Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Socio-Economic Planning Sciences 82 (2022) 101107

Contents lists available at ScienceDirect

Socio-Economic Planning Sciences

journal homepage: www.elsevier.com/locate/seps

Consumer behavior during the COVID-19 pandemic: An analysis of food purchasing and management behaviors in U.S. households through the lens of food system resilience

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ARTICLE INFO

Keywords:
COVID-19 pandemic
Food management
Household
Food waste
Resilience
Cold storage

ABSTRACT

The COVID-19 pandemic has stimulated considerable interest in the resilience of the U.S. food system. Less attention has been paid to the resiliency characteristics of the final link in the food system – individual households. We use national survey data from July 2020 to understand the food acquisition, preparation, and management strategies that households implemented in response to the pandemic. We find a substantial increase in the amount of food prepared and consumed at home which scales with respondents' time availability, perceived risks of dining out, and pandemic-induced income disruption. We then identify several household responses to support this increase in home food consumption that are in line with practices suggested to enhance resiliency at other links in the food supply chain, including increased cold storage capacity and enhanced in-house capability via improved cooking and food management skills. We discuss how responses such as improved food skills can reduce the propagation of shocks through the supply chain by allowing greater flexibility and less waste, while actions such as increased home cold storage capacity could undermine system resilience by exacerbating bullwhip effects, i.e., amplifying consumer demand shocks that are propagated to upstream food supply chain actors.

1. Introduction

The COVID-19 pandemic has stimulated considerable interest in the resilience of food systems in the United States and other countries, including attempts to understand how actors across the food supply chain responded to this systemic shock so that policies and practices can be altered to efficiently enhance food system resilience in preparation for future shocks [1,2]. Increasingly attention has turned toward understanding consumers' experience with regard to food behaviors in response to COVID-19. Rightfully, most initial attention focused on the bottom-line impacts of COVID-19 on consumer food security [3–6]. However, more attention is turning to capturing a deeper understanding of consumer food buying and management habits in response to COVID-19 [7–12].

In this article, we contribute to this growing literature by assessing consumer household food behaviors in response to COVID-19 through the lens of resilience. Resilience at the household level has been characterized as the ability to maintain this unit's basic function and structure in the face of shocks and disturbances [13] while food system resilience is characterized as the capacity of that system (both in whole and its constituent components) to provide sufficient, appropriate and accessible food to all even when faced with unforeseen shocks [14]. The emergence of COVID-19 and the accompanying onset of stay-at-home orders, the closure of many foodservice options, changes in disposable income, and shifts in time availability due to expanded or diminished work and non-work demands all represent a massive challenge to the resilience of the food system and to the final link in the food system - consumers.

For example, one of the early observations during the beginning of stay-at-home orders in mid-March 2020 was shortages of food items in

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[1] BR recognizes support from USDA-NIFA (#OHO01419).
[2] DQ recognizes grant support from Louisiana Board of Regents (AWD-002915).

https://doi.org/10.1016/j.seps.2021.101107
Received 28 February 2021; Received in revised form 7 June 2021; Accepted 21 June 2021
Available online 26 June 2021

grocery stores, due not only to upstream food supply chain disruptions but also to panic buying and/or hoarding by consumers. However, much is unknown about how the onset of COVID-19 has altered food acquisition beyond the initial stages of COVID-19 and how food is being managed once obtained by households. This study attempts to understand changes in individual and household food acquisition and management behaviors associated with the COVID-19 pandemic [13].

A survey conducted by Waste & Resources Action Programme (WRAP) in April 2020 found that people in the UK reported lower shopping frequencies but higher volumes of purchase per shopping trip. However, more efficient in-home food management behaviors were reported including creation of shopping lists, better pantry organization, and creative cooking. Given the self-reported measures of food waste for four product categories (potatoes, bread, milk, chicken), WRAP predicted up to a 34% decrease in the amount of uneaten food being thrown away compared to November 2019 [12]. During the lockdown in Italy, consumers also reported improved management of home inventories and stated that they wasted less food, with the largest decrease in food waste occurring among young people [11].

At the onset of the pandemic, large demand surges and empty shelves were observed at grocery stores across the United States as a result of consumers stockpiling food coupled with supply chain disruptions [15]. A study by Brizi and Biraglia (2021) explored the need for cognitive closure (desire for predictability during uncertainty) as an explanatory effect for stockpiling and observed those with a higher need for cognitive closure were more likely to perceive less food in their home, buy more food, and then waste more food [9]. Furthermore, each individual household's drive to provide resilience in its ability to deliver meals to its household led to stockpiling, which undermines the global resilience of the food system and undercuts sustainability through acquisition of energy-intensive home cold storage. Finally, the pandemic affected sustainability through an increase in online food purchases and accompanying plastic waste which was fueled by restaurant shutdowns, reusable bag bans, and efforts to maintain social distancing and sanitary surfaces [16].

Across the United States, households' food consumption behaviors were forced to change with the onset of mandatory shutdowns; however, the extent and permanency of these changes are yet to be determined, as are the implications for overall food system performance. In an April 2020 survey of U.S. households, more than 80% reported experiencing some change to their eating or food preparation habits due to the COVID-19 pandemic [17].

An interesting trend observed during the pandemic is a shift to in-home food preparation with a majority of consumers (60%) noting an increase in cooking at home; furthermore, less than 20% report getting more take-out or delivered meals due to the pandemic [17]. This shift could be the result of a variety of factors including changes to time and budget constraints as well as consumer risk aversion. The risks of both indoor and outdoor dining at foodservice locations are increased with COVID-19 as masks cannot be worn while eating or drinking. Consumers who wish to minimize the increased health risks of dining out during the COVID-19 pandemic could switch to cooking at home more. Higher cooking frequencies have also been associated with unemployment [18], and the COVID-19 pandemic has led to significant job disruption with 40% or more of adults reporting taking a pay cut or being laid off [19]. With unemployment skyrocketing, budget constraints may also motivate people to cook at home more often as cooking at home has been associated with income level [20]. This is supported by an April 2020 survey that revealed cost savings and healthier eating to be the top two reasons for cooking more frequently at home [21].

In July 2020, we replicated and expanded a 2018 online survey that measured refrigerated food inventory and utilization in U.S. households [22]. The objective of our study is to identify shifts in household food purchasing and management behaviors brought about by the COVID-19 pandemic. Factors that affect pandemic-induced cooking, enhanced cold storage capacity, and increased food storage and utilization are explored with particular consideration given to COVID-19-related risk factors to account for and explain consumer heterogeneity. Identifying significant factors can inform policy as well as provide insight about interventions that could encourage long-term adoption of improved food purchasing and management practices. Finally, we discuss the implication of our results on food system resiliency and sustainability.

2. Methods

2.1. Survey design

The survey was expanded from the 2018 survey described in Davenport, Qi, & Roe (2019).

[22]. Additional questions regarding food management and COVID-19 exposure, risk perception, and prophylactic behaviors were appended to capture the effect of the COVID-19 pandemic. The following analysis will focus on this latter portion of the survey.

The survey (IRB 2020E0589) was administered to residents of the United States in July 2020 via the online survey platform Qualtrics. Inclusion criteria required participants to 1) be the primary grocery shopping or share responsibility in grocery shopping, 2) cook or prepare food at home at least once a week, 3) have a refrigerator in their home, 4) be at home with access to their refrigerator, and 5) be 18 years of age or older. In total, 518 respondents from Qualtrics' online panels qualified for and completed the baseline survey. The baseline survey and weighted summary statistics are reported online.[3]

Survey participants were asked to count the number of items in eight food categories likely found in their refrigerators: vegetables; fruit; dairy, eggs, and non-dairy alternatives; meat, fish, poultry; beverages; prepared leftovers; condiments, sauces and jarred foods; and "other". Within each category, participants were prompted to provide details about one randomly chosen item such as label characteristics, amount remaining, and the likely fate of that item.

After completing the hands-on refrigerator inventory questions, participants provided information about when they last acquired groceries, grocery shopping behaviors, and weekly food expenditures. In addition, participants answered questions about refrigerator and freezer capacity, the relative fullness of refrigerators and freezers, employment, income, household size, and daily routines (including food-related routines such as cooking) as impacted by COVID-19. Risk perception of participants was evaluated through assessing the extent of preventative measures being followed and recording reactions to multiple scenario statements (e.g., In your judgement and given the current state of the coronavirus situation in your community, how likely would it be for someone who never had coronavirus to contract it from undertaking the <following activities>?). Finally, participants answered questions regarding demographic characteristics.

Approximately one week after completion of the baseline survey described above, participants were sent a short follow-up survey about refrigerator inventory, considerations in discarding food, and other food disposal habits.

2.2. Participant characteristics

The baseline survey was completed by 518 respondents. Nine respondents were dropped due to discrepancies in their reported household size,[4] resulting in a useable sample of 509. A total of 407 responses

[3] Available at https://cpb-us-w2.wpmucdn.com/u.osu.edu/dist/9/40885/files/2020/07/The-State-of-the-American-Refrigerator-2020-PDF.pdf.

[4] If participants were consistently not counting themselves in past and current household size, i.e., participants said they were male (female) and reported they had zero current and past male (female) adult household members, household size was adjusted by adding one. If the discrepancy could not be consistently identified, participants were dropped.

were collected from the follow-up survey. Four were dropped due to multiple responses from the same participant ID, and seven were dropped due to discrepancies in reported household size. Therefore, the useable sample of those who completed both surveys consisted of 396 responses. All statistical analyses were performed in Stata 15.1 and Stata 16.

Summary statistics for the two samples are shown in Table 1. Column 1 represents all participants who completed the baseline while column 2 represents only those who completed both the baseline and the follow-up survey. The subsample of participants who completed the follow-up survey in addition to the baseline survey was not significantly different demographically from all who took the baseline survey.

Participants were required to bear at least partial responsibility for grocery shopping and cook at home at least once a week. Two-thirds of participants cooked or prepared food at home more than four times per week. Over 80% of respondents indicated they were the primary shopper in their household with only 17% indicating joint or shared responsibility for this task.

As in most household food-related surveys, the majority of participants were female since food management responsibilities continue to be disproportionately borne by women [23]. Our sample was skewed towards a higher income and older population with less than 10% of participants age 18–34 and about 40% of participants reporting an annual household income of $100,000 or more. Our sample is also skewed in terms of race with a disproportionately high percentage of White participants (82.7%) and a disproportionately low percentage of Black participants (2.6%). The average household size was just over three members, and about 40% of households included children.

Table 1
Unweighted respondent summary statistics by sample.

		Baseline	Baseline and Follow-up
Characteristic	Description	n = 509	n = 396
Female		62.5%	62.4%
Age	18–34 years	9.2%	8.8%
	35–64 years	75.8%	76.8%
	65+ years	14.9%	14.4%
Race	White	82.7%	82.3%
	Black	2.6%	2.8%
	Asian	10.2%	10.6%
	Other	4.5%	4.3%
Income	Less than $50,000	17.9%	18.7%
	$50,000–$99,999	39.7%	40.4%
	$100,000 or more	42.4%	40.9%
Education	Graduate or professional degree	27.5%	27.3%
	Bachelor's degree	42.6%	41.7%
	Some college or associate degree	20.2%	20.7%
	High school diploma or GED	9.0%	9.6%
	Less than 12th grade	0.6%	0.8%
Household members	# of members (Mean ± S.D.)	3.2 ± 1.3	3.1 ± 1.1
	Children in household	42.4%	43.4%
Region of residence	Midwest	19.5%	20.7%
	Northeast	25.7%	25.8%
	South	31.8%	30.6%
	West	23.0%	23.0%
Primary grocery shopper in household?	Primary shopper	82.1%	82.6%
	Joint/shared responsibility	17.9%	17.4%
Cooking/preparing food at home	1-2 times per week	9.2%	8.6%
	3-4 times per week	22.6%	23.7%
	>4 times per week	68.2%	67.7%

2.3. Empirical modeling

Our analysis focuses on two key aspects of resilience: household production of food (i.e., cooking at home) and household cold storage management. We use recursive modeling[5] to account for two endogenous variables, perceiving shortages and cooking at home more. These two variables affect household cold storage management as households that perceive shortages are likely to stockpile food and households that cook at home more are likely to have more food stored at home for cooking; however, perceiving shortages, cooking at home more, and cold storage management are affected by many of the same explanatory variables. Therefore, we first regress perceiving shortage and cooking at home more on a variety of explanatory variables including risk perception and behavior, employment, and income disruption. Then we regress cold storage on the same set of explanatory variables in addition to perceiving shortages and cooking at home more. Multivariate regression analysis explaining each dependent variable is performed via logistic regression analysis with robust standard errors clustered at the individual risk profile level. Individual risk profile is discussed further in section 3.2.

3. Results and discussion

3.1. Household food expenditures and purchasing behavior

To date, there has been no federal mandate restricting activities in the U.S., although many state and local governments have imposed a variety of restrictions to combat the spread of COVID-19. Participants were asked about the extent of restrictions ("fully open/available" to "closed/unavailable") on activities such as indoor and outdoor restaurant dining in their community, the results of which are summarized in Table 2. At the time of this survey, most participants reported a partially restricted environment. Only one in twenty participants reported living in a community with fully closed outdoor dining, and one in five reported living in a community with fully closed indoor dining. The majority of participants, about two-thirds, reported partially restricted[6] dining options. Only 21% reported fully open outdoor dining, and just 12% reported fully open indoor dining in their communities.

When asked to indicate their opinion on the level of restriction placed on activities in their communities ranging from "too much" to "about right" to "too little," participants, on average, believed there was too little restriction with about 74% classifying the restrictions in their communities as "too little" and 24% as "too much." Only 2.5% of participants believed the restrictions in their communities were about right.

Participants were also asked a series of questions about their recent food purchasing behaviors including expenditures[7] on food at home (FAH) and food away from home (FAFH), shopping frequency and duration, and habits while shopping. Against the trend of declining food-

[5] Household food waste patterns are seasonal [41] preventing use of difference-in-differences with data from Davenport et al. (2019).

[6] Partially restricted activities are those that participants indicated to be "somewhat open/available" or "open/available with limited capacity."

[7] FAH is typical expenditures on groceries in the past month. FAFH includes expenditures on food eaten outside the home including restaurant take-out.

Table 2
Household food expenditures and purchasing behavior.

	Baseline (n = 509)	Baseline and Follow-up (n = 396)
COVID-19 restrictions		
Indoor dining		
Fully open/available	11.8%	12.1%
Partially open/available	63.3%	62.9%
Closed/unavailable	19.1%	18.9%
Not sure	5.9%	6.1%
Outdoor dining		
Fully Open/available	21.4%	21.7%
Partially Open/available	67.0%	66.7%
Closed/unavailable	5.1%	5.1%
Not sure	6.5%	6.6%
Respondent opinion on restriction in community		
Too much	24.2%	23.2%
About right	2.6%	2.8%
Too little	73.3%	74.0%
Food-related routines		
Food Expenditures[a]		
Food at home	74.6%	74.6%
Food away from home	25.4%	25.4%
Grocery shopping method		
In-store shopping	97.1%	97.2%
Curbside pick-up shopping	26.3%	24.5%
Delivery	20.8%	19.7%
Other	9.0%	7.8%
Grocery shopping frequency		
More than once a week	19.5%	18.7%
Once a week	53.1%	53.3%
Less than once a week	27.5%	28.0%
Grocery shopping 30+ minutes	64.4%	65.1%
Check nutrition labels		
Never/rarely	17.3%	16.4%
Sometimes	31.2%	33.6%
Often/always	51.5%	50.0%
Check expiration or date labels		
Never/rarely	8.7%	8.3%
Sometimes	20.0%	20.7%
Often/always	71.3%	71.0%
Food disposal behaviors		
Refrigerator cleaning frequency		
Never/rarely		8.6%
Sometimes		31.1%
Often/very often		60.4%
Use own car to do shopping	94.5%	94.4%
Compost/food waste disposal service		22.0%
Pet/animals that eat unwanted food		19.7%

[a] n = 507 in Baseline and n = 395 in Baseline and Follow-up.

at-home expenditures[8] and despite being several months into the COVID-19 pandemic with restaurants and bars open in many areas, respondents spent 75% of their food budget on food at home (FAH), which is higher than the 51% reported by the USDA ERS in 2019 [24]. The USDA ERS definition of food away from home (FAFH) includes the value of FAFH that is not paid for by the consumer (e.g., meals served on flights and in nursing homes, hospitals, and prison facilities) which this study does not; however, since this study was completed by households (not institutional facilities) and during a time in which business and airline travel were reduced, the effect of excluding this category of FAFH is likely minimal.

The majority of participants, 53%, reported grocery shopping, on average, once a week, and the vast majority of participants acquired at least a portion of their food through in-store shopping. More than one-quarter of respondents used a curbside pick-up or delivery service to obtain groceries as well. Over 60% of participants spent more than 30 min in total on grocery shopping including time spent ordering online, travel time, and time spent in-store. Despite the increase in risk associated with shopping, participants still engaged in mindful purchasing habits such as checking nutrition and date labels on packages.

In the follow-up survey, participants were asked about food disposal behaviors including frequency of refrigerator cleaning, factors considered in the decision to discard food, and food disposal methods. We define refrigerator cleaning as the act of looking through items in the refrigerator and removing items that will no longer be used or consumed. The majority of respondents, 60%, indicated they cleaned their refrigerator often or very often compared to less than 10% who indicated rarely or never cleaning their refrigerator. When disposing of food, almost 20% reported regularly feeding unwanted food scraps to pets or animals, and 22% composted or used a food disposal service. The factors considered in the decision to discard food are discussed and analyzed in section 3.6.

3.2. Consumer risk perception and behavior

A risk profile was identified for each participant based on their responses to three scenarios. For each scenario, participants were asked how likely it was for someone who had never contracted COVID-19 to contract the disease in the scenario and how likely they, the respondent, would be to undertake the activity outlined in the scenario. The three scenarios[9] were chosen to represent realistic situations during the pandemic. Participant responses are summarized in Table 3.

As indicated by the high percentage of respondents reporting in-store shopping, the perceived lowest risk scenario for contracting COVID-19 was grocery shopping with masks although only 60% of participants indicated they would likely personally undertake in-store shopping as described. The difference between this percentage and the percentage who reported in-store shopping could possibly be explained by more cautious future behavior (i.e., groceries acquired via in-store shopping is backward-looking while the likelihood of personally undertaking the activity is forward-looking) or the responsibility for in-store shopping being delegated to lower-risk household members.

Respondents perceived indoor dining without masks to be the highest risk scenario for contracting COVID-19 with the majority believing that someone partaking in this activity would be likely to contract COVID-19. Over 70% indicated they were unlikely to personally undertake indoor dining as described (Table 3, column 2). Even many of those who did not perceive this to be a risky activity for contracting COVID-19 indicated that they themselves would be unlikely to dine indoors. Respondents indicated more willingness to pick up take-out orders although only 27% believed they themselves were likely to do this.

Each respondent was assigned a risk profile based on their answers to the questions about these scenarios. For each scenario, respondents were recorded as either perceiving the likelihood of contracting COVID-19 as unlikely, neutral, and likely. Their personal likelihood of undertaking the activity was recorded in the same manner. The risk profile is composed of the combination of these six responses.

[8] Over the past several decades, the share of the food budget spent on food for consumption in the home, defined as food purchased at grocery stores and other retail stores, has been steadily declining as food consumed away from home (FAFH) has increased. In 1997, expenditures on food at home (FAH) accounted for 59% of the household food budget and fell to 51% by 2019 [24].

[9] Indoor dining without masks: "For 60 min sit in a crowded restaurant where patrons and staff do not wear masks." Grocery shopping with masks: "For 30 min shop in a medium sized grocery store where all patrons and staff wear masks." Picking up take-out with some masks: "For 15 min in line to pick up food from a restaurant where you momentarily get within 6 feet of unmasked people every 5 min"

Table 3
Consumer risk perception and behavior (n = 509).

Activity	Description	Likelihood of contracting COVID-19 from activity	Likelihood of personally undertaking activity
Indoor dining without masks	Very unlikely	21.6%	61.3%
	Somewhat unlikely	7.9%	10.0%
	Neutral	14.5%	9.6%
	Somewhat likely	21.6%	7.5%
	Very likely	34.4%	11.6%
	Unlikely	29.5%	71.3%
	Likely	56.0%	19.1%
Grocery shopping with masks	Very unlikely	15.1%	13.4%
	Somewhat unlikely	29.9%	8.6%
	Neutral	22.2%	17.5%
	Somewhat likely	18.7%	28.1%
	Very likely	14.2%	32.4%
	Unlikely	45.0%	22.0%
	Likely	32.8%	60.5%
Picking up take-out with some masks	Very unlikely	15.1%	30.7%
	Somewhat unlikely	13.6%	19.7%
	Neutral	28.3%	21.8%
	Somewhat likely	28.9%	15.5%
	Very likely	14.2%	12.4%
	Unlikely	28.7%	50.3%
	Likely	43.0%	27.9%

3.3. Consumer perception of food shortages

Across the United States, consumers have encountered bare shelves at grocery stores due to disruptions in the supply chain and increased demand. Twenty-seven percent of participants reported affirmatively to the question "The last time you got groceries, did you think that there would be a shortage of any food items?" Among those who perceived a shortage, 74% implicated meat, while other food categories expected to be in short supply were canned goods, frozen food, baking items, dairy, pasta, and fresh produce (Fig. 1).

Our regression analysis shows that those who were more likely to be shopping in-person at a grocery store were significantly more likely to expect food shortages (Table 4, column 1). Respondents' time availability for doing things that interest them was significantly associated with the perception of food scarcity on grocery store shelves. Respondents reporting less time available were more likely to report food shortages, possibly amplified by the inability to procure food items at an alternative store location due to time restrictions. Restrictions on food procurement could also explain why respondents who indicated that they are at increased risk of experiencing severe COVID-19 symptoms were more likely to expect food shortages. Geographically, respondents from the northeastern United States were more likely to have a perception of food shortage.

3.4. Household cooking habits and skills

As reported in Table 1, about two-thirds of respondents cooked or prepared food at home more than four times a week. A large shift in cooking at home was observed with 62% of participants reporting an increase in cooking at home compared to the same time in the previous year.

To assess households' ability to prepare and manage food with this shift to in-home food preparation, participants were asked to rank their cooking skills and food management skills on a sliding scale from "No skill at all" (0) to "Expert" (100) for February 2020 and July 2020 (the date of survey administration). Examples of food management skills were listed and included meal planning, shopping efficiency, proper storage, and reduced food waste. For each skill set, the difference between the July 2020 level and the February 2020 level was calculated to find the change in skill level over the course of the initial months of the pandemic. Over this time frame, respondents reported a 2.89 and 3.38% point increase in mean cooking and food management skills, respectively. The distribution of change in skill scores, shown in Fig. 2, was slightly wider and more positively skewed for participants who were cooking more during the pandemic with 33% reporting an increase of at least 2% points in cooking skills and 34% reporting an increase of 2pp or more in food management skills. Overall, 57% reported an improvement in at least one skill.

Respondents' perception of risk and their personal willingness to acquire prepared foods through other means were correlated with an increase in cooking at home (Table 4, column 2). As expected, those who were personally unlikely to dine indoors at foodservice establishments are more likely to report an increase in cooking at home. This is consistent with cooking at home and indoor restaurant dining being substitutes. Even with the personal likelihood of engaging in indoor dining held constant, those who believed the likelihood of contracting COVID-19 from indoor dining to be high were more likely to report an increase in cooking at home. Since the frequency of cooking at home was not directly measured, this could imply that those who consider dining out to be risky could be choosing to dine out less often than those who do not perceive indoor dining to be a risky activity. The personal likelihood of ordering a meal for pick-up from a restaurant was directly correlated with cooking at home more; those who were likely to order a meal for pick-up were also more likely to have increased cooking at home during the pandemic.

While cooking at home has been correlated with a healthier diet and lower per capita food expenditures [18,25], individuals often cite time constraints to cooking less [26,27]. Changes in time constraints due to adjustments in childcare (e.g., remote schooling, limited daycare availability), extracurricular activities (e.g., cancellation of sports, concerts, etc.), and employment (e.g., layoffs, restricted business travel, teleworking) alter the time available to individuals, a reason commonly cited for eating take-out or delivery [28,29]. Expectedly, we observed participants were likely to cook at home more if they reported having more time available to do things of interest to them; however, this relationship did not hold for those who reported having less time (i.e., those with less time were not less likely to have increased their cooking at home). In addition to time, available income often limits households' tendency to dine out. While the household's current income strata were not significantly related to cooking at home more, those who reported income disruption due to COVID-19 were more likely to report cooking at home more.

Household size was also correlated with an increase in cooking at home with larger households more likely to report an increase although households that had recently (i.e., in the last year) increased in size were less likely to report an increase in cooking at home. Larger households benefit from economies of scale in cooking at home [30], and the benefits may be even greater during the pandemic. However, these efficiencies may not yet be realized by households that have only recently increased in size. Finally, we note that participants in Western states had significantly higher odds of cooking more compared to the Midwest, possibly due to the rapid rise in COVID-19 cases in these states in July 2020 [31].

More time spent cooking at home has been associated with healthier

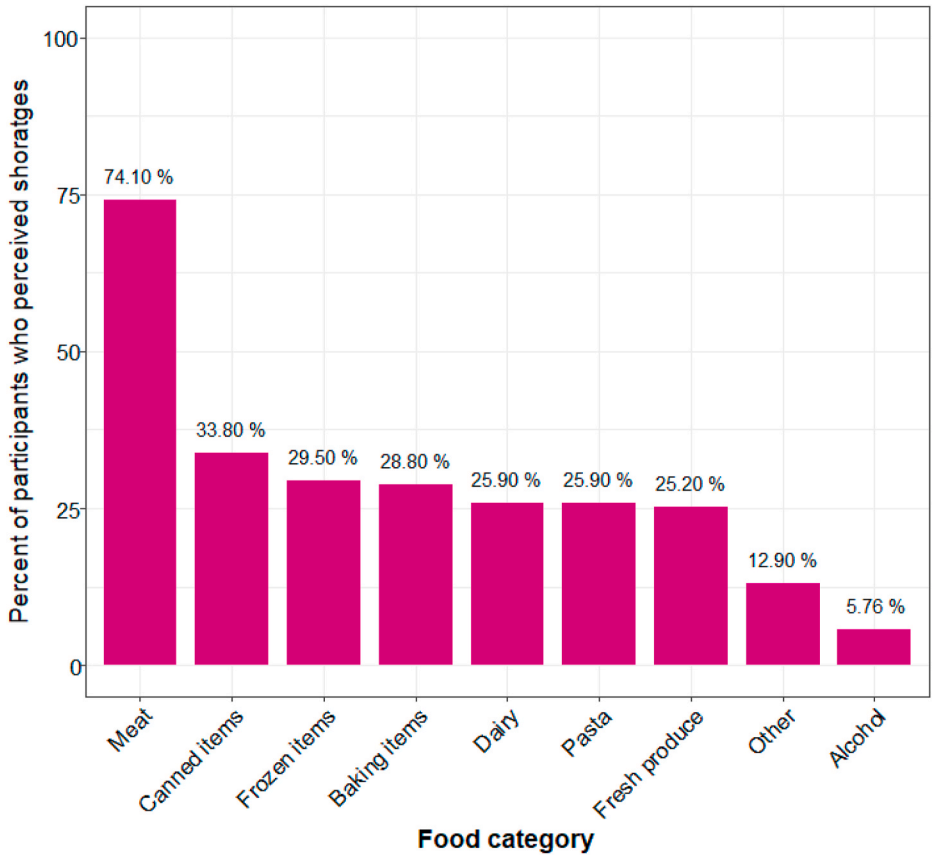

Fig. 1. Perceived food shortages at grocery stores by food category (n = 139).

eating [29,32], but with restrictions in place during the COVID-19 pandemic, restaurant dining is not always an option, and people with no other choice but to cook at home may engage in different behaviors than those who choose to cook at home even when restaurant dining is unrestricted. People who would otherwise not cook at home may have switched to more processed or convenience foods (i.e., pre-packaged salad kits). However, the documented increase in cooking and food management skills indicates that there is likely increased engagement with food preparation in the home. In addition, better cooking skills in parents are associated with lower consumption of ultra-processed foods by children [33].

The long-run effects of these changes in household behaviors, as well as the permanence of the behaviors themselves, is yet to be determined. The extended length of the lockdowns may have increased the likelihood that these behaviors are now habits with associated benefits being realized in the long run. In a December 2020 survey, Americans indicated they were likely to continue cooking at home even as pandemic restrictions ease with cost-saving and healthier eating being cited as key drivers [34]. Conversely, households may revert back to pre-pandemic habits or neglect skills acquired and improved during lockdowns after restrictions are lifted, thus negating any associated benefits with cooking at home.

3.5. Household cold storage capacity

Increasing storage is one common strategy for adding resiliency to food systems. As the final link in the food system, consumers may also adopt such a strategy in response to a shock like COVID-19 that drives their perceptions of disruption as manifested as perceived food item shortages. Among our sample, 32% reported an increased amount of food in their refrigerator compared to the same time last year, while 37% increased their frozen food stocks due to COVID-19-related changes (Fig. 3). In addition to a provisional increase in food storage, some participants expanded their cold storage capacity during the pandemic: 26% added at least one refrigerator, and 12% added at least one freezer. Table 4 shows logistic regression odds ratios for pandemic-induced increase in refrigerator (column 3) and freezer (column 4) food, as well as added refrigerator(s) (column 5) and freezer(s) (column 6). As seen in Table 4, cooking at home more was significantly associated with having increased food in refrigerators and freezers, while those who perceived shortages at grocery stores were significantly more likely to expand their capacity by adding refrigerator(s)/freezer(s).

Focusing on risk variables, we found that people who considered themselves or someone in their household at increased risk of developing severe COVID-19 symptoms were significantly more likely to be stockpiling by increasing refrigerated and frozen food, but less likely to expand their cold storage capacity. Since grocery shopping frequency increased in 2020 compared to 2018, and people were not significantly risk-averse to shopping at a grocery store, this stockpiling behavior seems to stem from fear/panic of future food shortages rather than that of contracting COVID-19. A decreased likelihood of dining indoors at a restaurant increased the odds of having more frozen food, likely due to their reliance on food prepared at home. This result is in line with a qualitative analysis by Lehberger, Kleih, and Sparke (2021) [35], where the inability to visit restaurants was listed as a key reason for stockpiling food during the pandemic. Further, being at higher risk for developing severe COVID-19 symptoms decreased the likelihood of expanding cold storage capacity. This may be explained by the fact that the low-income group was 1.6 times more likely to be considered at high risk of developing severe symptoms if exposed to COVID-19, compared to the high-income households. Thus, although high-risk, the low-income households likely didn't have the purchasing capacity to buy additional refrigerators or freezers.

Surprisingly, the less risk-averse participants, who were willing to

Table 4
Logistic regressions of perceived shortages, changes in cooking frequency, and household food storage habits during the COVID-19 outbreak.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Perceived shortages	Cooking more	More fridge food	More freezer food	Added fridge capacity	Added freezer capacity
Cooking more			3.603***	3.779***	1.765**	1.974
			(0.896)	(0.823)	(0.431)	(0.931)
Perceived shortages			1.141	1.238	2.014***	4.260***
			(0.321)	(0.324)	(0.442)	(1.300)
Employed	0.819	1.017	1.180	1.054	1.079	1.951
	(0.176)	(0.254)	(0.260)	(0.254)	(0.349)	(0.991)
More time available	0.953	3.621***	2.082***	1.757***	1.491	1.988
	(0.209)	(1.094)	(0.567)	(0.372)	(0.456)	(0.834)
Less time available	2.755***	1.052	2.085*	1.967*	0.721	1.059
	(0.884)	(0.340)	(0.876)	(0.728)	(0.239)	(0.660)
Household income ($50,000-$100,000)	1.081	1.256	1.307	1.272	1.817	0.703
	(0.328)	(0.320)	(0.414)	(0.341)	(0.686)	(0.432)
Household income (>$100,000)	0.977	1.764	1.595	1.284	2.246**	1.517
	(0.349)	(0.656)	(0.655)	(0.413)	(0.839)	(0.938)
Income disruption	1.733**	1.655**	0.899	0.836	0.743	0.905
	(0.380)	(0.356)	(0.214)	(0.195)	(0.208)	(0.377)
Received government aid during COVID-19	1.061	1.750	1.379	1.230	1.831	1.921
	(0.308)	(0.678)	(0.407)	(0.350)	(0.732)	(0.810)
Received Economic Impact Payment	1.294	1.481	0.959	0.867	1.158	2.157
	(0.378)	(0.560)	(0.252)	(0.254)	(0.326)	(1.199)
Increased risk of severe COVID-19 symptoms	1.523*	1.171	1.974***	1.447**	0.549**	0.423*
	(0.367)	(0.281)	(0.392)	(0.255)	(0.142)	(0.195)
Personal likelihood of indoor dining	0.861	0.656***	1.026	0.832*	1.456**	2.056***
	(0.0810)	(0.0666)	(0.121)	(0.0919)	(0.219)	(0.380)
Personal likelihood of in-store grocery shopping	1.158**	0.878	0.973	0.941	0.853	1.025
	(0.0716)	(0.0868)	(0.0825)	(0.0825)	(0.0956)	(0.161)
Personal likelihood of restaurant pick-up	1.006	1.194*	0.969	1.128	0.968	0.792
	(0.0970)	(0.114)	(0.0994)	(0.115)	(0.177)	(0.180)
Perceived risk of indoor dining	1.034	1.196**	0.867*	0.981	0.688***	0.716*
	(0.0839)	(0.0983)	(0.0751)	(0.0782)	(0.0836)	(0.135)
Perceived risk of in-store grocery shopping	1.049	1.099	1.003	1.074	1.058	1.119
	(0.0741)	(0.0903)	(0.0902)	(0.0918)	(0.120)	(0.213)
Perceived risk of restaurant pick-up	1.054	0.988	1.238**	1.020	1.583***	1.646**
	(0.101)	(0.0967)	(0.131)	(0.107)	(0.282)	(0.407)
Female	0.994	0.767	1.111	0.874	0.456**	0.582
	(0.168)	(0.194)	(0.279)	(0.195)	(0.143)	(0.216)
Participant age: 35–64 years	1.851	1.209	1.843	1.728	0.916	1.208
	(0.954)	(0.402)	(0.709)	(0.595)	(0.388)	(0.773)
Participant age: 65 and older	1.819	0.930	0.953	1.124	0.539	1.222
	(0.922)	(0.285)	(0.394)	(0.379)	(0.237)	(1.012)
White	1.157	0.519**	0.593	0.934	0.628*	1.205
	(0.362)	(0.146)	(0.191)	(0.280)	(0.165)	(0.580)
Bachelor's degree or higher	0.905	1.435	1.005	0.796	0.881	1.129
	(0.276)	(0.349)	(0.256)	(0.173)	(0.270)	(0.438)
Household size	1.089	1.181**	0.902	1.041	1.165*	1.420**
	(0.0820)	(0.0885)	(0.0762)	(0.0823)	(0.0929)	(0.214)
Change in household size (July 2019–July 2020)	0.960	0.779***	0.936*	1.001	1.018	0.787***
	(0.0318)	(0.0668)	(0.0322)	(0.0419)	(0.0384)	(0.0483)
Region of U.S.:						
Northeast	2.362**	1.191	1.726	1.761**	2.892***	0.872
	(0.965)	(0.387)	(0.594)	(0.502)	(1.158)	(0.518)
South	1.483	1.240	1.946*	1.372	2.476***	1.537
	(0.544)	(0.335)	(0.744)	(0.386)	(0.804)	(0.869)
West	1.221	1.663*	1.294	1.384	3.281***	1.010
	(0.442)	(0.495)	(0.530)	(0.395)	(1.090)	(0.671)
Constant	0.0277***	0.286*	0.0573***	0.0877***	0.0464***	0.000356***
	(0.0228)	(0.201)	(0.0409)	(0.0584)	(0.0424)	(0.000418)
Observations	508	508	508	508	508	508

Odds ratios reported with standard errors clustered at the risk profile level listed in parentheses.
*, **, *** indicates significance at the 10%, 5%, and 1% levels, respectively.

dine indoors at a restaurant, had significantly higher odds of adding freezers/refrigerators. It is also noteworthy that the effect of income was marginally significant in the added refrigerator(s) regression, with around 46% of the high-income population (annual household income greater than $100,000) expanding capacity vs 18% for the low-income group (annual household income less than $50,000). This may speak to the convenience aspect of expanding cold storage capacity, rather than the risk aspect. Higher-income people with the financial ability to purchase refrigerators/freezers, who were less risk-averse and perceived food shortages at grocery stores, seem to have purchased additional cold storage units for convenience.

Participants who experienced any kind of disruptions to their normal

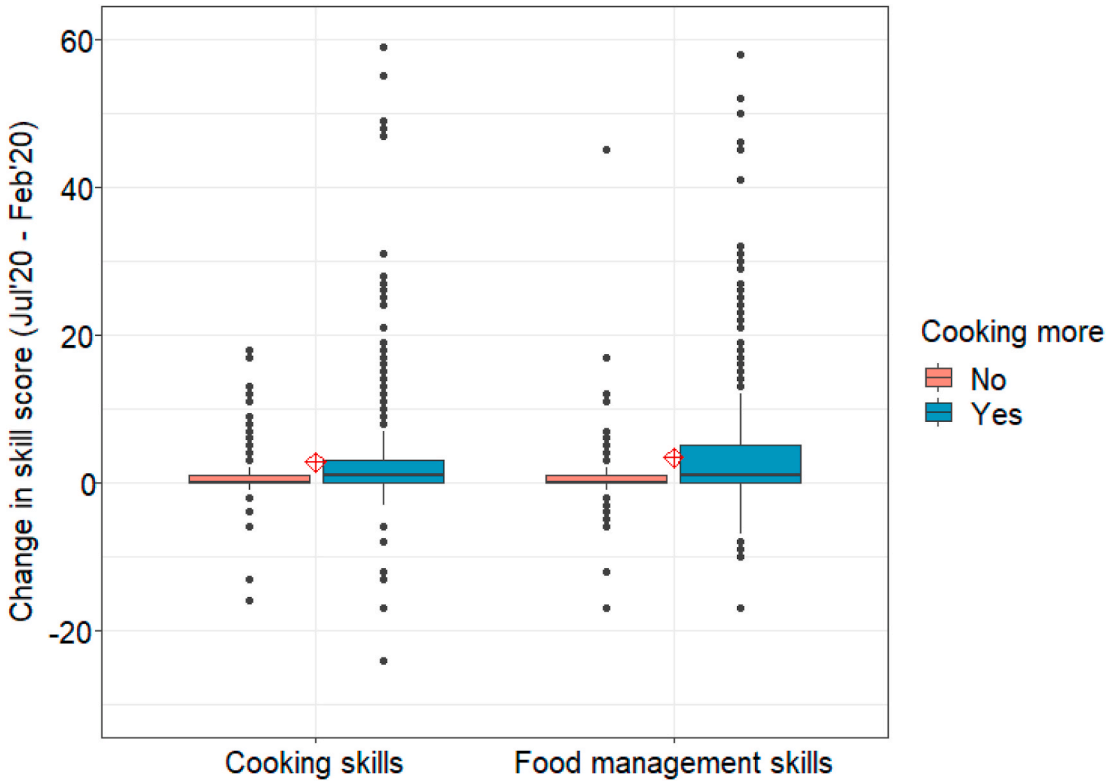

Fig. 2. Change in cooking skills and food management skills during the COVID-19 pandemic grouped by change in cooking frequency. *Notes*: Red diamonds represent mean change in skill scores, while the top (bottom) of the box represents the 75th (25th) percentile of the distribution. The solid horizontal line inside each box is the median while dots represent individual observations outside the inner fence of the distribution.

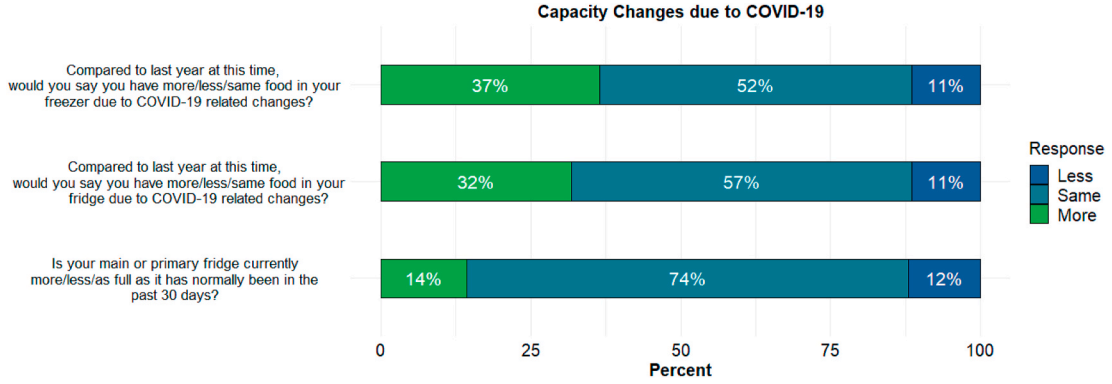

Fig. 3. Shifts in household cold storage inventory due to COVID-19 related change (n = 509).

schedule (i.e., they had more or less time than usual during the pandemic) were significantly associated with greater stockpiling of food in cold storage. This behavior has been observed in past psychological studies and stems from the need to take back control or the need for closure, which in turn has been shown to accentuate food waste behavior [9].

Additionally, households that were larger, that added people, and contained non-female participants were significantly more likely to purchase additional refrigerators and/or freezers. As compared to Midwestern participants (the omitted group), the odds of participants from these states expanding refrigerator capacity were observed to be significantly higher compared to Midwestern participants (the omitted group) which could possibly be explained by the spread of COVID-19 in southern and western states in July.

Although initial decreases in self-reported household food waste measures were observed across the world [11,12], long-term shifts in cold storage capacity through the addition of refrigerators/freezers could contribute to increased food waste if not managed properly. Increased space allows more opportunity for food to be hidden out of sight with the eventuality of being thrown away during a cleanout.

3.6. Factors considered in decision to discard food

In the follow-up survey, participants were asked about the importance of various factors in making food discard decisions. Fig. 4 shows the relative importance of discard considerations such as odor (how the food smells), whether the food looks safe to consume, whether the date on the package has passed, the date label phrase (e.g., sell-by, best-by, use-by), whether they trust the store's food quality, whether they have plans to use the food soon, if the food smells when discarded, amount they paid for the food, how full their refrigerator is, and whether they can compost the food. The order of importance of these factors during

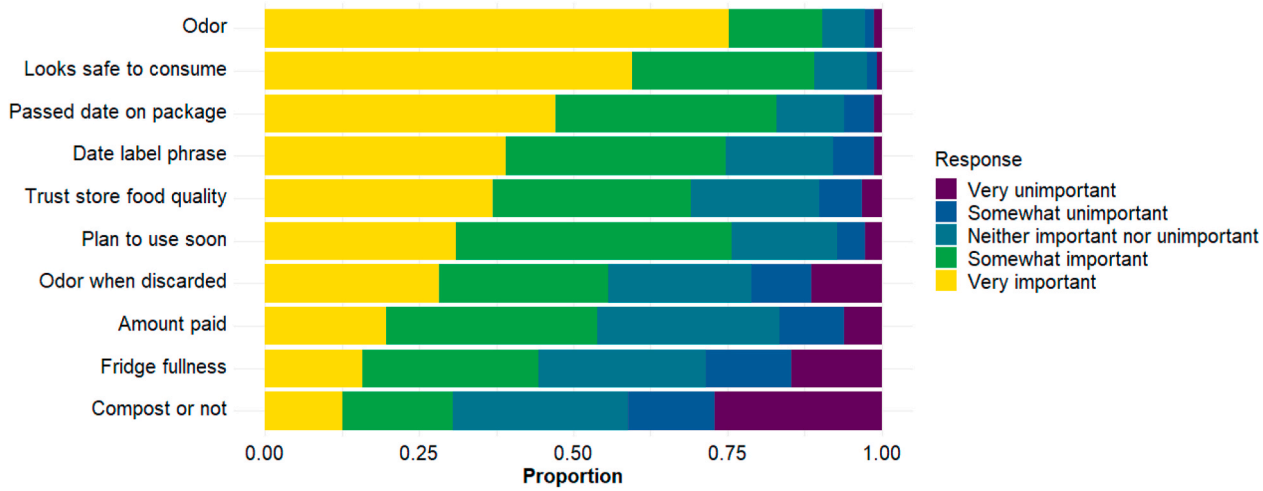

Fig. 4. Relative importance of factors in food discard decisions (n = 396).

the pandemic stayed identical to a similar assessment pre-pandemic in 2018 by Davenport et al. (2019), though with lower percentage of respondents placing importance on the topmost discard considerations (food odor and appearance) in 2020, and with higher total respondents (n = 396). Physical signals of food safety/quality (odor, appearance) are still identified as the most important considerations in discarding food during the COVID-19 pandemic, followed by label signals of food safety/quality (date and label phrase on the package).

Table 5 shows logistic regression results for each of the discard considerations against various food-related routines, shopping, and food disposal characteristics, household characteristics, and participant characteristics.

The COVID-19 pandemic may exacerbate the negative consequences of consumer confusion about date labels. As shown in Fig. 4, over 80% of participants place importance on the date label when making a discard decision. In these households, waste of stockpiled food is likely to be high. We noted frequent shoppers to be 5–7 times more likely to consider the date on the package when deciding to discard food, compared to people who shop once a month or less (Table 5, column 3). Consumers who shop more frequently may be doing so because of this consideration of the date on the package as date labels can induce consumers to discard foods [36] thus increasing their household demand for food. In addition, if consumers believe the date is important, they may need to shop more frequently to manage their food inventory in a manner consistent with this belief. Shopping frequently contributes to crowding in grocery stores, raising the risk of contracting COVID-19 for all shoppers and grocery store employees. This increase in shopping frequency combined with increased household demand and waste further strains a food system already stressed by the COVID-19 pandemic.

This is further supported by the correlation of regular refrigerator cleaning and participants placing importance on the date label phrase. Likewise, people who often or always check the date on food packages before purchasing were more likely to consider the label phrase when making a discard decision (Table 5, column 4). This factor was also positively associated with the "looks safe to consume" consideration.

For the "odor from discard" consideration, higher refrigerator cleaning frequency had a statistically significant effect along with occasional date checking, which also had a significant positive effect (Table 5, column 6). As observed in 2018, people who frequently cleaned their refrigerators were more likely to regard "trust store food quality" as an important food discard consideration. In contrast with pre-pandemic observations, those using their own car for grocery shopping had significantly higher odds of considering "trust store quality" as an important discard consideration (Table 5, column 7), and this could be explained by their ability to conveniently visit a store of their choosing without transportation hurdles or social distancing barriers. Higher refrigerator cleaning and grocery shopping frequencies significantly increased the odds of "fridge fullness" being an important consideration when discarding food (Table 5, column 9). Increased refrigerator cleaning frequency has been shown to suggest increased food waste of perishable refrigerated food items [22]. With increases in FAH expenditures and increased cold storage inventory due to COVID-19, encountering a full refrigerator might be a more frequent occurrence during the pandemic, especially for the population who were unable to purchase additional cold storage capacity. Having 10 or more pieces of fruits or vegetables in their refrigerators significantly reduced the odds of 'plan to use soon' being an important discard consideration (Table 5, column 2). Given that most people were stockpiling food during the pandemic, this likely reiterates hoarding behavior without considerations towards effective food management.

None of the food-related routines or shopping characteristics affected the "expense" or "plan to use soon" consideration. However, as expected, people with household incomes between $50,000 to $100,000 were significantly less likely than low-income households to place weight on the amount they paid for food when making discard decisions (Table 5, column 1). This effect was insignificant in the 2018 study, perhaps indicating households are prioritizing other factors such as food safety/quality over the cost of the food during the pandemic. Another explanation could be that in contrast with the medium-income group, low-income households were limited by budget constraints and might be prioritizing the expense over food safety/quality.

3.7. Discussion in the context of resilience

Resilient food systems are those that can provide sufficient, appropriate, and accessible food to all in the face of unforeseen disturbances. This requires resilience at the overall system level as well as resilience for each system component [14]. As the site of the majority of food consumption, households represent the focal downstream component of any food system, and understanding how households changed their food-related behaviors in response to COVID-19 and its consequences can inform how consumers sought to make their link in the food system resilient. Furthermore, we argue that understanding consumer responses can illuminate how individual actions might affect upstream food supply chain behaviors and, hence the resilience of the overall food system.

The supply chain literature suggests a number of strategies or actions that individual supply chain actors can apply to enhance resilience. These range from increased flexibility, added redundancy, enhanced efficiency, improved inventory management, deepened skillsets, and diversified sourcing to name a few [37]. Considering households as

Table 5
Odds ratios from logistic regressions of discard considerations for refrigerated food.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Expense	Plan to Use Soon	Date on Package	Date Label Phrase	Compost-ability	Odor from Discard	Trust Store Quality	Looks Safe	Fridge Fullness
Food-related routines									
Refrigerator Cleaning (Base: Never/Rarely)									
Sometimes	1.246	1.802	0.932	2.081*	0.800	2.049*	1.155	0.613	3.240**
	(0.529)	(0.693)	(0.409)	(0.795)	(0.408)	(0.791)	(0.467)	(0.444)	(1.746)
Often/very often	1.262	1.729	1.127	2.219**	0.938	1.764*	2.601***	0.504	2.386**
	(0.474)	(0.695)	(0.491)	(0.806)	(0.470)	(0.548)	(0.934)	(0.339)	(1.006)
Grocery Shopping Frequency (Base: Once a month or less)									
2 to 3 times a month	0.590	2.190	5.933***	1.532	0.517	0.787	2.555	1.781	2.345
	(0.355)	(1.600)	(3.509)	(1.039)	(0.365)	(0.297)	(1.625)	(1.383)	(1.568)
Once a week or more	0.442	2.298	7.114***	1.486	0.738	0.909	3.051*	2.100	2.703*
	(0.259)	(1.353)	(4.397)	(0.958)	(0.486)	(0.363)	(1.969)	(1.394)	(1.620)
Grocery shopping typically 30+ minutes	0.820	1.113	1.093	1.169	0.426***	0.845	0.708	1.773	0.928
	(0.209)	(0.280)	(0.443)	(0.314)	(0.112)	(0.181)	(0.227)	(0.625)	(0.205)
Check nutrition label (Base: Never/Rarely)									
Sometimes	0.794	1.229	0.972	1.088	0.927	0.869	0.977	0.777	1.400
	(0.234)	(0.515)	(0.337)	(0.458)	(0.428)	(0.305)	(0.408)	(0.260)	(0.442)
Often/Always	1.135	1.083	1.320	0.792	1.715	1.136	0.857	0.819	1.382
	(0.305)	(0.446)	(0.607)	(0.371)	(0.826)	(0.370)	(0.319)	(0.424)	(0.430)
Check date on package (Base: Never/Rarely)									
Sometimes	0.833	1.203	1.398	1.877	1.355	3.203**	0.827	2.627*	0.984
	(0.382)	(0.731)	(0.822)	(0.849)	(0.610)	(1.736)	(0.480)	(1.303)	(0.431)
Often/Always	0.952	1.584	1.675	4.285***	1.348	2.078	2.030	2.358*	1.506
	(0.381)	(0.950)	(0.910)	(1.879)	(0.627)	(0.999)	(1.056)	(1.075)	(0.615)
Other shopping & food disposal characteristics									
Use own car to do shopping	1.482	1.056	0.457	1.094	2.653	1.669	3.819***	0.807	1.086
	(0.655)	(0.513)	(0.297)	(0.491)	(1.846)	(0.692)	(1.766)	(0.704)	(0.552)
Compost/food waste disposal service	1.241	1.411	1.161	1.088	8.484***	1.250	0.779	1.499	1.404
	(0.376)	(0.486)	(0.528)	(0.359)	(2.541)	(0.407)	(0.275)	(0.717)	(0.441)
Pets/animals eat unwanted food	1.525	1.757	1.033	0.878	1.329	0.888	1.947*	0.943	1.272
	(0.497)	(0.706)	(0.452)	(0.275)	(0.397)	(0.287)	(0.676)	(0.417)	(0.464)
Respondent characteristics									
Race (Base: White)									
Black or African American	0.551	0.663	2.506	4.304	1.839	0.616	0.474	1.258	0.868
	(0.370)	(0.480)	(2.399)	(4.734)	(1.373)	(0.400)	(0.287)	(1.300)	(0.517)
Other	1.165	1.056	0.403***	0.623	1.511	0.673	1.437	0.836	1.892**
	(0.326)	(0.424)	(0.138)	(0.219)	(0.560)	(0.179)	(0.571)	(0.320)	(0.511)
Age (Base: 18–34 years)									
35–64 years old	0.577	0.430	1.230	0.693	0.490	0.368**	0.655	1.477	0.977
	(0.241)	(0.330)	(0.514)	(0.247)	(0.281)	(0.149)	(0.261)	(1.023)	(0.349)
65 years or older	0.359**	0.323	1.143	1.473	0.391*	0.267**	0.676	2.239	1.058
	(0.154)	(0.242)	(0.682)	(0.752)	(0.219)	(0.145)	(0.342)	(1.875)	(0.475)
Female	1.499*	1.274	1.926**	0.670	1.331	1.109	1.553**	1.564	1.260
	(0.319)	(0.327)	(0.527)	(0.215)	(0.348)	(0.238)	(0.331)	(0.545)	(0.239)
Bachelor's degree or higher	1.088	1.063	0.834	1.387	0.848	1.186	1.435	1.118	1.256
	(0.296)	(0.298)	(0.349)	(0.474)	(0.312)	(0.393)	(0.399)	(0.567)	(0.313)
Household Characteristics									
Annual household income (Base: Less than $50,000)									
$50,000 to $99,999	0.502**	1.533	0.728	0.838	1.155	1.069	0.751	0.868	0.642
	(0.175)	(0.604)	(0.332)	(0.326)	(0.500)	(0.413)	(0.247)	(0.437)	(0.208)
$100,000 or more	0.624	1.661	1.786	1.419	0.965	1.123	0.665	0.929	0.738
	(0.245)	(0.701)	(0.889)	(0.642)	(0.484)	(0.476)	(0.203)	(0.473)	(0.272)
Household Size	0.998	0.950	0.821	1.178	1.026	1.154	0.799*	0.862	1.019
	(0.116)	(0.169)	(0.169)	(0.205)	(0.177)	(0.151)	(0.105)	(0.258)	(0.150)
Number of children in household	0.942	0.973	1.253	1.149	1.137	0.882	1.312	0.942	1.349**
	(0.117)	(0.178)	(0.287)	(0.204)	(0.232)	(0.138)	(0.223)	(0.233)	(0.186)
10 or more pieces of fruit/veg	0.875	0.649**	0.596	0.697	1.025	0.666**	1.005	1.040	0.701
	(0.184)	(0.134)	(0.189)	(0.178)	(0.283)	(0.138)	(0.251)	(0.420)	(0.152)
Constant	3.264	0.733	1.139	0.241	0.196	0.421	0.198*	2.978	0.048***
	(2.565)	(0.729)	(1.401)	(0.253)	(0.214)	(0.406)	(0.175)	(5.949)	(0.042)
Observations	395	395	395	395	395	395	395	395	395

Standard errors clustered at the risk profile level.
*, **, *** indicates significance at the 10%, 5%, and 1% levels, respectively.

individual supply chain organizations, we argue that their responses are consistent with actions aimed to enhance resilience. For example, our documentation of improved cooking and food management skills points to a household 'workforce' that has a deeper skillset, which supports resilience, particularly if these skills promote flexibility (e.g., being able to make a meal when certain ingredients are unavailable or on the verge of expiring) and efficiency (reducing wasted food). Our documentation of both an increase in cold food storage capacity, through the acquisition of additional refrigerators and freezers, and of increased perceptions in how fully cold food storage is being utilized, points to redundancy actions, i.e., stockpiling of raw materials for meal preparation.

While both types of actions can work to enhance household resilience, these actions may hold different implications for system-wide resilience. Increased cold storage capacity, for example, may work against system-wide resilience due to its likely implications for consumer purchasing patterns and restocking behaviors. In the well-known case of 'bullwhip' effects, for example, it has been robustly documented that the stockpiling of supplies by downstream entities in a supply chain leads to heightened volatility in demand by subsequent upstream actors, as larger, less frequent orders are placed [38]. These larger orders act as shocks that propagate and grow as they move up linkages along the food supply chain, which would likely undermine system-wide resilience. Therefore, we would expect that as the final actor in the food supply chain, households that expand cold food storage capacity and use more of that capacity, enhance household resilience at the expense of system-wide resilience. We also note that refrigerators and freezers are among the most energy-intensive appliances in most homes; hence adding units also undermines sustainability.

On the other hand, enhanced skills in food preparation and management imply that households have the capacity to respond flexibly to shocks that are propagated downstream. For example, as cooking skills increase, one might expect additional flexibility to respond to occasional shortages of key ingredients or to use stored items that might be approaching label dates, while enhanced food management skills would mean needing to purchase less total food because waste is reduced. Such responses would seem to support overall food system resilience as upstream shocks (shortages) would be more easily absorbed by households. We also note that reducing food waste results in a reduction of greenhouse gas emissions [39,40] and is therefore supportive of sustainability.

We note that grocery stores and other upstream actors are likely better equipped than households to deal with COVID-19 related shocks, as these actors have formal inventory management systems and plans. However, we argue that COVID-19 has potentially introduced a different profile of shocks propagating from the final supply chain actor (households) due to households' resiliency responses. The interesting question that we are unable to answer in this study is whether the net impact of resiliency responses by households during COVID-19 supports or undermines overall resiliency of the entire food system. As discussed, improved cooking and food management skills that help increase household flexibility in the event of shocks may lead to less waste, soften demand for food on a per person basis, and reduce panic purchases that propagate upstream. However, increased household cold storage capacity may stimulate food stockpiling, leading to larger occasional purchases when restocking is required, which propagate shocks up the food supply chain, potentially exacerbating existing bullwhip effects. Further research is warranted to disentangle these complex system-wide issues.

4. Conclusions

The effects of the COVID-19 pandemic are only beginning to be understood. The onset of COVID-19 and the subsequent societal changes created a unique set of shocks to food systems, including to the management of food by households, the final link in food supply chains. To the best of these authors' knowledge, we provide one of the few comprehensive analyses of how household food management responded to this large and unique set of shocks. Furthermore, we contribute to this literature by placing the responses of households in a broader context of the larger discussion of food systems resilience.

Sixty-two percent of respondents report an increase in cooking at home compared to the same time in the previous year. This major shift to in-home food preparation was associated with time availability, perceived risks, and income disruptions and has several potential implications such as healthier eating, improved household food management, and changes in consumer food waste. Fifty-seven percent of participants reported an increase in cooking and/or food management skills, which indicates that there is likely increased engagement with food preparation in the home.

Over 40% of participants reported having more refrigerated or frozen food due to COVID-19 indicating some level of stockpiling. Not only were people stockpiling refrigerated and frozen food, they also expanded their cold storage capacity with 26% adding at least one refrigerator and 12% adding at least one freezer.

We then interpret these responses through the lens of food system resilience and find that key responses such as enhanced cooking and food management skills and increased cold food storage capacity and capacity utilization represent typical individual strategies to improve resilience. However, we note that different individual resilience responses may hold distinct implications for overall food system resilience, with increased home cold storage capacity potentially exacerbating system-wide volatility and undermining resilience.

Author contributions

Kathryn Bender: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing.

Aishwarya Badiger: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing.

Brian Roe: Conceptualization, Funding acquisition, Investigation, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Yiheng Shu: Conceptualization, Investigation, Methodology, Software, Writing – review & editing.

Danyi Qi: Conceptualization, Funding acquisition, Investigation, Supervision, Writing – review & editing.

Funding sources

Roe recognizes funding from the Ohio Agricultural Research and Development Center (Award #OHOA1632). Qi recognizes grant support from Louisiana Board of Regents (AWD-002915).

Declaration of competing interest

None.

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