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# A Mixed-Methods Approach to the Development of a Disaster Food Security Framework

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## ARTICLE INFORMATION

### Article history:

Submitted 25 August 2022  
Accepted 1 May 2023

### Keywords:

food security  
disasters  
framework  
hurricane  
COVID-19

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<https://doi.org/10.1016/j.jand.2023.05.005>

## ABSTRACT

**Background** Limited research on food systems and food insecurity (FI) following disasters finds contextual differences in post-disaster food systems that shape dimensions of FI. Measurement limitations make it difficult to address FI and develop effective practices for disaster-affected communities.

**Objective** To develop, validate, and test a Disaster Food Security Framework (DFSF).

**Design** Mixed-methods approach was used, including in-depth interviews to understand lived experiences during disasters; expert panel input to validate DFSF designed using responses from in-depth interviews; and quantitative testing of robustness of DFSF using the coronavirus disease 2019 pandemic as a disaster example.

**Participants and setting** The in-depth interviews included participants from Vermont (n = 5), North Carolina (n = 3), and Oklahoma (n = 2) who had been living in those states during Hurricane Irene (2011), Hurricane Florence (2018), the Moore tornadoes (2013), and coronavirus disease 2019 pandemic (2020). The expert panel consisted of researchers and practitioners from different US geographical regions and food-related disciplines (n = 18). For the quantitative testing survey, data from 4 US states (New York, New Mexico, Vermont, and Maryland; n = 3,228) from the National Food Access and COVID Research Team was used.

**Main outcome measures** The outcomes from the in-depth interviews were dimensions of disaster FI, those from the expert panel was a content validity ratio, and those from the quantitative testing was the number of items and components to be included.

**Analyses performed** Inductive and deductive reasoning were using when reporting on the in-depth interviews and expert panel results, including frequencies. The quantitative testing was conducted using multiple correspondence analysis.

**Results** The in-depth interviews revealed four dimensions of FI: availability (supply and donation), accessibility (economic, physical, and social), acceptability (preference and health), and agency (infrastructure and self-efficacy). The panel of experts reported high content validity for the DFSF and its dimensions (content validity ratio >0.42), thus giving higher credibility to the DFSF. Multiple correspondence analysis performed on 25 food-related variables identified one component with 13 indicators representing three of the four dimensions: availability, acceptability, and accessibility, but not agency.

J Acad Nutr Diet. 2023;123(10S):S46-S58.

**D**ISASTERS AND ENVIRONMENTAL DISRUPTIONS are increasing in frequency and intensity due to climate change.<sup>1,2</sup> Although there is a growing body of research on food security, there is little research in disaster settings.<sup>3-5</sup> The limited research conducted post-disaster shows that although disasters range tremendously in form and impacts, they share distinct contextual differences that shape dimensions of food insecurity not captured with

current food insecurity metrics.<sup>4,6</sup> The Food and Agriculture Organization (FAO) states that food security is a multidimensional concept that includes availability, accessibility, utilization, and stability over time.<sup>7</sup> The United States Department of Agriculture (USDA) describes food security as “consistent, dependable access to enough food for active, healthy living.”<sup>8</sup> In the United States, the USDA developed the Household Food Security Survey Module (HFSSM) to assess and monitor food insecurity. The HFSSM is a single-dimensional measure that is considered the gold standard for measuring food insecurity severity and has been adapted for use in different cultural contexts.<sup>9,10</sup> Current validated

## Statement of Potential Conflict of Interest

See page S58.

metrics provide no guidance on dimensions of food insecurity within disaster settings. Disasters create widespread disruption to the social, built, and natural environments.<sup>11</sup> For example, access in the FAO and USDA conceptualizations focus primarily on financial resources for food, which misses important physical barriers to food access that are common in a disaster context when the built and natural environment are destabilized, such as damaged roads and personal vehicle loss. Without reliable data on food accessibility, availability, acceptability, and agency for households experiencing disruptions (eg, hurricanes and pandemics), it is difficult to measure food insecurity and develop effective supports for affected individuals. This is becoming increasingly important as global climate change is increasing the frequency and severity of disaster events.<sup>2</sup>

The USDA HFSSM was designed to assess food security, focusing on financial resources, and the severity<sup>9,10</sup>—and does this well. However, the current metric excludes aspects of food insecurity important for understanding health in a disaster context: physical barriers to food, access to appropriate foods for times of disruption, changes in food availability and utilization, and high levels of uncertainty and fear that may accompany food access during disasters. Measuring only household financial aspects of food insecurity limits our understanding of the causes of food insecurity to pecuniary drivers and limits interventions to those that address monetary barriers to food access. The HFSSM has been used in disaster contexts<sup>12,13</sup> despite the unique food security challenges presented, such as ensuring sufficient calories and dietary quality amid disruption to infrastructure, supply chains, and organizational and social systems.

The 2019 novel coronavirus disease (COVID-19) pandemic presented an opportunity to study periods of disruption and dimensions of food insecurity not captured with the HFSSM. The effects of the pandemic on the food system were widespread, influencing all parts of the food chain and the entire US population. Stay-at-home orders and social distancing presented physical barriers to food sources; supply chains struggled to adapt resulting in disruptions to food availability;<sup>14–17</sup> and many items, such as meat and shelf-stable foods, became difficult to find.<sup>18–21</sup> Safety became a concern when grocery shopping, which highlighted the fear about the virus in addition to food supplies.<sup>18,21</sup> Food availability was further disrupted by virus-related uncertainty and news reports of so-called panic buying.<sup>17</sup> Following natural hazard events, additional types of disruptions influence food security. For example, following a hurricane, people may experience physical barriers to food from flooded roads or damaged transportation, damaged homes and kitchens influence household food storage and preparation capacity, closed or damaged grocery stores temporarily reduce food availability, and/or limited food options through emergency feeding operations that may not meet dietary or cultural needs.<sup>4,6</sup> Whereas the specific patterns of disruptions to food security vary by disaster type, the disruptions share common themes. Further, disasters and public health emergencies magnify existing social and economic inequalities that may result in increased financial constraints.<sup>22</sup>

Chodur and colleagues<sup>23</sup> developed a fault tree model to analyze food system vulnerabilities in light of threats and emergencies like climate change, epidemics, civil unrest, or war. The model outlines paths by which hazardous events

## RESEARCH SNAPSHOT

**Research Question:** What are the key components that constitute food insecurity when preparing for, coping with, or recovering from disasters and public health emergencies?

**Key Findings:** Four main food challenges were identified and included in the disaster food security framework: availability (food supply and donations), accessibility (physical, social, and economic), acceptability (health and preference), and agency (infrastructure and self-efficacy).

can disrupt food systems and security, ranging from basic (eg, road closures) to intermediate (eg, disrupted food distribution). They broadly classified food system failures into accessibility, availability, and acceptability.

The present study builds on Chodur and colleagues<sup>23</sup> model to create and validate a framework for household food insecurity for disasters. The USDA HFSSM serves an important purpose for monitoring national progress on addressing food insecurity and for comparisons over time. It also serves an important role in providing a stable measure over many decades for monitoring the influence of federal nutrition assistance programs such as the Supplemental Nutrition Assistance Program. New measures that focus in on specific populations or contexts can increase surveillance capacity and provide important, actionable information. Measuring a broad range of barriers to household food security in a disaster context can identify specific types of disruption experienced at the household level as an indicator of food system disruption to support a broader range of food insecurity interventions across the food system. This study leverages survey data from the National Food Access and COVID Research Team (NFACT)<sup>13</sup> to test the framework quantitatively. This manuscript presents the process and results of the first phase of the development and validation of a disaster food security scale (DFSS): Development of Disaster Food Security Framework (DFSF). This framework will be used to inform the next steps in developing the DFSS such as questionnaire development, cognitive testing of the survey questionnaire, and the eventual validation of the scale meant for assessing food insecurity during disasters and emergencies.

## METHODS

The development of the DFSF was implemented in multiple phases. A detailed summary of all phases is available elsewhere.<sup>24</sup> This article presents results from Phase I: Development, Validation, and Testing of a DFSF. Phase I defines disaster food insecurity, identifies disaster food insecurity dimensions, establishes a framework and definition to illustrate the components of food insecurity in the disaster and emergency setting, and validates the framework and definition.

### In-Depth Interviewing with Target Population

**Sample Selection.** A convenience sample of 10 individuals with past disaster experience from Vermont, North Carolina, and Oklahoma were selected to participate in in-depth interviews. Participants were recruited from a pool of individuals who participated in previous disaster studies (Irene in 2011, the Moore tornadoes in 2013, Hurricane Florence in

2018, and COVID-19) to capture a range of hazard types and experiences with food insecurity. The pool of participants consisted of contact information for 30 individuals from North Carolina, 24 from Oklahoma, and 18 from Vermont. Participants were contacted through e-mail messages and telephone calls. Of those from North Carolina, 3 completed an interview, 6 were unreachable, 16 were unresponsive, and 5 refused. Of those from Oklahoma, 2 completed an interview, 3 were unreachable, 13 were unresponsive, and 6 refused. Of those from Vermont, 5 completed an interview and 13 participants refused.

**Semistructured Interviewing Process.** Qualitative interviews were conducted in April and May 2022 (by co-author N.K. with three note takers). The main interviewer was trained in qualitative design methods and interviewing techniques by the Disaster Health Research Lab at the University of Maryland Baltimore County. A semistructured interview guide was used.<sup>24</sup> The guide was developed by the research team based on the food insecurity framework by Chodur and colleagues<sup>23</sup> and existing definitions of food insecurity from the FAO<sup>8</sup> and the USDA.<sup>25</sup> Participants were invited to complete the interview virtually via online conference calls (WebEx) or via telephone calls. A verbal informed consent process was completed before commencing the interview. All interviews were recorded. Participants received an incentive of a \$20 grocery store gift card.

**Analysis and Interpretation.** Each interview was transcribed in Webex and by the lead interviewer, then imported and analyzed in NVIVO Pro.<sup>26</sup> An inductive and a deductive approach was used to identify the dimensions of food insecurity described by participants, as well as their definitions of food security. The first and second reviewer went through the interviews independently and assigned themes to minimize bias. After assigning themes independently, both reviewers met to discuss agreements and reconcile disagreements, if any. Statements were grouped thematically by food insecurity dimension. Following analysis, a framework was drawn to represent aspects of food insecurity in disasters and a definition of disaster food security was developed.

### Validation by Experts

**Survey to Establish Content Validity.** Following the in-depth interviews to create a draft of the DFSF, an online survey via Qualtrics<sup>27</sup> was conducted to evaluate framework content validity and the definition of disaster food security. The survey asked about field of expertise and years of experience, adequacy of proposed food insecurity dimensions and the complete framework, and adequacy of draft definition of disaster food security. The survey tool is available online.<sup>24</sup>

**Expert Participant Selection and Sample.** A purposive sample of 24 professionals from different geographies, disciplines, and organizations were identified to complete the content validity survey. This expert group consisted of academic researchers, food security experts, nutritionists, disaster researchers, and food assistance professionals.

**Statistical Analysis.** Descriptive statistics were computed to report frequencies and percentages for the distribution of responses by category for each food insecurity dimension in

the DFSF. A content validity ratio (CVR) was calculated for each dimension and subdimensions. The CVR is an item statistic recommended for the rejection or retention of specific items.<sup>28</sup> Next, a content validity index (CVI) was computed; this is the mean of the CVR values of the dimensions and subdimensions. Here, CVI represents the extent to which the DFSF and its components are a valid representation of food insecurity in disaster settings as determined by the experts. In addition, a CVR was calculated for the complete framework and for the disaster food security definition. To assess content validity, cutoffs proposed by Lawshe<sup>28</sup> were used. For a sample of 15 experts, the minimum value cutoff is 0.49 and for 20 experts, the minimum value for cutoff is 0.42. The present analysis used a cutoff of 0.42 as the minimum ratio for validity.

**Qualitative Analysis.** Answers to the open-ended questions were examined to extract information that would improve the DFSF and definition. The feedback was summarized and used to refine the framework and definition. The refined framework and definition were presented to a scientific advisory group consisting of six academics, researchers, and those with field expertise. Consensus was reached where all members of the scientific advisory group reported agreement.

### Testing with NFACT

**Study Setting and Population.** COVID-19 was chosen as a contemporary public health disaster to quantitatively test the robustness of the DFSF and its dimensions, recognizing that further testing with additional disasters is warranted. The data comes from NFACT surveys, a multistate research effort to understand food access during COVID-19.<sup>13</sup> Surveys were conducted during 2020 after the United States declared a state of emergency due to the severe acute respiratory syndrome coronavirus 2 outbreak. Each state and organization using the NFACT survey adapted the questionnaire to suit their respective state needs. Survey data from Arizona, Connecticut, Maryland, New Mexico, New York, and Vermont were considered, but only 4 states (Maryland, New Mexico, New York, and Vermont) included relevant and corresponding variables that could be used for the purposes of this analysis (state-specific methodology is available elsewhere).<sup>13</sup> Briefly, Maryland, New Mexico, and Vermont sampled the general population and New York sampled populations with higher prevalence of food insecurity, including low-income households and racial and ethnic minorities. New Mexico and Vermont used a convenience sampling method, whereas Maryland and New York used representative samples with a survey panel from Qualtrics.<sup>27</sup> These states were selected because they implemented common food access questions that could be pooled to capture different dimensions of food insecurity.

**Data Collection.** Data for the present study were obtained through membership in NFACT and a Data Use Agreement (Award No. 001562-00001).

**Statistical Analysis.** NFACT survey data were examined to extract items suitable for use as proxy indicators of the food security dimensions identified in the DFSF. Only items present in all state surveys were considered. A multiple correspondence analysis (MCA) was performed on items to

identify those best representing food insecurity in disaster and emergency settings. MCA is a modified version of exploratory factor analysis or principal component analysis that is designed for categorical variables rather than continuous variables.<sup>29</sup> Analyses were conducted using Stata version 17<sup>30</sup> for descriptives and R version 4.0.3 FactoMineR<sup>31</sup> and PCAmix<sup>32</sup> packages were used for factor extraction and rotation.

First, the distribution of variables in the pooled sample of participants was summarized using frequencies and percentages for each variable category. Variables with categories reporting frequencies of  $\leq 5\%$  or  $\geq 95\%$  were excluded due to insufficient variation.<sup>33</sup> Variables with  $>20\%$  missing data were also excluded. Second, polychoric correlations were performed on all selected variables.<sup>33,34</sup> Variables indicating negative correlations with other variables were either reverse coded, if appropriate, or dropped from the analysis. Variables with low interitem correlations ( $\rho < 0.05$ ) were dropped. Kaiser-Meyer-Olkin statistic for the measure of sampling adequacy<sup>35</sup> and Bartlett test of sphericity for interitem correlation<sup>36,37</sup> were performed to ensure robustness of factor analysis with the selected variables. MCA with the Burt matrix was performed on the remaining variables.<sup>38</sup> Scree plot was used to select the number of dimensions for extraction. Factor extraction using orthogonal (varimax) rotation was performed to explore correlation between dimensions. Dimensions were extracted and named based on the variables with factor loadings  $\geq 0.30$ .

## Institutional Review Board Approval

This research was approved by University of Maryland Baltimore County (protocol No. 000908) and University of Vermont (protocol No. 000873) and secondary data were accessed through a Data Use Agreement (award No. 001562-00001) with NFACT at the University of Vermont.

## RESULTS

### In-Depth Interviews

Ten participants completed interviews: Three from North Carolina, 2 from Oklahoma, and 5 from Vermont; 3 were men and 7 were women; and 4 were retired, 4 were in full-time employment, and 2 were in part-time employment. Interviews lasted between 30 and 45 minutes. Four domains emerged from experiences of food insecurity following disaster exposure: accessibility, acceptability, lack of utilization, and availability. Table 1 summarizes the number of participants who reported challenges in specific food security domains during COVID-19, Hurricanes Irene (2011) and Florence (2018), and the Moore Tornadoes (2013).

### Food Security Definition

All participants were asked what food security means to them. Almost all participants used statements like “always having something in the pantry” (dfss463) and preference such as “healthy food” (dfss854, dfss542) or “food the family enjoys eating” (dfss196). Others also reported on diversity so that “we wouldn’t have to go, you know, just eating beans for weeks” (dfss658). Some respondents defined food security as having food that is “decent” (dfss196), “organic,” (dfss943, dfss463) or “locally grown” (dfss463). For some, food secure meant food being “affordable” (dfss658), “within our budget”

**Table 1.** Food insecurity themes identified as negative lived experiences in disaster settings by 10 participants from North Carolina, Oklahoma, and Vermont during individual in-depth interviews carried out between April and May 2022

Theme	No. of participants <sup>a</sup>
<b>Acceptability</b>	8
Needs/preference	6
Nutrition	8
<b>Accessibility</b>	8
Economic <sup>b</sup>	5
Physical	6
Social <sup>c</sup>	5
<b>Utilization</b>	7
Agency	7
<b>Availability</b>	10
Supply	9
Assistance	1

<sup>a</sup>The total number of participants do not always add up to 10 because some participants did not report on some of the themes and others reported on multiple themes.

<sup>b</sup>That is, affordability.

<sup>c</sup>Including emotions.

(dfss768), having the “ability to pay for [food]” (dfss196), having “enough to be able to share” (dfss196, dfss463), “going out to eat” (dfss906), “not worrying about obtaining food on a regular basis” (dfss107), and the certainty of obtaining “whatever groceries I need” (dfss943). Participants mentioned that to be food secure, people needed transportation as a resource to access food and food being available at home (dfss196, dfss542). Food security was also described in terms of being “able to prepare the food” (dfss196), having the “ability to do whatever is needed to process it [food], cook it, get it on the table” (dfss658), being “able to replace [food] once you use [the food]” (dfss196) and that “there’d be things available” (dfss943) for purchase.

### Accessibility

**Economic Access.** Many participants reported issues with food affordability during disasters. For example, when talking about food experiences during the pandemic, one respondent (dfss658) stated: “So, instead of canned beans, I was actually cooking a bag of beans because they were cheaper.” That participant further explained: “Suddenly losing \$6,000 a year, or an income that I previously had, affected the ability to buy food.” Another respondent (dfss768) described:

*Sometimes we end up spending more money than we intended because the thing that we wanted was out of stock and so it's like [buying] whatever we can find.*

There were also pandemic-specific considerations, such as the need to store extra food in case of quarantine that affected the economic access to food. One respondent (dfss768) noted that buying more food to last 2 weeks “was a cost issue for us.”



**Physical Access.** Many respondents reported that the pandemic upended their physical access to food stores. One respondent (dfss196) highlighted how the systems in place at stores during the pandemic were restrictive to those who did not drive, particularly the elderly:

*... food insufficiency was not because of money, but because they couldn't get to the food they needed. [Supermarkets] were open and mostly for drive-through pickup. The problem was there were elderly people who do not drive.*

Others (dfss196, dfss854) noted how the systems meant to make food more physically accessible during the pandemic were not adequate:

*What did not work for us here was the delivery services. We tried to order from Instacart and it would not deliver here. (dfss196)*

Some participants (dfss542, dfss463, dfss107, dfss906) reported changing their in-person shopping behaviors by changing grocery stores or shopping hours for safety such as social distancing or masking. For example, one respondent explained:

*I went further to get food because we're very rural here and the closest grocery store was not doing a good job with masking and those types of things. (dfss463)*

**Social Access.** In this subdimension, participants described social dining and feelings or emotions associated with the social aspect associated with food. Participants (dfss463, dfss658, dfss768) explained how the pandemic affected their social life that often centered around food and cooking:

*You just didn't even get [the] opportunity to cook for other people and enjoy that sharing part of it, and that was definitely an emotional stress. (dfss768).*

Participants described other emotions related to food experiences caused by the pandemic. One participant (dfss463) expressed anxiety and fear about food:

*I just remember being very anxious about food... I was deeply concerned and fearful that my life was gonna shift dramatically and I was gonna go hungry and not enjoy eating and, um, you know, it was just this very [deep] seated fear.*

Several other respondents (dfss906, dfss196, dfss463, dfss658, dfss768) additionally reported feeling uncertain about food availability:

*I think the biggest concern and worry was that if we used up what we purchased and had on hand, since we didn't have our freezer and refrigerator stocked, um, that we wouldn't be able to find it again. (dfss196)*

## Acceptability

**Health.** Several respondents (dfss854, dfss463, dfss768, dfss906, dfss943, dfss196) stated that there was "not much to pick from" (dfss906) or "there was less of a selection" (dfss854) of food in grocery stores showing a lack of food diversity that could indicate nutrition insecurity. Whereas

nutritional quality may be a lower priority in an acute crisis, in a longer-term disaster, lost nutritional value increases in importance. In addition, some respondents (dfss542, dfss463, dfss768, dfss943) with dietary restrictions were unable to meet their needs for alternative products, such as nondairy milks for those with lactose intolerance. One participant (dfss542) noted:

*My personal diet was more limited because of health stuff. So, making sure that I was getting what I was able to eat was kind of tricky.*

Concerns over food safety were also mentioned particularly with respect to fresh produce. During the pandemic, the worry was that food packages and fresh produce would contain the infection agent. Although Hurricane Irene did not hit her home directly, one respondent (dfss854) said:

*I know a lot of people were getting Escherichia coli and I did too 'cause so much stuff was flooding into water supplies."*

**Preference.** Six participants (dfss906, dfss943, dfss854, dfss542, dfss463, and dfss196) reported not being able to find preferred food items and had to substitute with unfamiliar items. The magnitude of preferred food inaccessibility varied. One respondent (dfss854) remarked:

*You weren't going to starve, but I couldn't get certain things I wanted to cook with or that I used all the time or just liked.*

Another respondent (dfss463) described:

*I was a little concerned about the quality of the food, because we had to compromise and not buy local organic.*

Finally, respondent dfss854 stated:

*You couldn't get a lot of frozen vegetables or normal stuff that you'd eat—just oddball things.*

## Utilization

**Agency.** Some participants reported that although they were able to find and purchase food, they experienced challenges in making use of the food that was available during the postdisaster period. For example, one participant (dfss768) described how having a small kitchen made it difficult to undertake the more extensive preparation required for the foods they could obtain at that time. Another example with respect to cooking was described by respondent dfss196 as follows:

*I went to take out a big Dutch oven and realized, oops, we don't have one anymore... [We] went to the stores to buy to replace pots pans. We had to replace our blender, our food processor, our Kitchen Aid mixer, the big stand mixer. Some of them were in storage and they didn't survive storage [during Hurricane Florence].*

The challenges with the ability to use food was defined differently in the aftermath of hurricanes and tornadoes. The main issues identified by respondents dfss196, dfss107, dfss906, dfss943, and dfss658 were power loss that resulted in spoilage of refrigerated or frozen items and inability to use

stoves or microwaves for making food. One participant (dfss107) noted:

*Immediately after the hurricane, we had to cook on the gas grill... because the electricity was out. That was the immediate aftermath and any food that was in the freezer was lost.*

### Availability

**Supply.** Almost all participants reported food supply availability issues regardless of the hazard type. One respondent (dfss943) explained:

*For a while our food store, which was at the end of this 6-mile road, got flooded. So, it didn't have any refrigeration for food there for a while. You know, they just had stuff that was on the shelves.*

Another participant (dfss658) shared:

*The thing I remember the most was a lot of empty shelves, so being unable to actually find the things that I needed. There wasn't a lot of things. At the time, since there was such a shortage, we had very little food in the house.*

**Assistance.** Of 10 participants, only one reported applying for federal food assistance during the pandemic. They did not qualify for federal assistance but received food bank and state food program assistance. The participant (dfss658) commented about food assistance:

*Those monthly food boxes were a godsend. If you want, they were very valuable just providing some basics that you could use and, you know, when you're trying to stretch, those are incredibly useful.*

More participants (dfss943, dfss196, dfss107) had positive recollections about their experience with food assistance during hurricanes and tornadoes than during COVID-19:

*I think we ate more of the foods we were able to get from the contributions to the food bank. We depended on that, because they did provide us with some variety that we might not have had otherwise.*

### Framework Validation by Experts

**Participant Characteristics.** Of 24 invited experts, 18 completed the survey (75% response rate). The experts had 10 to 40 years of experience in their respective fields. Some of the experts did not rate all the dimensions and subdimensions. The majority of expert participants rated the dimensions, subdimensions, framework, and definition as adequate (CVR >0.42 for all values). The calculated CVI (>0.42) indicated all components of the framework were adequate and valid representations of food insecurity in disaster settings (Table 2).

**DFSF.** The framework was designed to illustrate dimensions and subdimensions described in the previous section from in-depth interviews with disaster-affected populations. Comments for the DFSF were positive. One expert suggested validating the framework for different hazards. Some descriptions of the DFSF were "important," "good," and

**Table 2.** Descriptive and content validity statistics for evaluation of Disaster Food Security Framework by experts (n = 18)

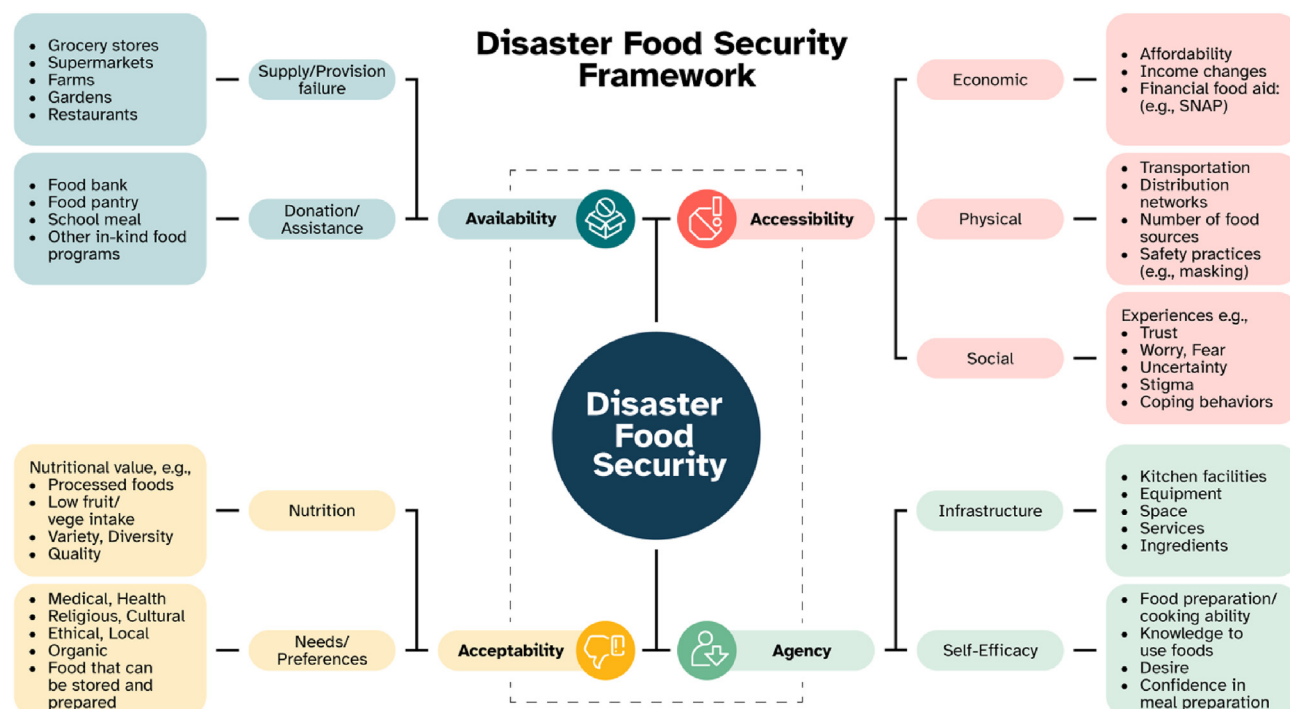
Category	Adequate	Inadequate	Total	CVR <sup>a</sup>
	← n (%) →		n	
<b>Dimension</b>				
Availability	16 (94.1)	1 (5.9)	17	0.88
Accessibility	15 (88.2)	2 (11.8)	17	0.76
Acceptability	16 (94.1)	1 (5.9)	17	0.88
Utilization	16 (94.1)	1 (5.9)	17	0.88
<b>Subdimension</b>				
Food supply failure	15 (93.8)	1 (6.3)	16	0.88
Food assistance failure	15 (88.2)	2 (11.8)	17	0.76
Economic accessibility	15 (88.2)	2 (11.8)	17	0.76
Physical accessibility	15 (88.2)	2 (11.8)	17	0.76
Social accessibility	15 (88.2)	2 (11.8)	17	0.76
Health acceptability	15 (88.2)	2 (11.8)	17	0.76
Preference acceptability	16 (94.1)	1 (5.9)	17	0.88
Agency	13 (76.5)	4 (23.5)	17	0.53
<b>CVI<sup>b</sup></b>	0.79			
<b>Framework</b>	17 (94.4)	1 (5.6)	18	0.89
<b>Definition</b>	14 (77.8)	4 (22.2)	18	0.56

<sup>a</sup>CVR = content validity ratio, an item statistic recommended for the rejection or retention of specific items. Any value above 0.42 should be retained.

<sup>b</sup>CVI = content validity index, which represents the extent to which the disaster food security framework and its components are a valid representation of food security in disaster settings. Values above 0.42 indicate adequacy.

"complete." The Agency subdimension received the least number of adequate ratings and has the lowest CVR (Table 2). Comments from the expert validation survey also indicated confusion related to the term *utilization*, which refers primarily to nutrition in the FAO definition; therefore, the dimension Lack of Utilization was modified to Agency as a dimension with two subdimensions: Infrastructure and Self-efficacy. Infrastructure covers equipment (eg, stove and refrigerator) and services (eg, water and electricity) needed to safely prepare and store foods. Self-efficacy refers to the ability to utilize available resources to obtain and prepare foods. These changes are reflected in the Figure.

**Disaster Food Security Definition.** The experts were given a disaster food security definition: "All people have physical, social, and economic access to sufficient, safe, and nutritious food that can be utilized to meet their dietary needs and food preferences when preparing for, coping with, and recovering from a disaster." Comments related to the definition were positive with most of the experts agreeing with the framing of the definition. One expert with 10+ years of experience in social, cultural, and behavioral factors related to food choices and nutrition policy noted that the definition "aligns well



**Figure.** Disaster Food Security Framework (DFSF).<sup>a</sup> Framework builds upon work of Chodur and colleagues.<sup>23</sup> SNAP = Supplemental Nutrition Assistance Program.

with the international definition of food security, which to me is important.” Two experts, one with 40 years of experience in food insecurity research and another with 10 years of experience in disaster research noted that “agency is explicit in the framework but only implicit in the definition.” Two disaster experts suggested that an element of time be included in the definition because immediately after a disaster “tolerances and perceptions of social obstacles to food access for instance may be different than when 6-months into the recovery.” Based on this feedback, the disaster food security definition was refined to: “All people have physical, social, and economic access to sufficient, safe, and nutritious food that can be prepared and stored to meet their dietary needs and food preferences while preparing for, coping with, and recovering from a disaster.”

### Multiple Correspondence Analysis with NFACT Data

Of 33 food-related variables identified from NFACT surveys, six were excluded due to missing data and two were removed due to negative correlations. The remaining 25 variables were used in this analysis (Table 3). After excluding participants with none of the relevant variables and participants with missing data, the sample included 3,228 participants from four states: New York, Vermont, Maryland, and New Mexico. Participant demographic characteristics are summarized in Table 4. One-third of participants from the pooled surveys were men and more than half were White. About one-quarter of respondents were Hispanic, had children, or lost their job during the COVID-19 pandemic. The majority had at least some college education or earned \$25,000 or more per year in 2019.

The Kaiser-Meyer-Olkin statistic at 0.93 and the Bartlett test of sphericity at  $P < 0.05$  both indicate adequacy of the 25 variables for factor analysis. The scree-plot of eigenvalues suggested one relevant dimension that accounted for 63.9% of the total variance in the variables. Thirteen variables loaded at  $\geq 0.30$  onto the dimension representing disaster food insecurity (Table 5). Some questions from the 6-item HFSS Module were also included. Together these 13 variables were found to represent three of the four dimensions illustrated in the DFSF (ie, availability, acceptability, and accessibility). The Agency dimension and its subdimensions (Infrastructure and Self-efficacy) were not represented.

### DISCUSSION

Food insecurity during disasters and emergencies remains an understudied topic despite the essentiality of food and the increasing incidence of disasters. This study's aim was to develop and validate a disaster-specific framework for food insecurity. Having identified food insecurity experiences from those who lived through disasters and from experts who work in the field, the framework developed here highlights the multidimensionality of food insecurity when preparing for, coping with, and recovering from a disaster.

Food insecurity in the United States has been measured for 25 years by the USDA using the HFSSM.<sup>39</sup> The HFSSM captures important information on food insecurity and severity; however, it is limited to financial resources for food and severity of food insecurity. The USDA notes that the metric does not completely address the definition, notably that it does not specifically measure whether or not an individual has enough food for an “active, healthy life” as defined in the food security definition. It focuses heavily on measuring



**Table 3.** Distribution of selected disaster food experience variables reported by 3228 participants from the National Food Access and COVID Research Team survey

Food-related variables	n (%)
<b>Had challenges knowing where to find help for getting food</b>	
Never	2,260 (70)
Sometimes	506 (15.7)
Usually	276 (6.6)
Always/every time	186 (5.8)
<b>Need help with information about food assistance programs</b>	1,199 (37.1)
<b>Throw away less food than usual</b>	2,176 (67.4)
<b>Need more (or different) foods in stores</b>	2,163 (67)
<b>USDA<sup>a</sup>: Food didn't last (since COVID-19<sup>b</sup>)</b>	
Never true	2,041 (63.2)
Sometimes true	757 (23.5)
Often true	430 (13.3)
<b>USDA: Couldn't afford balanced meal (since COVID-19)</b>	
Never true	2,046 (63.4)
Sometimes true	748 (23.2)
Often true	434 (13.4)
<b>USDA: Cut size or skip meal (since COVID-19)</b>	974 (30.2)
<b>USDA: Eat less than should (since COVID-19)</b>	965 (29.9)
<b>USDA: Ever hungry (since COVID-19)</b>	801 (24.8)
<b>Extra money will help with food access</b>	1,946 (60.3)
<b>Buying a lot more items in a single trip</b>	2,202 (68.2)
<b>Need access to public transit or rides</b>	792 (24.5)
<b>Need different hours in meal programs or stores</b>	1,268 (39.3)
<b>Had to reduce number of grocery trips to avoid COVID-19 exposure</b>	
Never	468 (14.5)
Sometimes	605 (18.7)
Usually	888 (27.5)
Always/every time	1,267 (39.3)
<b>Had to go to more places than usual to find the food my household wanted</b>	
Never	961 (29.8)
Sometimes	1,324 (41)
Usually	610 (18.9)
Always/every time	333 (10.3)

(continued)

**Table 3.** Distribution of selected disaster food experience variables reported by 3228 participants from the National Food Access and COVID Research Team survey (continued)

Food-related variables	n (%)
<b>Had to stand "too close for safety" to other people, when getting food (less than 6 ft away)</b>	
Never	1,145 (35.5)
Sometimes	1,226 (38)
Usually	534 (16.5)
Always/every time	323 (10)
<b>Worry about food becoming more expensive for household</b>	2,341 (72.5)
<b>Worry food will become unsafe or contaminated</b>	1,668 (51.7)
<b>Worry that household will not be able to get or will lose access to programs that provide free food or money for food</b>	957 (29.7)
<b>Worry that there will not be enough food in the store</b>	1,596 (49.4)
<b>Worry that household won't have enough food if we have to stay at home and can't go out at all (due to quarantine or illness)</b>	1,586 (49.1)
<b>Worry about losing so much income that you can't afford food</b>	1,379 (42.7)
<b>Could not find as much food as I wanted to buy (food not in store)</b>	
Never	901 (27.9)
Sometimes	1,425 (44.1)
Usually	567 (17.6)
Always/every time	335 (10.4)
<b>Fruit and vegetable consumption during COVID-19</b>	
More or same as pre-COVID-19	2,547 (78.9)
Less than pre-COVID-19	681 (21.1)
<b>Could not find the types of food my household prefers to eat</b>	
Never	788 (24.4)
Sometimes	1,577 (48.9)
Usually	580 (18)
Always/every time	283 (8.8)

<sup>a</sup>USDA = US Department of Agriculture.<sup>b</sup>COVID 19 = Coronavirus disease 2019.

severity, primarily how frequent food insecurity occurs. Limitations of the HFSSM include its focus on capturing breadth, rather than focusing in on specific contexts or populations. Although there is benefit to this approach, the

**Table 4.** Demographic characteristics of 3228 participants from the National Food Access and COVID Research Team survey included in the multiple correspondence analysis for the Disaster Food Security Framework testing

Characteristic	n (%) <sup>a</sup>
<b>State</b>	
Maryland	645 (20)
New Mexico	1,066 (33)
New York State	511 (15.8)
New York City	454 (14.1)
Vermont	552 (17.1)
<b>Male</b>	1,003 (31.1)
<b>Race</b>	
White	1,921 (59.5)
Asian	93 (2.9)
Black	605 (18.7)
Native American	175 (7.6)
Other	305 (9.5)
<b>Hispanic</b>	799 (24.8)
<b>Age (y)</b>	
18-34	960 (29.7)
35-54	1,106 (34.2)
55+	1,156 (35.8)
<b>Education</b>	
Some high school (no diploma)	76 (2.5)
High school graduate or GED <sup>b</sup>	497 (15.4)
Some college	610 (18.9)
Associates degree or technical school	411 (12.7)
Bachelor's degree	930 (28.8)
Postgraduate degree	685 (21.2)
<b>Annual income</b>	
≤\$24,999	762 (23.6)
\$25,000-\$49,999	724 (22.4)
\$50,000-\$74,999	622 (19.3)
\$75,000-\$99,999	422 (13.1)
≥\$100,000	651 (20.2)
<b>Any children</b>	844 (26.3)
<b>Lost employment</b>	814 (25.2)

<sup>a</sup>All missing data are at <2%. Counts may not sum to 3228 due to missing data. Percentages may not sum up to 100% due to missing data.

<sup>b</sup>GED = general education diploma.

DFSf offers an additional perspective and information that is context specific. The domains identified in the validation of the DFSf add important elements of physical and social accessibility to financial accessibility and include food availability, acceptability, and agency to navigate times of disruption. The additional context-specific information

provides actionable information for agencies and organizations working to protect and restore food security in a disaster context. Postdisaster, providing additional financial resources to individuals for food is of limited benefit if they are not able to get to a grocery store or if the shelves are empty or full of food that is not usable.

The multidimensionality of food security and the complexity of its measurement have been previously discussed by the FAO.<sup>7</sup> Its report on and definition of food security recognizes four relevant dimensions: availability, access, utilization, and stability of the 3 other food security components over time. Although the DFSf dimensions align with recognized international definitions from the FAO, the specifics of the dimensions were more complex and relevant to disaster settings. First, the FAO refers to the availability dimension solely as food supply from imports and/or domestic production, whereas the DFSf extends that concept further by focusing on community-level availability. Availability was further split to create separate categories for food available via mainstream sources such as groceries, and food provided through food assistance and donation. This is because in the United States, food assistance programs, food banks, food pantries, and other food donation approaches constitute an important source of food for food-insecure households and in postdisaster settings. Second, the access dimension in the FAO definition and in the DFSf represent affordability and physical access. However, having social access to food in the FAO definition implies having access to culturally acceptable food and obtaining the food in socially acceptable ways. On the other hand, because the focus is on disaster food insecurity, social access was defined as the fears, worries, or uncertainties associated with food access in that context. Third, agency is an additional dimension in the DFSf that is not present in the FAO's. The DFSf description of agency focuses on the ability of household to prepare and safely store food, accounting for equipment (eg, stove, sink, refrigerator, and freezer), services (eg, electricity, water, and disposal), and other needs (eg, ingredients and functional kitchen) as well as self-efficacy to successfully utilize food resources. Fourth, acceptability was included as another dimension to account for health needs, dietary restrictions, preferences, and nutrition aspects in terms of quantity, quality, and safety of foods available and accessible to households. This is a component that is not wholly included in the FAO's definition, although discussions by experts do highlight that limitation.<sup>8</sup> Fifth, the element of stability was included over time by acknowledging that in the disaster context, multiple time points are important such as when preparing for, coping with, and recovering from a disaster. However, although ideally all elements of food security should be stable throughout these time points, it is recognized that in acute disaster contexts, prioritization may shift to supporting basic caloric needs and safety.

### Strengths and Limitations

A literature search showed that this is the first study undertaken to develop and validate a food insecurity framework relevant for disaster and public health emergency settings. A 3-step mixed-methods approach was used to ensure that the framework qualitatively reflects the lived experiences of people and is quantitatively representative of the disaster

**Table 5.** Factor loadings of food security experience variables from the National Food Access and COVID Research Team survey used in multiple correspondence analysis for testing disaster food security framework (DFSF)

Variable	Factor loading <sup>a</sup>	Potential DFSF dimension
Could not find as much food as I wanted to buy (food not in store)	<b>0.39</b>	Availability- Supply failure
Could not find the types of food my household prefers to eat	<b>0.34</b>	Availability- Supply failure Acceptability- Preference
Had challenges knowing where to find help for getting food	<b>0.45</b>	Accessibility- Social
Had to go to more places than usual to find the food my household wanted	<b>0.35</b>	Accessibility- Physical
Had to stand "too close for safety" to other people, when getting food (less than 6 ft away)	0.25	Accessibility- Physical, Social
Had to reduce number of grocery trips to avoid COVID-19 <sup>b</sup> exposure	0.04	Accessibility- Physical
Need access to public transit or rides	0.16	Accessibility- Physical
Need different hours in meal programs or stores	0.23	Accessibility- Physical
Extra money will help with food access	0.28	Accessibility- Affordability
Need help with information about food assistance programs	<b>0.32</b>	Availability- Food assistance failure
Need more (or different) foods in stores	0.16	Availability- Food assistance failure
Worry that there will not be enough food in the store	0.29	Accessibility- Social
Worry about food becoming more expensive for household	0.24	Accessibility- Social, Economic
Worry food will become unsafe or contaminated	0.23	Accessibility- Social Acceptability- Health
Worry that household will not be able to get or will lose access to programs that provide free food or money for food	<b>0.38</b>	Accessibility- Social Accessibility- Economic Availability- Food assistance failure
Worry about losing so much income that you can't afford food	<b>0.43</b>	Accessibility- Social Accessibility- Economic
Worry that household won't have enough food if we have to stay at home and can't go out at all (due to quarantine or illness)	<b>0.35</b>	Accessibility- Physical
USDA <sup>c</sup> : Food didn't last (since COVID-19)	<b>0.58</b>	Accessibility- Economic
USDA: Couldn't afford balanced meal (since COVID-19)	<b>0.56</b>	Accessibility- Economic
USDA: Cut size or skip meal (since COVID-19)	<b>0.58</b>	Accessibility- Economic
USDA: Eat less than should (since COVID-19)	<b>0.56</b>	Accessibility- Economic
USDA: Ever hungry (since COVID-19)	<b>0.51</b>	Accessibility- Economic
Buying a lot more items in a single trip	0.02	Accessibility- Physical
Throw away less food than usual	0.03	Agency
Fruit and vegetable consumption during COVID-19	0.12	Acceptability-Health

<sup>a</sup>Values in boldface type indicate variables that loaded significantly ( $\geq 0.3$ ) onto the dimension.

<sup>b</sup>COVID-19 = coronavirus disease 2019.

<sup>c</sup>USDA = US Department of Agriculture.

food insecurity concept. This methodological approach increases the robustness of the findings presented in this article. Further, in the development of the framework, people's experiences across multiple disaster types (hurricanes, tornadoes, and pandemic) were considered. As such, the framework can be applied to many disasters and emergencies, although additional validation will be beneficial among people affected by other types of hazards (eg, flood, drought, and wildfires). In Step 2, the evaluation obtained from food

and disaster researchers, who work in the field and are exposed to food-insecure populations in different settings, provides an indication of the usability of the framework and definition in assessing food insecurity in the context of disasters. In addition, the framework was applicable to relevant data from the COVID-19 pandemic, a social disaster in the form of a public health emergency, to quantitatively assess the feasibility of developing a Disaster Food Security Scale (DFSS) based on the DFSF, and to explore whether or not all

dimensions of the framework can be represented in a single measure. This study had a large sample of participants from different states and a large number of relevant food-related variables that made the MCA possible. It is interesting to note that the USDA HFSSM variables were also loaded onto the dimension representing disaster food insecurity. This is suggestive of the feasibility of including additional questions with the existing HFSS metric for a more comprehensive assessment and monitoring of food insecurity in the disaster context.

This study has several limitations. First, in-depth interviews were conducted with 10 participants. Although data saturation was reached in the reported lived experiences of food insecurity during disasters and qualitative research does not aim for comprehensive representation, a larger sample with greater diversity across demographics, disasters, geographies, and at-risk populations could provide further assurance that no critical categories were missed.<sup>40</sup> When recruiting participants for in-depth interviews, past disaster experience was prioritized to understand experiences with accessing food in that specific context. During these in-depth interviews, food security status was not directly evaluated; however, there were a range of food access issues discussed by participants. Moreover, when questioned about experiences with hurricanes and tornadoes, those were less easily recalled because participants had more immediate COVID-19 pandemic experience. Therefore, results based on NFACT the survey responses may differ from responses that would have been provided after other types of hazards due to potential recall bias. For instance, COVID-19 was mostly an invisible risk with the exception of the lockdowns and mandated protective actions such as masking. On the other hand, tornadoes and hurricanes are more visible, causing structural damage such as destruction of buildings, power lines, and roads. Second, the NFACT survey include only one variable that could be used to represent the agency dimension and therefore was not detected in the MCA. As such, the MCA result suggested an incomplete representation of the framework illustrated in the Figure. In Phase II of this research to develop a DFSS, it will be ensured that new items, reflective of all dimensions, are included when developing the survey questions. It should be noted that the NFACT questions were not designed with the creation of a DFSS in mind, so the variables used may not all be appropriate. For example, the framing of the NFACT questions and answers used for the MCA varied; some were dichotomous, others categorical or ordinal. In Phase II we will ensure standardization of the way questions are asked and in the response options. We also had to exclude two states (Arizona and Connecticut) from the MCA due to missing variables. However, in sensitivity analyses, including participants from these states, the results were consistent with those presented in Table 3. Finally, no validation was performed for the MCA result because this was an exploratory analysis of the feasibility of a DFSS using the framework developed.

## CONCLUSIONS

As practitioners, researchers, and policy-makers focus on bolstering food security when preparing for, coping with, and recovering from disasters and emergencies, the DFSF helps to advance the understanding of barriers to food access. The DFSF

contributes to identification of potential intervention points within the local food environment. For example, accessibility limitations due to physical barriers to food security such as road flooding point to interventions that bolsters community infrastructure in high-risk areas, prioritization of restoring infrastructure critical for restoring food access, or potentially locating additional food sources away from roads likely to flood. When populated with the relevant data, the framework may serve as a quantitative tool to assess food insecurity in the disaster context. In line with this rationale, the DFSF will be used in the development of a disaster-specific food security scale. This scale will then be used in monitoring and surveillance programs as climate-related disasters and public health emergencies become more common.

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## STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

## FUNDING/SUPPORT

This work was supported with a grant from the US Department of Agriculture (USDA) through the Tufts University Food Sec 25 Project (USDA cooperative agreement 59-4000-0-0067). This article represents the work of the authors and may not represent the opinions or policies of Tufts University or USDA. Arizona data collection was supported by a coronavirus disease 2019 (COVID-19) seed grant from the College of Health Solutions, Arizona State University. Connecticut data collection was supported by Stop & Shop and the Hunger to Health Collaboratory (H2HC). Maryland data collection was supported by a Directed Research grant from the Johns Hopkins Center for a Livable Future. Massachusetts data collection was supported by Stop & Shop and the H2HC. New York State data collection was funded by the Natural Hazards Center, Quick Response Grant. The Quick Response program is based on work supported by the National Science Foundation (NSF) (Award No. 1635593). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of NSF or the Natural Hazards Center. New York City data collection was supported by St John's University Vincentian Institute for Social Action. Vermont data collection was made possible through grants provided by The University of Vermont College of Agriculture and Life Sciences and the Office of the Vice President of Research, as well as a COVID-19 Rapid Research Fund grant from the Gund Institute for Environment. This article is published as part of a supplement supported by the U.S. Department of Agriculture, Economic Research Service.

## ACKNOWLEDGEMENTS

This research is conducted as part of the National Food Access and COVID-19 Research Team (NFACT). NFACT is a national collaboration of researchers committed to rigorous, comparative, and timely food access research during the time of coronavirus disease 2019. To learn more, visit: [www.nfactresearch.org](http://www.nfactresearch.org).

The authors thank the following individuals: Erin Biehl for Science Advisory Group participation; Francesco Acciai and Punam Ohri-Vachaspati of Arizona State University for instrumental support with data collection and cleaning the Arizona data; Gaby Phillips and Aracely Tellez for help with translating the New Mexico survey into Spanish; Katie Martin, More Than Food Consulting, for contributing Connecticut NFACT data to this project. Emily Belarmino, Farryl Bertmann, Christi Sherlock, Mattie Alpaugh, and Thomas Wentworth from the University of Vermont; Kaitlyn Harper, Joelle Robinson, and Brianna Bradley from Johns Hopkins University for supporting the Maryland survey; Preety Gadhoke and Barrett Brenton for leading NYC data collection; Jordan Fisher, University of Maryland Baltimore County, Visual Arts major, for graphic design support.

## AUTHOR CONTRIBUTIONS

All authors contributed to study conceptualization; L. Clay and N. Koyratty developed the approach; L. Clay, R. Neff, A. J. Josephson, R. M. Zack, M. Niles, and S. Rogus provided data for the project; N. Koyratty and S. Bliss led secondary data acquisition and new data collection, N. Koyratty led data analysis; all authors contributed to interpreting the results; L. Clay and N. Koyratty drafted the manuscript; all authors reviewed and provided feedback on the manuscript.