may introduce recall and reporting biases, potentially affecting the accuracy of the dietary intake information. Another limitation is the focus on urban populations, which may not fully represent the dietary impacts of the pandemic on rural communities that may have faced different food accessibility challenges. Third, the measurement of nutritional risk in this study was limited to diet intake assessment and did not include anthropometric, biomarker and physical indicators of nutritional status. Lastly, while the study controls for various socioeconomic factors, it does not account for other potential influences, such as mental health status or regional variations in lockdown measures, which may have also affected dietary behaviors during the pandemic.

Future studies should consider longitudinal designs to more accurately capture the causal relationships between socioeconomic factors and dietary changes over time, particularly in response to ongoing public health crises. Examining rural populations and regional variations in food access would provide a fuller picture of how different communities adapt their dietary behaviors under similar stressors. Additionally, including variables such as mental health status, food environment, and access to government assistance programs could offer more nuanced insights into the drivers behind dietary shifts. Further research could also explore interventions that address psychological factors, such as stress and food-related anxiety, which may have influenced eating behaviors during the pandemic. The 2025 Dietary Guidelines for Americans currently emphasizes healthy eating patterns at every life stage, customized meal plans that honor preferences and cultural considerations, moderation in added sugars and saturated fats and reduced sodium. However, the DGA scientific committee responsible for designing these guidelines based on rigorous literature reviews should consider the addition of robust analyses of studies concerning population vulnerabilities in food supply and access during crises to develop a best practices tool for nutritional considerations during national disasters. Finally, studies should investigate how diverse population groups can be better supported in maintaining nutritious diets during crises, focusing on policies and programs that improve food security and dietary resilience across all socioeconomic levels.

5. Conclusions

This study highlights the complex impact of the COVID-19 pandemic on dietary behaviors across various socioeconomic groups, demonstrating that both income and education levels significantly influenced changes in food consumption and nutritional vulnerability. Lower-income individuals showed greater reductions in healthier food groups such as fruits, vegetables, and lean proteins, likely due to financial constraints, while individuals with higher education unexpectedly exhibited higher nutritional vulnerability, possibly influenced by stress and disruptions in usual food access. These findings underscore the need for inclusive public health interventions that address the nutritional needs of all groups during crises rather than focusing solely on conventional socioeconomic distinctions. By promoting food security, improving access to affordable, nutritious foods, and addressing stress-related eating behaviors, future policies can better support resilient and equitable dietary health. The insights from this study can guide public health planning and policymaking to mitigate dietary disparities and nutritional risks in future public health emergencies.

Author Contributions

Conceptualization, L.M.-L., A.A., P.J., E.A., and T.J; methodology, L.M.-L., A.A., and X.D.; software, L.M.-L., A.A., and X.D.; validation, L.M.-L., A.A., and X.D.; formal analysis, L.M.-L., A.A. and X.D.; investigation, L.M.-L., A.A., P.J., and E.A.; resources, L.M.-L.; data curation, L.M.-L. and AA.; writing—original draft preparation, L.M.-L., A.A. and X.D.; writing—review and editing, L.M.-L., A.A., P.J., E.A., X.D., and T.J., visualization, L.M.-L., A.A., and X.D. supervision, L.M.-L.; project administration, L.M.-L.; funding acquisition, L.M.-L. All authors have read and agreed to the published version of the manuscript.

Funding

This research project was funded by the Agriculture Experimental Station with funds from the Hatch Act to land-grant universities for multistate research projects, National Institute of Food and Agriculture, USDA. The funder had no role in the design, collection, analyses, interpretation of data, or writing of the manuscript.

Institutional Review Board Statement

This study was approved by the Institutional Review Board of the University of the District of Columbia. The IRB approval number is 1380607-5, and the approval date is 23 July 2020.

Informed Consent Statement

Informed consent was obtained from all participants involved in the study.

Data Availability Statement

Data used during the current study are available from the corresponding author.

Conflicts of Interest

The authors have no competing interests.

List of Abbreviations

COVID-19: Coronavirus Disease 2019
DST: Dietary Screening Tool
FSSs: Fats, Sugars, and Sweets
SDH: Social Determinants of Health
USDA: United States Department of Agriculture
IRB: Institutional Review Board
OR: Odds Ratio
CI: Confidence Interval
DGA: Dietary Guidelines for Americans
SAS: Statistical Analysis System

References

[1] Janssen, M., Chang, B. P., Hristov, H., Pravst, I., Profeta, A., and Millard, J., "Changes in food consumption during the COVID-19 pandemic: Analysis of consumer survey data from the first lockdown period in Denmark, Germany, and Slovenia." *Frontiers in Nutrition*, 8, 635859. July 2021.

[2] Bennett, G., Young, E., Butler, I., and Coe, S., "The impact of lockdown during the COVID-19 outbreak on dietary habits in various population groups: A scoping review." *Frontiers in Nutrition*, 8, 626432. July 2021.

[3] Bakaloudi, D. R., Jeyakumar, D. T., Jayawardena, R., and Chourdakis, M., "The impact of COVID-19 lockdown on snacking habits, fast-food and alcohol consumption: A systematic review of the evidence." *Clinical Nutrition*, 41 (7), 3038–3045. April 2022.

[4] AlMughamis, N., AlAsfour, S., and Mehmood, S., "Poor eating habits and predictors of weight gain during the COVID-19 quarantine measures in Kuwait: A cross-sectional study." *F1000Research*, 9, 914. August 2020.

[5] Deschasaux-Tanguy, M., Druesne-Pecollo, N., Esseddik, Y., De Edelenyi, F. S., Allès, B., Andreeva, V. A., Baudry, J., Charreire, H., Deschamps, V., Egnell, M., et al., "Diet and physical activity during the coronavirus disease 2019 (COVID-19) lockdown (March–May 2020): Results from the French NutriNet-Santé cohort study." *American Journal of Clinical Nutrition*, 113 (5), 924–938. December 2021.

[6] Husain, W., and Ashkanani, F., "Does COVID-19 change dietary habits and lifestyle behaviours in Kuwait: A community-based cross-sectional study." *Environmental Health and Preventive Medicine*, 25, 61. October 2020.

[7] Zeigler, Z., Forbes, B., Lopez, B., Pedersen, G., Welty, J., Deyo, A., and Kerekes, M., "Self-quarantine and weight gain related risk factors during the COVID-19 pandemic." *Obesity Research and Clinical Practice*, 14 (3), 210–216. May 2020.

[8] Sidor, A., and Rzymski, P., "Dietary choices and habits during COVID-19 lockdown: Experience from Poland." *Nutrients*, 12 (6), 1657. June 2020.

[9] Pellegrini, M., Ponzo, V., Rosato, R., Scumaci, E., Goitre, I., Benso, A., Belcastro, S., Crespi, C., De Michieli, F., Ghigo, E., et al., "Changes in weight and nutritional habits in adults with obesity during the 'lockdown' period caused by the COVID-19 virus emergency." *Nutrients*, 12 (7), 2016. July 2020.

[10] Gallo, L. A., Gallo, T. F., Young, S. L., Moritz, K. M., and Akison, L. K., "The impact of isolation measures due to COVID-19 on energy intake and physical activity levels in Australian university students." *Nutrients*, 12 (6), 1865. June 2020.

[11] Di Renzo, L., Gualtieri, P., Pivari, F., Soldati, L., Attinà, A., Cinelli, G., Leggeri, C., Caparello, G., Barrea, L., Scerbo, F., et al., "Eating habits and lifestyle changes during COVID-19 lockdown: An Italian survey." *Journal of Translational Medicine*, 18, 229. June 2020.

[12] Ruiz-Roso, M. B., de Carvalho Padilha, P., Mantilla-Escalante, D. C., Ulloa, N., Brun, P., Acevedo-Correa, D., Arantes Ferreira Peres, W., Martorell, M., Aires, M. T., de Oliveira Cardoso, L., et al., "COVID-19 confinement and changes of adolescent's dietary trends in Italy, Spain, Chile, Colombia and Brazil." *Nutrients*, 12 (6), 1807. June 2020.

[13] Bracale, R., and Vaccaro, C. M., "Changes in food choice following restrictive measures due to COVID-19." *Nutrition, Metabolism & Cardiovascular Diseases*, 30 (7), 1423–1426. May 2020.

[14] Scarmozzino, F., and Visioli, F., "COVID-19 and the subsequent lockdown modified dietary habits of almost half the population in an Italian sample." *Foods*, 9 (5), 675. May 2020.

[15] González-Monroy, C., Gómez-Gómez, I., Olarte-Sánchez, C. M., and Motrico, E., "Eating behaviour changes during the COVID-19 pandemic: A systematic review of longitudinal studies." *International Journal of Environmental Research and Public Health*, 18, 11130. November 2021.

[16] Bonfanti, R. C., Sideli, L., Teti, A., Musetti, A., Cella, S., Barberis, N., Borsarini, B., Fortunato, L., Sechi, C., Micali, N., et al., "The impact of the first and second wave of the COVID-19 pandemic on eating symptoms and dysfunctional eating behaviours in the general population: A systematic review and meta-analysis." *Nutrients*, 15 (8), 3607. August 2023.

[17] Monroe-Lord, L., and Ardakani, A., "How COVID-19 Pandemic Changed Consumption of Fruits and Vegetables by Older Adults." *Innovation in Aging*, 5 (Suppl. 1), 726. 2021.

[18] Souza, T. C. M., Oliveira, L. A., Daniel, M. M., Ferreira, L. G., Della Lucia, C. M., Liboredo, J. C., and Anastácio, L. R., "Lifestyle and eating habits before and during COVID-19 quarantine in Brazil." *Public Health Nutrition*, 25, 65–75. 2022.

[19] Monroe-Lord, L., Harrison, E., Ardakani, A., Duan, X., Spechler, L., Jeffery, T. D., and Jackson, P., "Changes in food consumption trends among American adults since the COVID-19 pandemic." *Nutrients*, 15 (7), 1769. April 2023.

[20] Monroe-Lord, L., Ardakani, A., Jackson, P., Asongwed, E., Duan, X., Schweitzer, A., Jeffery, T., Johnson-Largent, T., and Harrison, E., "Dietary Shifts since COVID-19: A Study of Racial Differences." *Nutrients*, 16 (8), 3164. August 2024.

[21] Caso, D., Guidetti, M., Capasso, M., and Cavazza, N., "Finally, the chance to eat healthily: Longitudinal study about food consumption during and after the first COVID-19 lockdown in Italy." *Food Quality & Preference*, 95, 104275. 2022.

[22] Marmot, M., "Social determinants of health inequalities." *Lancet*, 365, 1099–1104. 2005.

[23] Monroe-Lord, L., and Ardekani, A., "COVID-19 Pandemic-Related Changes in Nutrition Behaviors of Older Adults." *Current Developments in Nutrition*, 5 (Suppl. 1), 39. 2021.

[24] Ardakani, A., Monroe-Lord, L., and Spechler, L., "P070 COVID-19 pandemic changes in fruit and vegetable consumption among various demographic populations." *Journal of Nutrition Education & Behavior*, 54, S50–S51. 2022.

[25] Loopstra, R. *Vulnerability to Food Insecurity Since the COVID-19 Lockdown*. The Food Foundation: London, UK, 2020.

[26] Power, M., Doherty, B., Pybus, K., and Pickett, K., "How COVID-19 has exposed inequalities in the UK food system: The case of UK food and poverty." *Emerald Open Research*, 2, 11. 2020.

[27] Laborde, D., Martin, W., Swinnen, J., and Vos, R., "COVID-19 risks to global food security." *Science*, 369, 500–502. 2020.

[28] Darmon, N., and Drewnowski, A., "Does social class predict diet quality?" *American Journal of Clinical Nutrition*, 87, 1107–1117. 2008.

[29] McKey, K., "Socioeconomic status and health: The challenge of the gradient." *American Psychologist*, 61, 103–116. 2006.

[30] Lesser, I. A., and Nienhuis, C. P., "The impact of COVID-19 on physical activity behavior and well-being of Canadians." *International Journal of Environmental Research & Public Health*, 17, 3899. 2020.

[31] Cosgrove, K., Vizcaino, M., and Wharton, C., "Predictors of COVID-19-related perceived improvements in dietary health: Results from a US cross-sectional study." *Nutrients*, 13, 2097. 2021.

[32] Ordoñez-Araque, R., and Caicedo-Pineda, L., "Impacts of COVID-19 on the dietary habits of low- and high-income households in Ecuador." *Current Research in Food Science*, 4, 44–51. 2021.

[33] World Health Organization. *A Conceptual Framework for Action on the Social Determinants of Health.* Geneva, Switzerland, 2010.

[34] Qualtrics. *Provo, UT.*, 2020. Available online: https://www.qualtrics.com (accessed on 13 August 2020).

[35] United States Census Bureau. *The Urban and Rural Classifications.* Suitland, MD, USA, 2013.

[36] U.S. Department of Agriculture. *What is MyPlate?* 2020. Available online: https://www.myplate.gov/eat-healthy/what-is-myplate (accessed on 22 November 2021).

[37] Malik, V. S., Popkin, B. M., Bray, G. A., Després, J.-P., Willett, W. C., and Hu, F. B., "Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: A meta-analysis." *Diabetes Care*, 33, 2477–2483. 2010.

[38] Micha, R., Michas, G., and Mozaffarian, D., "Unprocessed red and processed meats and risk of coronary artery disease and type 2 diabetes: An updated review of the evidence." *Current Atherosclerosis Reports*, 14, 515–524. 2012.

[39] Bailey, R. L., Miller, P. E., Mitchell, D. C., Hartman, T. J., Lawrence, F. R., Sempos, C. T., and Smiciklas-Wright, H., "Dietary screening tool identifies nutritional risk in older adults." *American Journal of Clinical Nutrition*, 90, 177–183. 2009.

[40] Bailey, R. L., Mitchell, D. C., Miller, C. K., Still, C. D., Jensen, G. L., Tucker, K. L., and Smiciklas-Wright, H., "A dietary screening questionnaire identifies dietary patterns in older adults." *Journal of Nutrition*, 137, 421–426. 2007.

[41] Marra, M., Thuppal, S. V., Johnson, E. J., and Bailey, R. L., "Validation of a dietary screening tool in a middle-aged Appalachian population." *Nutrients*, 10, 345. 2018.

[42] Davitt, E. D., Heer, M. M., Winham, D. M., Knoblauch, S. T., and Shelley, M. C., "Effects of COVID-19 on university student food security." *Nutrients*, 13, 1932. 2021.

[43] Devereux, S., Béné, C., and Hoddinott, J., "Conceptualising COVID-19's impacts on household food security." *Food Security*, 12, 769–772. 2020.

[44] Kirkpatrick, S. I., and Tarasuk, V., "Food insecurity is associated with nutrient inadequacies among Canadian adults and adolescents." *Journal of Nutrition*, 138, 604–612. 2008.

[45] Drewnowski, A., and Specter, S. E., "Poverty and obesity: The role of energy density and energy costs." *American Journal of Clinical Nutrition*, 79, 6–16. 2004.

[46] Pechey, R., Monsivais, P., Ng, Y. L., and Marteau, T. M., "Why don't poor men eat fruit? Socioeconomic differences in motivations for fruit consumption." *Appetite*, 84, 271–279. 2015.

[47] Lin, B.-H., Yen, S. T., Huang, C. L., and Smith, T. A., "U.S. demand for organic and conventional fresh fruits: The roles of income and price." *Sustainability*, 1, 464–478. 2009.

[48] Malkan Bakhrul Ilmi, I., Nur Hasan Syah, M., Wahyuningsih, U., and Crosita Octaria, Y., "Determinants of fruit consumption in adult women in Indonesia." *F1000Research*, 12, 783. 2023.

[49] Hui, L., "Research on impacts given by grain price fluctuation on customers in inflation period." *Research Journal of Applied Sciences, Engineering and Technology*, 5, 4118–4122. 2013.

[50] Lu, K., and Yu, B., "The impact of high food prices on poverty in China." *Development Practice*, 21, 794–802. 2011.

[51] Aruga, K., Islam, M. M., and Jannat, A., "Effects of the State of Emergency during the COVID-19 Pandemic on Tokyo Vegetable Markets." *Sustainability*, 14 (15), 9719. August 2022.

[52] Revoredo-Giha, C., Russo, C., and Twum, E. K., "Purchases of fruit and vegetables for at-home consumption during COVID-19 in the UK: Trends and determinants." *Frontiers in Nutrition*, 9, 847996. April 2022.

[53] Yang, R., Raper, K. C., and Pruitt, J. R., "The influence of recession and income strata on consumer demand for protein sources." *Applied Economics*, 51 (42), 4615–4628. 2019.

[54] Andreoli, V., Bagliani, M., Corsi, A., and Frontuto, V., "Drivers of protein consumption: A cross-country analysis." *Sustainability*, 13 (13), 7399. July 2021.

[55] Mulik, K., and Haynes-Maslow, L., "The impact of food insecurity on diet quality during the COVID-19 pandemic: The role of government nutrition assistance programs." *Journal of Nutrition Education & Behavior*, 53, 203–210. 2021.

[56] Tan, S. T., Tan, C. X., and Tan, S. S., "Changes in dietary intake patterns and weight status during the COVID-19 lockdown: A cross-sectional study focusing on young adults in Malaysia." *Nutrients*, 14 (2), 280. January 2022.

[57] Park, S., Lee, S. H., and Blanck, H. M., "Characteristics associated with being a high consumer of sweet foods and sugar-sweetened beverages among US adults during the COVID-19 pandemic." *Nutrients*, 15 (10), 2363. May 2023.

[58] Niles, M. T., Bertmann, F., Belarmino, E. H., Wentworth, T., Biehl, E., and Neff, R., "The early food insecurity impacts of COVID-19." *Appetite*, 149, 104915. 2020.

[59] Béné, C., "Resilience of local food systems and links to food security—A review of some important concepts in the context of COVID-19 and other shocks." *Agricultural Economics*, 51, 1076–1100. 2020.

[60] Dubowitz, T., Dastidar, M. G., Troxel, W. M., Beckman, R., Nugroho, A., Siddiqi, S., and Cantor, J., "Food insecurity in a low-income, predominantly African American cohort following the COVID-19 pandemic." *American Journal of Public Health*, 111, 494–497. 2021.