

Review

The Folly of Food Waste amidst Food Insecurity in the United States: A Literature Review

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Abstract: Food insecurity is an economic and social condition that involves individuals having limited or uncertain access to healthy food. Despite the well-intentioned efforts of both governmental and not-for-profit organizations in addressing food insecurity, well over one-in-ten households in the U.S., the wealthiest nation in the world, experience food insecurity every year. The objective of this literature review was to identify and explicate the methods and outcomes of food insecurity interventions that have been conducted among U.S. adults. This literature review identified 38 studies detailing several government programs and research interventions designed to address food insecurity. Results from the review highlight how the Supplemental Nutrition Assistance Program (SNAP), The Emergency Food Assistance Program (TEFAP), and not-for-profit food banks have demonstrated success in improving food insecurity. However, the prevalence of food insecurity among U.S. households has fluctuated without any sustained decreases that achieve a food insecurity rate that remains below 10 percent of the population. Food waste, which refers to food that is edible yet discarded at the retail or consumption phases, is rampant in the U.S., as approximately 30 percent (66.5 million tons) of edible food is wasted after leaving the farm every year. Food waste prevention efforts that involve rescuing edible, nutritious food and redistributing it to individuals who are food insecure can promote both environmental wellbeing and public health through simultaneous reductions in food waste and food insecurity.

Keywords: food insecurity; food waste; food assistance; food is medicine; literature review



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1. Introduction

Food insecurity is an economic and social condition that involves individuals having limited or uncertain access to healthy food [1]. According to the United States Department of Agriculture (USDA), there are four ranges of food security, including high food security, marginal food security, low food security, and very low food security [1]. Individuals and households experiencing high food security or marginal food security are considered to be food secure, while those experiencing low food security or very low food security are identified as food insecure [1].

The Economic Research Service (ERS) of the USDA began the process of identifying and measuring food security in the 1990's as a part of the U.S. Food Security Measurement Project [2]. This project was a product of the National Nutrition Monitoring and Related Research Act of 1990 (NNMRR) [3], which was passed by the 101st Congress of the United States to carry out three objectives: (1) create a National Nutrition Monitoring Advisory Council, (2) establish the National Nutrition Monitoring and Related Research Program, and (3) publish dietary guidelines for the U.S. general public that provide information and instructions concerning healthy foods and eating behaviors. The Ten-Year Comprehensive Plan that resulted from the NNMRR included a recommendation to develop “a standardized mechanism and instrument(s) for defining and obtaining data on the prevalence of ‘food insecurity’ or ‘food insufficiency’ in the United States” [3]. After performing cognitive assessments and field tests of a conceptualized food security questionnaire, the U.S. Census

Bureau then proceeded to administer the questionnaire as a supplement to the Current Population Survey of 1995 [4]. A few years later, in 1998, the ERS assumed responsibility for administering the Census Bureau's food security survey and subsequently coordinating both the data analysis and the reporting of study results for USDA research on food security and food security measurement [5].

Since food security first started being measured among U.S. households in 1995, the prevalence of food insecurity in the U.S. was lowest in 1999 [6], at 9.7 percent of households, and highest in 2011 [7], at 14.9 percent of households [8]. During the Great Recession, the largest ever single-year increase in household food insecurity prevalence was observed in the U.S., as the incidence of food insecurity swelled from 11.1 percent of households in 2007 [9] to 14.6 percent of households in 2008 [8,10]. After peaking in 2011, the prevalence of household food insecurity in the U.S. has declined during the past nine years for which data are available [8]. In 2022, 12.8 percent of U.S. households (17 million) were food insecure [11]. Of these households, 5.1 percent (6.8 million) experienced very low food security and endured an involuntary decrease in both the quality and quantity of the food intake [11].

Food insecurity is associated with a host of unhealthy behaviors and poor physical health outcomes. Given that food insecurity disrupts eating patterns, diet-related problems that are correlated with food insecurity can consist of nutritional deficiencies [12] and metabolic syndrome [13]. Food insecurity increased the odds of behaviors that are detrimental to physical health, which include disordered eating behaviors [14], physical inactivity [15], smoking cigarettes [16], risky sex [17], and alcohol and drug abuse [16–18]. Physical ailments related to food insecurity can also involve poor sleep quality [19], cognitive impairment [20], obesity [21], high blood pressure [22], and inflammation [23]. Individuals experiencing food insecurity are also at an increased risk of developing various chronic diseases including type-2 diabetes [24], cardiovascular disease [25], and cancer [26].

1.1. Food Insecurity as a Detriment to Health and Wealth

The health risks associated with food insecurity are multifaceted in posing hazards that expand beyond the physiological realm. Individuals experiencing food insecurity are also at a greater risk of experiencing numerous mental health problems [27]. Food insecurity increases the likelihood of individuals experiencing high stress levels [28], anxiety [29], depression [30], and suicidal behaviors [27]. Related markers of poor mental health that are linked to food insecurity involve poor coping skills [31], social isolation [28], stigma [32], hopelessness [33], and addiction [34]. Potentially unpreventable risk factors of poor mental health related to food insecurity include adverse childhood experiences [35], generational poverty [36], abuse (i.e., physical, psychological, sexual) [37,38], interpersonal violence [39], trauma [40], and the death of a loved one [41]. Certain preventable risk factors of poor mental health that are associated with food insecurity involve physical inactivity [15], disordered eating behaviors [14], and poor sleep quality [19].

The adverse effects that food insecurity experiences impose on people can span far beyond the health spectrum. A myriad of social factors contribute to or may be an outcome of the problem of food insecurity in the U.S. Socioeconomic factors that predict food insecurity involve various forms of financial hardship including unemployment [42], earning a low income, having competing expenses [43], high food prices [42], and inflation [42]. Environmental factors that are associated with food insecurity involve the presence of food deserts [44], neighborhood safety and walkability [45], housing instability [46], and homelessness [47]. Sociocultural factors related to food insecurity include food procurement and preparation skill deficiencies [48], a lack of information about how to obtain affordable food [49–52], food waste practices [53], low financial literacy [54], unreliable transportation [55], and low social support among family and friends [56]. Moreover, sociopolitical factors contributing to food insecurity include an insufficient breadth of food service programs [57] and other government policy shortcomings [58]. Overall, the aforementioned consequences of food insecurity concerning outcomes relating to physical health,

mental health, and social wellbeing present vulnerable individuals with an array of additional burdens that exacerbate the co-occurring problems contributing to their food insecurity.

1.2. The Disparate Prevalence of Food Insecurity

Not all people in the U.S. experience food insecurity the same way, as these experiences vary across groups of people [59]. Stark age [59], gender [60], income [59], and racial and ethnic [61] disparities exist regarding the prevalence and severity of food insecurity. Working-age middle adults (ages 35–64) encounter higher rates of food insecurity compared to young adults (ages 18–34) and older adults (ages 65+) [59]. Females have a greater risk of experiencing food insecurity, as it is more common for females to be single parents [62] and they typically earn a lower income than men [63]. Income disparities are arguably the most pronounced since food insecurity experiences are often the result of financial hardship which places individuals and households classified as low-income or below the poverty line among those most likely to be food insecure [64]. Racial and ethnic disparities also exist, as there has historically been a higher prevalence of food insecurity among individuals who are Black, Indigenous, and People of Color compared to their White counterparts [65]. For example, the highest rates of food insecurity among U.S. households in 2022 were found among individuals who were non-Hispanic-Black (22.4%) or Hispanic-Latinx (20.8%) [11]. Other disparities that persist concerning food insecurity in the U.S. include college students being at a greater risk than non-college students [66], immigrants being at a greater risk than non-immigrants [65], and individuals who are houseless being at a greater risk than individuals with a home [47]. Given the many population-based disparities as it relates to food insecurity, there is an obvious lack of health equity as it relates to food insecurity and chronic disease across the various groups of people within the U.S. [67].

1.3. The State of Food Assistance

Current government, non-profit, and grassroots programs in the U.S. that are aiming to promote food security operate with the purpose of reaching individuals experiencing food insecurity to provide them with necessary food assistance. A few relevant programs that have been designed and implemented to promote food security among adults with or without children include the Supplemental Nutrition Assistance Program (SNAP); the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC); The Emergency Food Assistance Program (TEFAP); food banks; and community gardens. SNAP, previously referred to as the Food Stamp Program, is a U.S. federal government program managed by the Food and Nutrition Service of the USDA that provides individuals and families with income-based food assistance [68].

People enrolled in SNAP receive monthly financial benefits through an electronic benefits transfer (EBT) card, which allows them to purchase select food and drink items from participating businesses [69]. SNAP recipients are permitted to purchase fruits, vegetables, meat, dairy products, breads, cereals, snacks, and even seeds and plants to be cultivated for food production [70]. Obtaining regular access to SNAP benefits can yield meaningful food security improvements among vulnerable individuals by providing them with consistent access to a sufficient quantity and quality of food [71].

Being eligible to receive SNAP benefits requires that a household's gross income be less than 130 percent of the federal poverty threshold for the household size with their net income being less than 100 percent of the poverty threshold [72]. Work requirements to qualify for SNAP benefits expect people aged 16 to 59 to work at least 30 h a week with exceptions for students, caregivers, people living with a disability, and people in drug rehabilitation [72]. Adults aged 18 to 49 who are not pregnant and do not have dependents under the age of 18 living in the household are required to work at least 80 h per month [72]. Although, state governments may waive work requirements in high unemployment areas to increase access for individuals who need food assistance the most. Individuals who are ineligible for SNAP benefits but otherwise may need food assistance include full-time

college students and undocumented immigrants, while non-citizen adults must have lived in the U.S. for at least five years or must be receiving disability-related assistance [73].

A recent research report published during the COVID-19 pandemic highlighted an increased rate of food insecurity accompanied by stagnant SNAP participation among low-income U.S. households [74]. Authors of this report also admonished food assistance program representatives to facilitate SNAP participation among the most vulnerable populations [74]. Given the promising potential that SNAP benefits hold for promoting food security among vulnerable people, it is imperative that individuals who are food insecure and eligible for SNAP be identified and informed about their opportunity to obtain steady access to a sufficient amount of healthy food.

TEFAP is another program that provides critical support for people who are experiencing food insecurity [75]. Similar to SNAP, TEFAP is also a federal USDA program administered by the Food and Nutrition Service that provides emergency food assistance to promote food security and improve the diet of individuals and families who are suffering financial hardship. TEFAP is organized to have the federal government purchase food and then allocate it to state, tribal, and local entities based on the amount of people who are unemployed and the number of people living under the poverty level [76]. The food assistance provided by the U.S. government is then apportioned to partnering agencies (i.e., food bank networks, community action groups), which then distribute the food to smaller local entities (i.e., food pantries, soup kitchens, non-profit organizations) that are located within or near low-income communities with high rates of food insecurity. Local agencies then engage in food security promotion efforts by providing critical food assistance to individuals and families experiencing food insecurity. TEFAP is essential for most food assistance entities to help people experiencing food insecurity, which is why the USDA committed up to \$1 billion in 2021 for purchasing food and bolstering food bank infrastructures to prevent food insecurity in low-income communities [77].

Food banks serve a critical purpose in facilitating the distribution of free food to individuals experiencing food insecurity who otherwise could not afford to purchase enough food to feed themselves or their families [78]. The world's first ever food bank to be established was St. Mary's Food Bank of Phoenix, Arizona [79]. St. Mary's Food Bank was established by John van Hengel in 1977 through a \$3000 loan provided by St. Mary's Basilica of Phoenix in response to a first-person testimony from a mother of 10 children who regularly visited the St. Vincent de Paul soup kitchen and reported that she had been depending on food from grocery store dumpsters to feed her children [79,80]. The concept of food banking was an instant success, as St. Mary's Food Bank distributed 275,000 pounds of food in its initial year [81]. This number has since been multiplied 401 times over, as St. Mary's Food Bank distributed 110,427,114 pounds of food in 2021 [82].

As the number of food banks in the U.S. increased, van Hengel established a national organization to create a network of food banks in 1979, which was originally named Second Harvest and is now known as Feeding America [81]. As of 2022, Feeding America maintains a network of over 200 food banks that regularly distribute food to over 60,000 food pantries and meal programs across the U.S. [83]. Food banks affiliated with Feeding America operate by using a warehouse model to collect and store donated food that is then distributed to intermediaries like food pantries, soup kitchens, and other non-profit organizations on the front line in low-income communities [84]. With the valuable financial support of TEFAP along with regular food donations made by food producers, food retailers, and community members, food pantries have the potential to play a big role in preventing food insecurity among the most vulnerable individuals and households.

Barriers to accessing food assistance can be categorized as either predisposing access barriers (e.g., skills, information) or enabling access barriers (e.g., finances, transportation) [85]. Predisposing access barriers consist of personal characteristics (i.e., age, knowledge, values), while enabling access barriers pertain to financial incomes, resources, and policies [85]. Interventions that target the removal of food access barriers are essential for promoting food security across vulnerable populations. Therefore, the purpose of this

literature review is to elucidate the variety of food insecurity interventions that have been conducted among U.S. adults, while accentuating the near absence of interventions that have targeted the simultaneous reductions of both food waste and food insecurity.

2. Methods

The research articles ($n = 37$) compiled for this literature review were accessed from Google Scholar using the following key terms in various search term combinations: food insecurity, food security, nutrition insecurity, nutrition security, food access, food desert, food assistance, food pantry, SNAP, intervention, experimental, quasi-experimental, randomized controlled trial, longitudinal, U.S., United States, and Adults. Study inclusion criteria required the research articles to employ a quantitative, qualitative, or mixed-methods approach and include a sample of U.S. adults, a measure of food security, a food insecurity intervention, a longitudinal analysis of food security outcomes, and the existence of an English-language version of the research manuscript. Research articles including interventions applied by non-research entities were included.

3. A Review of Food Insecurity Interventions

An assortment of longitudinal food insecurity studies have either used observational methods to examine the impact of existing food assistance resources on food insecurity or intervention methods to test novel approaches for promoting food security (Table 1). A meta-analysis of 39 studies ($n = 170,605$) that examined the effect of interventions to address food insecurity yielded results detailing how interventions offering food assistance ($OR = 0.53$; 95% $CI = 0.33, 0.67$) and interventions offering monetary assistance ($OR = 0.64$; 95% $CI = 0.49, 0.84$) both reduced the odds of food insecurity [86]. Researchers in a separate study simulated an intervention by using longitudinal data from the CPS to identify whether a combined cash and food benefits program could reduce food insecurity among a national sample of U.S. adults ($n = 28,194$), and they determined that allocating an additional \$1000 to each participant in the sample would have attenuated the risk of food insecurity ($\beta = -0.011$; $p < 0.05$) [87].

Table 1. Food insecurity intervention studies conducted among U.S. adults ($n = 37$).

Citation	Study Design	Intervention	Sample Size	Statistic
Oronce et al. (2021) [86]	Meta-Analysis	Monetary and Non-Monetary Food Assistance	170,605	Monetary: OR = 0.64 Non-monetary: OR = 0.53
Schmidt, Shore-Sheppard, & Watson (2016) [87]	Quasi-experimental	Monetary Food Assistance	28,194	Food Insecurity: $\beta = -0.011$
Fox et al. (2016) [88]	Qualitative	Motivational Interviewing	116	N/A
Martel et al. (2018) [89]	Qualitative	Motivational Interviewing	954	N/A
Ratcliffe, McKernan, & Zhang (2011) [90]	Longitudinal Cohort	SNAP Use	65,269	Food Insecurity: $\beta = -0.582$
Yen et al. (2008) [91]	Longitudinal Cohort	SNAP Use	2179	Food Insecurity: $\beta = -3.604$
Eicher-Miller et al. (2009) [92]	Quasi-Experimental	Nutrition Education	219	Food Insecure: $D = -9.3$
Nord (2012) [93]	Longitudinal Cohort	SNAP Use	1030	Food Insecurity: OR = 0.34
Mabli & Ohls (2015) [94]	Longitudinal Cohort	SNAP Use	3375	Food Insecure: $D = -11.1$

Table 1. Cont.

Citation	Study Design	Intervention	Sample Size	Statistic
Harper et al. (2022) [95]	Longitudinal Cohort	SNAP Enrollment	470	Mid-Pandemic: D = 4.5
Savoie-Roskos et al. (2016) [96]	Quasi-Experimental	Double-Up SNAP Bucks	54	Food Security Score: D = -0.7
Durward et al. (2019) [97]	Quasi-Experimental	Double-Up SNAP Bucks	138	Very Low Food Security: D = -12
Roncarolo, Bisset, & Potvin (2016) [98]	Longitudinal Cohort	Food Pantry Use	450	Food Insecurity: OR = 0.22
Martin et al. (2012) [99]	Quasi-Experimental	Food Choice at a Food Pantry	233	Food Security Score: D = -1.64
Martin et al. (2013) [100]	Quasi-Experimental	Food Choice at a Food Pantry	128	Very Low Food Security: OR = 0.42
Flynn, Reinert, & Schiff (2013) [101]	Quasi-Experimental	Cooking Classes	63	Food Security Score: D = -1.13
Royer & Wharton (2023) [102]	Quasi-Experimental	Informational Nudges	24	Food Insecure: D = -0.44
Cheyne (2020) [103]	Quasi-Experimental	Food Box Delivery and Health Education	462	Food Insecure: D = -6.3
Wright et al. (2019) [104]	Quasi-Experimental	Food Assistance Information	125	Food Security: OR = 1.10
Rivera et al. (2016) [105]	Quasi-Experimental	Nutrition Education	575	Food Secure: D = 0.9
Chojnacki et al. (2021) [106]	Quasi-Experimental	Monetary Food Assistance	2202	Food Insecure: D = 0.9
Londhe, Ritter, & Schlesinger (2019) [107]	Longitudinal Cohort	Increased Access to Healthcare	722	Food Insecurity: $\beta = -0.06$
Himmelstein (2019) [108]	Longitudinal Cohort	Increased Access to Healthcare	41,053	Food Insecure: D = -2.23
Andrade et al. (2019) [109]	Longitudinal Cohort	Monetary Food Assistance	443	Food Insecurity: $\beta = -2.21$
Lee, Johnson, & Brown (2011) [110]	Longitudinal Cohort	Home-Delivered Meals	717	Food Security: OR = 1.65
Frongillo & Wolfe (2010) [111]	Longitudinal Cohort	Home-Delivered Meals	101	Food Insecure: D = -0.15
Richardson et al. (2017) [112]	Case-Control	New Supermarket	831	Food Insecure: D = -11.8
Cueva et al. (2018) [113]	Quasi-Experimental	Mobile Grocery Truck	101	Food Insecure: D = -14
Briefel, Chojnacki, & Gabor (2021) [114]	Quasi-Experimental	Food Box Delivery	2859	Food Insecure: D = -2.8
Marshall et al. (2022) [115]	Quasi-Experimental	Nutrition Education	371	Food Insecure: D = -0.49
Phojanakong et al. (2020) [116]	Quasi-Experimental	Trauma-Informed Programming	372	Food Insecurity: OR = 0.45

Table 1. Cont.

Citation	Study Design	Intervention	Sample Size	Statistic
Carney et al. (2012) [117]	Quasi-Experimental	Garden and Gardening Resources	131	Food Insecure: D = −12.5
Chatterjee, Brown, & Block (2018) [118]	Quasi-Experimental	Food Rescue and Redistribution	33	Food Security Score: D = 2.2
Khan, Schiff, & Mello (2019) [119]	Quasi-Experimental	Food Box Delivery	93	Food Insecure: D = −35.5
Wright et al. (2015) [120]	Quasi-Experimental	Home-Delivered Meals	51	Food Secure: D = 18.7
Berkowitz et al. (2019) [121]	Quasi-Experimental	Home-Delivered Meals	44	Food Insecure: D = −20
Wetherill et al. (2018) [122]	Quasi-Experimental	Food Box Delivery and Nutrition Education	43	Non-Significant (Statistic Not Provided)
Aiyer et al. (2019) [123]	Quasi-Experimental	Food Prescription Program	172	Food Insecure: D = −94.1

β = Beta Coefficient, **D** = difference, **OR** = Odds Ratio; **Bolded Statistic** = Significant at $p < 0.05$, Non-bolded Statistic = Non-Significant at $p < 0.05$.

Individuals experiencing food insecurity in the U.S. often qualify for much needed food assistance benefits, like SNAP. Results from a longitudinal study among parents of children who were medical clinic patients in the midwestern U.S. ($n = 116$) qualitatively describe how one-time communication is likely not a sufficient approach to bolster SNAP enrollment among households experiencing food insecurity, as few parents who were food insecure reported registering for SNAP after being asked by a clinician if they would like to receive assistance enrolling for SNAP [88]. Conflicting qualitative evidence from a similar but separate study conducted in a medical setting found that referring patients who were food insecure ($n = 954$) to food assistance resources could boost SNAP enrollment [89].

Longitudinal research among a national sample of U.S. households ($n = 65,269$) determined that SNAP participation reduced household food insecurity over time ($\beta = -0.582$; $p < 0.01$) [90]. These findings support additional evidence from a seminal study among a national sample of U.S. adults ($n = 2179$) that examined the effect of the food stamp program on food security, and concluded that food stamp program participation could help alleviate food insecurity ($\beta = -3.604$; $p < 0.01$) [91]. Intervention research among female heads of households in the midwestern U.S. ($n = 219$) sought to identify the effect of a food stamp nutrition education program on household food security, which yielded estimates indicating that a greater proportion of the experimental group was food secure (94%) than the control group (84.7%) and a lesser proportion of the experimental group was food insecure (6%) compared to the control group (15.3%) at the end of the intervention ($p = 0.03$) [92].

Observational research among adults who were enrolled in SNAP ($n = 1030$) at some point during 2001–2009 found that individuals who remained enrolled in SNAP had lower odds ($OR = 0.34$; $p < 0.001$) of experiencing very low food security in comparison to those who unenrolled from SNAP during the study [93]. A separate longitudinal study among SNAP recipients ($n = 3375$) examined how enrolling in SNAP impacted their food security status over time, and determined that the prevalence of household food insecurity had been reduced to 53.9 percent at six months after SNAP enrollment from the 65 percent when those same households had just enrolled in SNAP ($D = -11.1$, $SE = 0.9$; $p < 0.01$) [94]. Another longitudinal study among a national sample of U.S. adults ($n = 470$) during the COVID-19 pandemic produced outcomes which suggested that SNAP enrollment among food insecure households was greater during the pandemic (67%) than before the pandemic (62.5%) ($p < 0.01$) [95].

A separate research intervention among adults in the southwestern U.S. ($n = 54$) matched participants dollar-for-dollar up to \$10 in SNAP dollars spent to purchase fruits and vegetables at farmers' markets, which found that the intervention reduced the study group's average food insecurity scores (Baseline = 3, Follow-Up = 2.3; $p < 0.05$) [96]. While a follow-up study among adults in the southwestern U.S. ($n = 138$) sought to build upon these findings by implementing the same intervention that matched up to \$10 in SNAP dollars spent at farmers' markets to purchase fruits and vegetables [97]. Results from this second study suggested that the intervention lowered the prevalence of low food security (Baseline = 36%, Follow-Up = 33%) and very low food security (Baseline = 34%, Follow-Up = 22%) while increasing high and marginal food security (Baseline = 30%, Follow-Up = 45%) ($p = 0.001$) [97].

A longitudinal study that tracked adults who were obtaining food from traditional (i.e., food banks) or alternative (i.e., community gardens) resources over nine months ($n = 450$) yielded results which suggested that utilizing food pantries lowered the odds of severe food insecurity (OR = 0.22; 95% CI = 0.10, 0.44) [98]. Food pantry-based interventions have been found to improve food security along with outcomes related to dietary behaviors and health [124,125]. A food insecurity intervention conducted among food pantries examined the extent to which food security could be improved by allowing food pantry clients ($n = 233$) to choose their own food rather than having it prepackaged for them [99]. Findings from this intervention study suggested greater improvements were observed in the intervention group for both the food security scores (Intervention = -1.64 , Control = -0.65 ; $p = 0.01$) and the fruit and vegetable servings (Intervention = $+1.90$, Control = -1.40 ; $p < 0.01$) when compared with the control group [99].

Further findings from the same intervention in a different study indicated that participants in the intervention group ($n = 113$) had lower odds of experiencing very low food security (OR = 0.42; 95% CI = 0.24, 0.72) in comparison to the control group ($n = 115$) [100]. Separate research intervention that tested whether cooking classes could improve the food security status of food pantry clients ($n = 63$) found that intervention group participants had lower food insecurity scores at the six-month post-intervention follow-up ($M = 2.07$, $SD = 2.9$) than at baseline ($M = 3.2$, $SD = 36$; $p < 0.01$) [101]. A pilot research intervention among food pantry clients in the Southwestern U.S. ($n = 24$) sent informational nudges to participants that informed them of when, where, and how to access proximal food assistance, and determined that the prevalence of food insecurity in the intervention group was reduced by 44% after two months ($D = -0.44$, $SE = 0.20$; $p = 0.04$) [102]. Another intervention study among food pantry clients ($n = 462$) used diabetes-appropriate food boxes and text message-based health education to promote food security, and determined that the intervention reduced the prevalence of food insecurity from 68.8 percent at baseline to 62.5 percent after six months ($\chi^2 = 72.6$; $p < 0.001$) [103]. Food insecurity intervention research among military veterans ($n = 125$) used targeted communication of food pantry services at veteran service organizations in an effort to promote food security among veterans [104]. Outcomes derived from this study suggested that the intervention improved the odds of both adult (OR = 1.10, $SE = 0.04$; $p = 0.01$) and household (OR = 1.10, $SE = 0.04$, $p = 0.009$) food security from baseline to post-intervention follow-up [104]. Food insecurity interventions expand beyond food pantries by evaluating the impact of government assistance on food security.

A randomized controlled trial conducted among adults in the midwestern U.S. ($n = 575$) used an educational program intervention to inform participants about identifying healthy foods and cooking healthy meals [105]. Outcomes from this study indicated that greater improvements occurred in the intervention group for both adult ($D = 0.9$, $SE = 0.3$; $p < 0.01$) and household ($D = 1.2$, $SE = 0.4$; $p < 0.01$) food security when compared with the no-treatment control group [105]. A randomized controlled trial conducted among households in the southern U.S. ($n = 2202$) investigated whether supplementing pre-existing SNAP benefits based on income and distance to grocery store would improve the food insecurity of adults and children in the household [106]. Findings from this intervention suggested that the SNAP

supplement did not change the prevalence of food insecurity among adults (treatment = 53.9%, control = 53%; $p = 0.65$) or children (treatment = 37.1%, control = 35.2%; $p = 0.81$) [106].

Longitudinal research examining the impact of Medicaid expansion on household food security in a national sample of U.S. counties ($n = 722$) discovered that expanded Medicaid eligibility yielded county-wide reductions in household food insecurity ($\beta = -0.06$; $p = 0.01$) [107]. Further results from another longitudinal study which evaluated the effect of Medicaid expansion on the food security status of low-income U.S. adults ($n = 41,053$) highlight how expanding Medicaid eligibility reduced the prevalence of very low food security (PR = -2.23 ; 95% CI = $-2.25, -2.21$) [108]. Separate longitudinal research among low-income adults in the midwestern U.S. ($n = 443$) investigated the impact of periodic payment allocation derived from an earned income tax credit, and found that participants receiving the periodic cash payment intervention experienced decreased food insecurity over time ($\beta = -2.21$; $p = 0.004$) [109].

Another longitudinal study among older adults in the southern U.S. ($n = 717$) evaluated the extent to which changes in food security status occurred as a result of the Older Americans Act Nutrition Program (OAANP), which is a government program distributing home-delivered meals and meals to be served in group settings (i.e., senior centers, faith-based organizations) [110]. Findings from this study emphasize how the odds of achieving food security were greater in nutrition program participants (OR = 1.65; 95% CI = 1.10, 2.48) when compared with those who were on the program waitlist [110]. A similar longitudinal study among older adults in the northeastern U.S. ($n = 101$) tracked how the home-delivered meals aspect of the OAANP impacted food security status over time, which yielded results indicating that food insecurity was reduced from baseline to six-months ($D = -0.102$; $p < 0.01$) and baseline to 12-months ($D = -0.154$; $p < 0.01$) [111].

Case-control research involving a natural quasi-experiment among households in the northeastern U.S. ($n = 831$) focused on the impacts of a new supermarket in a low-income food desert, which detected reductions in food insecurity among households in the neighborhood with the new supermarket in comparison to those from a separate low-income neighborhood that was also located in a food desert ($D = -11.8$; $p < 0.01$) [112]. Separate research used a mobile grocery truck to target nutritional outcomes Native American households in the southwestern U.S. ($n = 101$), and found that the intervention had no effect on household food insecurity prevalence from baseline (57%) to follow-up (43%) ($p = 0.29$) [113]. A cluster randomized controlled trial among households with children in the southern U.S. ($n = 2859$) sought to identify whether home delivery of a monthly food box containing healthy food could improve food security over the span of 12 months [114]. Results derived from this research suggested that the prevalence of adult ($D = -2.8$; $p = 0.002$) and household ($D = 2.4$; $p = 0.003$) food insecurity at 12-months was lower among participants in the intervention group than to those in the control group [114].

Another cluster randomized controlled trial among parent-child dyads in the southern U.S. ($n = 371$) tested the extent to which an educational nutrition program impacted household food insecurity [115]. Results indicated larger decreases in the proportion of food insecure participants within the intervention group at the immediate post-intervention ($D = -0.32$, SE = -0.07 ; $p = 0.002$) and two-year post intervention ($D = -0.49$, SE = -0.22 ; $p < 0.001$) in comparison to those in an active control group that received a different educational program intervention [115]. An intervention study among parents of young children in the northeastern U.S. ($n = 372$) examined whether trauma-informed programming could promote household food security through lessons provided to participants that focused on emotional management, financial skills, and social and family dynamics [116]. Findings from this study indicated that participants with full participation in the trauma-informed program had lower odds of household food insecurity (OR = 0.45; 95% CI = 0.22, 0.90) in comparison to those with little-to-no participation [116]. A community-based participatory research project among Hispanic farmworker families in the western U.S. ($n = 131$) implemented a community gardening intervention involving the provision of seeds for planting and educational sessions on cultivating fruits

and vegetables, which resulted in a reduced prevalence of food insecurity among participating families (Baseline = 15.6%, Follow-Up = 3.1%; $p = 0.006$) [117].

A research intervention among families residing in motel-shelters ($n = 33$) tested whether rescuing surplus food from colleges could promote household food security, and found a non-significant difference in changes of food security scores existed between the intervention group that received meals and the control group that did not receive meals ($D = 2.2$; $p = 0.63$) [118]. A study examining the impact of a federal food-box delivery program on the food security status of low-income older adults in the northeastern U.S. ($n = 93$) determined that the program reduced the prevalence of food insecurity among participants receiving the intervention at senior housing (Baseline = 84.4%, Follow-Up = 48.9%; $p < 0.001$), while the food security status of those who had to retrieve the food boxes from local food pantries was unchanged (Baseline = 85.1%, Follow-Up = 78.8%; $p = 0.37$) [119]. Intervention research among older adults in the southeastern U.S. ($n = 51$) examined whether a program that provided three home-delivered meals per week promoted food security, and discovered that the intervention improved the food security status of participants over the span of two months (Baseline = 59.7%, Follow-Up = 78.4%; $p < 0.001$) [120].

An intervention study among adults with diabetes in the northeastern U.S. ($n = 44$) tested whether providing home delivery of 10 meals per week could improve outcomes for both healthy eating and food security [121]. Outcomes from this study highlighted a lower prevalence of food insecurity among intervention group participants (42%) than those who were in the control group (62%) ($p = 0.047$) [121]. A research intervention among medical clinic patients in the southern U.S. who had at least one chronic disease ($n = 43$) evaluated whether providing a monthly food box, one nutrition education booklet, and five meal recipes could improve food security [122]. Results from this research indicated that no significant changes in food security occurred during the intervention [122]. Additionally, another research intervention among medical clinic patients in the southern U.S. ($n = 172$) tested the extent to which food insecurity could be alleviated through a food prescription program involving the distribution of nutrition education materials along with 30 pounds of fresh produce and nonperishable food items every two weeks for up to 12 food pantry visits [123]. Findings from this study suggested that the program drastically reduced the prevalence of food insecurity among participants from 100 percent at baseline to 5.9 percent immediately following the nine-month intervention ($p < 0.01$) [123].

Synopsis

Despite the abundance of governmental and non-governmental approaches being taken to promote food security, millions of American households experience food insecurity every year. The compiled research evidence from this literature review indicates how most research interventions yielded favorable outcomes, yet the collective magnitude of these interventions' impact still falls short in eliminating hunger in the world's wealthiest country. Most food insecurity interventions included monetary assistance via SNAP or income supplements, food pantry-related efforts (i.e., food choice, cooking classes), or food delivered to homes (i.e., food boxes, meals). Only one food insecurity intervention study was identified that applied a food rescue and redistribution approach for alleviating food insecurity. Therefore, an urgent need remains for the creation and testing of innovative, far-reaching approaches to preventing food insecurity. Most importantly, it is necessary that these approaches be scalable and capable of widespread impacts in the U.S. with potential for international replication.

4. Future Directions

While widespread food insecurity persists in the U.S., approximately 30 percent (66.5 million tons) of edible food is wasted after leaving the farm every year [126]. A combined snapshot of this seemingly paradoxical food insecurity and food waste problem is underscored in a report by the Food and Agriculture Organization of the United Nations that estimates 900 million people worldwide are undernourished and food insecure despite

roughly 1.3 billion tons of food going to waste annually [127]. The untapped potential of food rescue and redistribution programs could turn the problem of excessive food waste into a sustainable solution for alleviating food insecurity among vulnerable people groups in the U.S. who are at the greatest risk of diet-related chronic diseases. Widespread establishment of food rescue and redistribution partnerships between food assistance entities and grocery stores, cafeterias, and restaurants would carry the possibility of mitigating consumer, corporate, and organizational food waste while providing individuals who are food insecure with much needed nutritious food [128].

Addressing the problem of food waste would not only alleviate food insecurity [53], but it would drastically reduce greenhouse gas emissions that are both harmful to our environment and contribute to climate change [129,130]. Recent estimates suggest that 15 percent of municipal solid waste in the U.S. consists of food waste [131], and food waste in landfills produces methane, a greenhouse gas with 28 times the global warming potential of carbon dioxide [132]. It is therefore posited that each U.S. resident wastes enough food each year to produce 315 pounds of carbon dioxide equivalent, which amounts to 28 percent of all landfill greenhouse gas emissions [133]. Further evidence indicates that more than 25 percent of agricultural fresh water and 4 percent of oil in the U.S. is used to cultivate food that is eventually wasted [134].

It is critical for the U.S. congress to authorize and fund the comprehensive food waste prevention efforts of prominent organizations, like the USDA's TEFAP, which is actively promoting Farm to Food Bank projects. These projects are intended to decrease food waste at the agricultural production, processing, and distribution level through by donating food to entities that provide food assistance to individuals experiencing food insecurity [135]. Separately, the USDA's National Institute for Food and Agriculture (NIFA) is investing \$15 million in funding for competitive grant programs geared toward the establishment of partnerships between food producers, providers, food recovery organizations, and food assistance organizations [135]. The primary objective of these food waste prevention efforts is the formation of an inter-organizational cooperative that can effectively prevent both food waste and food insecurity in communities throughout the U.S.

Outside of the partnerships that various food banks establish with grocery stores in their communities for food rescue operations [136], there has been just one known evidence-based research intervention that aimed to reduce food waste with a primary intention of getting rescued food into the hands of individuals who were food insecure [118]. Given the continual squandering of natural resources resulting from food waste and the consequential negative environmental impacts, it is urgent that feasible approaches to prevent consumer food waste and promote food security are identified and evaluated for broader implementation. Unrelatedly, other innovative approaches to promoting food security that require further support include the novel 'food is medicine' field of nutrition security research, which includes produce prescription programs and medically tailored meals that are imperative for addressing public health problems (e.g., overweight/obesity, type 2 diabetes, heart disease) related to, and exacerbated by, food insecurity [137].

5. Conclusions

Eliminating barriers to food access is essential for mitigating the problem of food insecurity. It is critical that a greater priority be placed on eliminating food insecurity with approaches that involve reducing food waste through effective food rescue and redistribution programs. Food security promotion enhances public health through the prevention of chronic diseases that result from poor diet, nutritional deficiencies, and hunger. Rescuing edible, nutritious food and distributing it to individuals who are food insecure can promote both environmental and public health through simultaneous reductions in food waste and food insecurity.

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