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Frozen food purchasing and home freezing of fresh foods: associations with household food waste

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Abstract

Purpose – Freezing extends the shelf life of food. Home freezing of fresh foods and the purchase of frozen foods have been advocated as approaches to reduce food waste in US households. This paper discusses how commonly US households apply these practices, quantifies frozen food waste and relates these practices to food waste.

Design/methodology/approach – We add questions to the summer 2022 wave of the US Household Food Waste Tracking Survey. The novel survey data provide important baseline information and household behaviours, such as food waste, home freezing of fresh food and the purchase of frozen foods. We analyse the association among these behaviours from more than 1,000 US households.

Findings – We find that US household wastes about 26 g per person per week of food that was once frozen, which is about 6% of all household food waste. The finding indicates that a small portion of food waste in US households comes from frozen food. Vegetables and meats are the most commonly discarded frozen foods. Among the frozen items reported as discarded, about 30% were purchased as frozen rather than purchased fresh and then frozen at home by the consumer and about 30% more were reported as discarded from the refrigerator rather than directly from the freezer. The findings are important for informing strategies to reduce household food waste.

Research limitations/implications – While the data provide important baseline information and correlate the use of freezing with lower waste levels, more work is needed to understand if interventions encouraging frozen food purchase or home freezing would reduce household food waste.

Originality/value – We provide unique, detailed information about the quantity of frozen food waste in US households and the relationships between consumer food waste and the practices of frozen food purchasing and home freezing.

Keywords Household food waste, Freezing, Frozen food, Consumers

Paper type Research paper

1. Introduction

Food waste is a serious problem in the United States. In 2021, almost 40% of the entire US food supply was wasted, equivalent to 89 metric tons of uneaten food (RFWED, 2023). The average US household wastes around 32% of the food it purchases, which adds up to about $240bn of household expenditures that largely go to landfill (Yu and Jaenicke, 2020). Simultaneously, 10.2% of people in the US experience food insecurity (Gundersen *et al.*, 2023). The reduction of food waste offers an excellent opportunity to reduce the emissions that contribute to global climate change (IPCC, 2023). Therefore, finding solutions to food waste is significant for people and the environment, as it can address food insecurity, decrease economic loss, and protect the environment.

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Household food waste occurs when food, an inherently perishable item, becomes inedible in the eyes of the consumer. A fundamental response to perishability is to wield technologies to extend the shelf-life of food, which permits consumers more opportunities to consume food before they perceive it to be inedible. Freezing is a technology that wields low temperatures to extend the shelf-life of food and is a tool that has been promoted to reduce household food waste (Brown *et al.*, 2014; Alinovi *et al.*, 2021; van Holsteijn and Kemna, 2018; Mattila *et al.*, 2019). Food can be frozen during processing with temperature maintained by distributors, retailers and consumers until the food is ready for preparation. Alternatively, the consumer can freeze food that was not purchased as frozen for the purpose of saving food. Home freezing is often advocated as a means for extending the shelf life of fresh food purchases and reducing food waste (Gunders, 2022).

There is also evidence that the onset of COVID caused some people to buy and store more frozen food to avoid potential future food shortage during early stages of COVID (Beard-Knowland, 2020; Baker *et al.*, 2020; AlTarrah *et al.*, 2021) and led to increased home freezer capacity (Bender *et al.*, 2022). As frozen food has become more popular since COVID, it becomes increasingly relevant to explore the interactions between fresh and frozen food waste. Our study uses data collected more than two years after the onset of the pandemic to examine these dynamics. By analysing consumption patterns, waste levels, and storage practices, we aim to understand how frozen food usage influences overall and categorical food waste. The exploration will shed light on whether the preference for frozen foods led to reductions in fresh food waste, or if some consumer behaviours might inform useful strategies for food waste reduction and storage efficiency.

A critical question is whether consumers are using frozen foods and home freezing in a manner that reduces food waste or, alternatively, simply to delay inevitable waste (Hebrok and Heidenstrom, 2019), or, as Evans (2012) suggests, using home freezers as "coffins of decay." The extant literature fails to provide a definitive view of the net effect of the application of freezing on the amount of wasted food, and this lack of knowledge hampers formulation of food waste reduction interventions and education programs.

This study has three major research questions. First, what is the quantity of food that was once frozen that is wasted in US households? Second, what household characteristics are associated with the use of commercial and home food freezing methods? Finally, is overall household food waste associated with reliance on these freezing methods? To answer these questions, we use primary data collected as part of the US Household Food Waste Tracking Survey (Li *et al.*, 2023). The data speak to the amount of discarded food that was either purchased as frozen (commercially frozen) or frozen by consumers after purchase (home frozen), to relevant household characteristics including propensity to purchase frozen food, and to overall food waste amounts and behaviours.

Our results contribute to a select number of previous studies that have examined the relationship between frozen food and food waste (Table 1). These papers typically contrast the waste rates of fresh and frozen foods (Martindale, 2014; Martindale and Schiebel, 2017; Janssen *et al.*, 2017; Neff *et al.*, 2021). Distinct from most previous efforts, we utilise US *data* and provide a granular view of this process, both in terms of assessing the amount of frozen food waste in a wide array of commonly purchased food categories and identifying the last location of wasted food prior to discard (directly from the freezer or from the refrigerator). Moreover, this study considers other influential factors such as household food shopping frequency and the household's recent history of cleaning the fridge, freezer, and pantry when assessing total food waste and frozen food waste. By incorporating these elements, we provide a nuanced understanding of the dynamics of frozen foods within the household food

Study	Country	Food categories	Theoretical foundation	Summary
Martindale (2014)	UK	Broad range of frozen and fresh food categories (i.e. meat and fish, fruit and vegetable, bakery)	None	Sample size: 83 households • 5.59% of frozen food gets wasted • 10.46% of fresh food gets wasted • 47% more fresh food is wasted than frozen food
Martindale and Schiebel (2017)	Austria	Six food groups: fruit, vegetables, bread, pasta, meat, and fish	None	Sample size: 2,800 households • 1.60% of frozen food gets wasted • 9.30% of fresh food gets wasted • Fresh food waste is 5.8 times greater than the frozen food waste
Janssen *et al.* (2017)	The Netherlands	Vegetables (i.e. spinach, peas, broccoli), fish, readymade meals, and berry fruit	None	Sample size: 506 households • The waste index rates are different across food categories, i.e. 10% of fresh spinach gets wasted; 6% of frozen spinach gets wasted
Canals *et al.* (2008)	UK and Spain	Broccoli	None	Sample size: N/A • 20% of fresh broccoli gets wasted • 5% of frozen broccoli gets wasted
Neff *et al.* (2021)	United States	Seafood	a new conceptual model that integrates insights from extensive research on consumer seafood and food waste behavior	Sample size: 43 • 3.78% of fresh food gets wasted • 2.52% of frozen food gets wasted
This study	United States	Nine food categories, including vegetable, fruit, potato, grain, meat, mixed dishes, dairy, condiment and snack	None	Sample size: 1,067 • Household average reported waste is 800 grams per week • About 50 grams (6%) of waste come from frozen foods

Source(s): Authors' own work

Table 1.
Summary of relevant studies on frozen food waste at consumer level

waste generation process. These insights can illuminate development of targeted strategies to reduce food waste, promoting more sustainable consumption patterns, and enhancing food security.

2. Materials and methods

2.1 Sample population

US residents who participate in consumer panels managed by a commercial vendor (Prolific) were invited to participate in a two-part online survey during the summer of 2022 (1817 initiated, 1,067 (59%) provided complete responses). All participants provided informed consent and received compensation. The inclusion criteria specified that participants must be 18 years or older and responsible for at least half of the household food preparation, which ensured that the participant had adequate knowledge of food waste at the household level, where the household is the unit of observation and analysis. Recruitment quotas were implemented to ensure sufficient representation by geographical region, race and age group. Post-hoc sample weights based on age, household income and household size were applied to all descriptive statistics and analyses. No data was collected during the weeks that involved major holidays. The protocol was approved by the Ohio State University Internal Review Board.

Table 2 presents summary statistics for various demographic, socioeconomic, and regional characteristics of a sample population (n = 1,167), along with a comparison to the US average. Our sample has some key characteristics close to the US average, such as household size and composition, and household income.

2.2 Survey approach

The study was conducted by adding questions to the summer 2022 wave of the US Household Food Waste Tracking Survey, which is designed to consistently track the discard of once edible food by American households (Li *et al.*, 2023; Shu *et al.*, 2021) (see Appendix for copy of the survey instruments). The tracking survey involves participants completing an initial survey, which concludes with an announcement that a follow-up survey will be sent in approximately one week. During the following seven days, participants were instructed to pay attention to the amounts of different foods discarded, fed to animals, or composted in their households due to reasons such as expiration dates, spoilage, or no longer being desired. They were advised to exclude items such as bones, pits, and shells that they would typically not consume, i.e., no data is collected about inedible food waste. About a week later, participants received the follow-up survey, which required them to report the amount of food wasted over the past 7 days in 24 food categories. They were asked to report the waste amount by selecting from one of several ranges of possible amounts (listed in cups), and the gram weight for categories with volumetric ranges was derived by assigning an appropriate mass to the midpoint of the selected range consistent with the food category. Respondents were provided a visual guide to assist them in estimating food volumes prior to reporting waste amounts. For categories with highly variable weights per volume (e.g. a cup of raw asparagus weighing about 7 times more than a cup of raw chopped arugula), the gram weight was determined using consumption data for items commonly consumed in the United States (see Shu *et al.*, 2021 for details). To calculate the total weekly household food waste, the reported gram amounts for all categories were summed up.

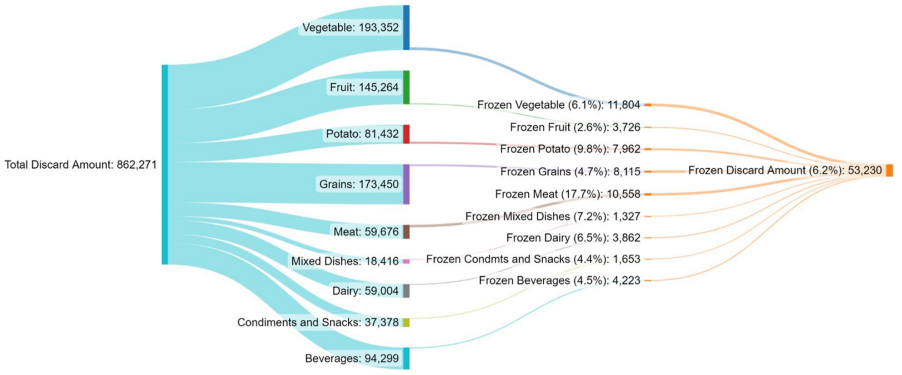
In addition to reporting waste amounts, participants in this study were also asked to estimate the percentage of discarded food in each reported category that were frozen items. The gram weight for frozen food in each category was derived by multiplying the total waste amount for that specific food category by the estimated percentage of discard that was frozen food. If participants reported any frozen food, they were prompted to check if one or more of the following was applicable for those discarded frozen items: purchased as frozen food; not frozen when purchased then frozen at home; removed from the freezer at the time of discard; and removed from refrigerator at the time of discard.

Variable	Mean		SD	Min, max
	Sample	US average		
Age				
18–44	0.371	0.356		
45–64	0.354	0.254		
65+	0.275	0.168		
Primary Racial Identification				
White	0.833	0.578		
Black	0.060	0.124		
Asian	0.054	0.060		
Another primary identification	0.053	0.238		
Identify as				
Latino	0.038	0.187		
Female	0.569	0.509		
Education				
< Bachelors	0.429			
Bachelors	0.399			
> Bachelors	0.173			
Household Income (annual $)				
<50k	0.379	0.390		
50-99k	0.286	0.315		
100k+	0.335	0.295		
Household Size and Composition				
1 member	0.268	0.280		
2 members	0.375	0.346		
3+ members	0.357	0.374		
Percent of household members are				
Children 5 or younger	0.031		0.108	0, 1
Children 6–17	0.081		0.175	0, 1
Adult Males	0.395		0.304	0, 1
Adult Females	0.482		0.315	0, 1
Employment Status				
Full Time	0.438			
Part Time	0.175			
Other	0.388			
Region				
Northeast	0.324	0.171		
South	0.244	0.383		
Midwest	0.206	0.208		
West	0.227	0.238		

Note(s): All figures based upon sample with post-hoc weights applied. $N = 1{,}067$
Source(s): Authors' own work

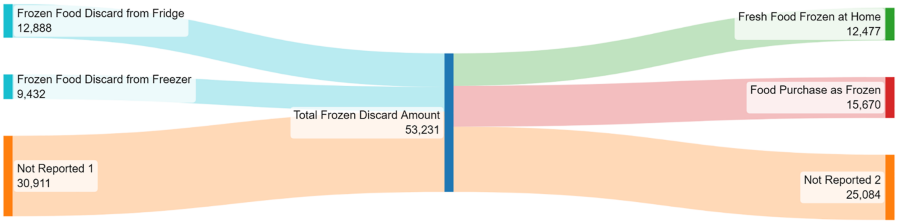
Table 2. Sample summary statistics for demographics

In addition to the waste questions, respondents were asked to indicate how often they typically bought frozen food (never, rarely, sometimes, frequently) and, of those who buy at least some frozen food, how often they buy frozen food because it helps reduce food waste (never, rarely, sometimes, frequently). They were also asked to report if, after their most recent shopping trip, they froze any food that was not purchased as frozen (yes, no, unsure). Table 2 provides summary statistics for the post-hoc weighted sample. Figure 1 provides a visualization of the discarded food by category and by frozen status while Figure 2 illustrates the fraction of frozen food waste that meets key criteria concerning who froze the food (processor vs home freezing) and the pre-discard location of frozen foods.



Note(s): Post-hoc weights applied, percentage of waste as frozen denoted in parentheses, $N = 1067$
Source(s): Authors' own work

Figure 1.
Sankey diagram of sample's reported grams of waste during the reporting week by food category and frozen status



Note(s): Grams reported by entire sample during their reporting week with post-hoc weights applied, $N = 1067$
Source(s): Authors' own work

Figure 2.
Sankey diagram of the sources of discarded frozen foods

2.3 Data analysis approach

We use logistic regression models to investigate the relationship between frozen food purchasing behaviour and individual and household characteristics. To explore the association between food waste amounts and these same characteristics, we use a censored regression model (Tobit) to account for the fact that a non-trivial fraction of the observed waste amounts are zero (censored at zero). All models apply post-hoc sample weights to ensure the sample is more representative of the US population in terms of household size, income and age – each of which have been shown to be critical explanatory variables with respect to food waste levels (Li *et al.*, 2023).

3. Results

Inspection of Table 3 and Figures 1 and 2 provides a detailed picture of how freezing interacts with wasted food among this sample of US consumers. While the average household reported wasting more than 800 grams of food per week, only about 6% (49.9 g) of this was frozen food, despite that 84% report purchasing frozen food "frequently" (38%) or "sometimes" (46%) and that 59% report freezing food that was not originally purchased as frozen. Table 3 provides more insights into frozen food purchasers and post-purchase food freezers. Frozen food purchasers are most likely to be respondents who report shopping only two to three

Variable	Mean	SD	Min, max
Wasted food			
g per household	807.914	948.657	0, 9020.1
g per person	376.173	474.464	0, 8360.0
Wasted frozen food			
g per household	49.876	240.977	0, 3768.4
g per person	22.023	106.552	0, 1539.3
Purchase frozen food			
Never	0.004		
Rarely	0.156		
Sometimes	0.461		
Frequently	0.379		
Purchase frozen food to reduce waste*			
Never	0.230		
Rarely	0.213		
Sometimes	0.371		
Frequently	0.181		
Freeze Food Not Purchased as Frozen			
Yes	0.587		
No	0.399		
Unsure	0.014		
Food Shopping Frequency			
>1/Week	0.249		
Weekly	0.519		
2–3 times/month	0.202		
Monthly or less frequently	0.030		

Note(s): All figures based upon sample with post-hoc weights applied. $N = 1{,}067$, except the "Purchase frozen food to reduce waste" with $N = 1{,}063$
Source(s): Authors' own work

Table 3. Sample summary statistics for food waste and food purchasing pattern

times per month, are in the lowest income category (<$50,000 annual household income) and live in northeastern states. Respondents who identify as Asian and have no young children are the least likely to report frequently shopping for frozen foods. With respect to freezing fresh food after purchase, respondents who are in the older two age groups (45 years and older) and in larger households (3 or more people) are significantly more likely to do so.

Figure 1 presents a comprehensive analysis of the total and frozen food waste, both in quantity and percentage, across a diverse array of commonly purchased food categories, while previous studies typically focus on a narrower selection of food categories. Figure 1 reveals the fraction of wasted food that was reported as frozen food with the overall figure at 6%. Nearly 18% of all discarded meat was frozen, about 10% of all potatoes, 6% of all vegetables and nearly 3% of all fruit. While we did not elicit the fraction of a household's food inventory or purchases that were frozen, we can turn to the most recent national statistics for certain food categories. For example, 7.2% of available vegetables (by weight) in 2019, 45.1% of all potatoes, and 3% of all fruit (excluding fruit juice) were in a frozen format (USDA, 2023). When looking at the total amount of frozen waste, meats (20% of total frozen waste) and vegetables (22%) are the most commonly discarded frozen foods with potatoes and grains constituting about 15% each.

Among consumers who report the details of their frozen food waste, Figure 2 demonstrates that more frozen items actually are discarded from the refrigerator than from the freezer (12,888g vs 9,432g, or about 37% more) while more of the discarded items were purchased as frozen rather than frozen by the consumer after purchase (15,670g vs 12,477g, or about 26%

more). The novel findings suggest that some consumers may need instructions or guidance on effectively translating purchased frozen items into fully utilised meal components, e.g. clearer thawing and preparation instructions on frozen foods.

Consumers report purchasing frozen foods with the specific intent to reduce waste frequently (18%) or sometimes (37%, Table 3), suggesting that more than half view frozen foods as a food waste mitigation tactic. The profile of this segment (Table 4, model 3) is similar to that of frequent frozen food buyers in that infrequent shoppers (2–3 times per month) and lower income households are significantly more likely to fall into this group, as are respondents who identify as female.

Table 4 shows that people who frequently (weekly or 2–3/month) shop for food are more likely to frequently purchase frozen foods compared to people who shop for food very frequently (>weekly). Moreover, people who purchase food less frequently (2–3/month) are more likely to purchase frozen food to reduce food waste than others. We also find some associations between food freezing behaviours and household characteristics. For example, households with more than one member are more likely to purchase frozen foods frequently or freeze food that is not purchased as frozen compared to other households. Households with higher income are less likely to purchase frozen foods frequently than households with lower income. Households living in the Northeast regions have a higher probability of frequently purchasing frozen foods than households living in the Midwest.

The censored regression results in Table 5 provide insights into the relationship between overall food waste and freezing behaviours (model 1). When controlling for a broad array of potentially confounding household characteristics and behaviours, the model reveals that respondents who frequently buy frozen food have food waste levels that are not significantly different than those who buy frozen foods less frequently. However, respondents that freeze fresh foods after purchase do report significantly less total food waste (about 102 g less, which is about 13% of the sample average) than other respondents. The characteristics with the strongest association with overall food waste involve whether the respondent recently cleaned the household's food storage areas – those who have cleaned their refrigerator, freezer or pantry in the past 7 days report the greatest waste levels.

Results in Table 5 also provide insights into the level of frozen items that were discarded in the past week (model 2). Those who have recently cleaned their freezer report significantly more frozen waste, though general tendencies concerning frozen food purchases and self-freezing fresh items are only marginally significantly associated with frozen discard levels in the past 7 days. Several personal characteristics also are significantly associated with greater amounts of discarded frozen items (e.g. those in the middle age category and respondents who identify as Black).

The last 4 models in Table 5 reveal personal and household characteristics that are associated with the origin and the disposal pathway of frozen items that are discarded. For example, frequent purchasers of frozen food are significantly more likely to discard items that were purchased as frozen food. Part-time workers, older respondents, those in larger households, and respondents identifying as Black also report significantly more discarded items that were originally purchased as frozen. Those who have recently cleaned their freezer are significantly associated with the discard identified in the last four columns of the table: waste purchased as frozen, waste frozen after purchase, waste discarded from the freezer, and waste discarded from the fridge.

Respondents are given an opportunity to acknowledge reasons why the amount of food wasted during their reporting week may be unusual compared to their normal household operation. Figure 3 depicts how often several key reasons are proffered by respondents who report discarding any amount of frozen items during their reporting week versus respondents who discard no frozen items. Overall, those who discarded frozen items offered more reasons why the waste level was unusual, with eating out unexpectedly, trying

	(1) Frequently purchase frozen foods (vs Sometimes, rarely or never)	(2) Freeze food not purchased as frozen (yes vs no and unsure)	(3) Frequently purchase frozen food to reduce waste (vs Sometimes, rarely or never
Shopping Frequency (Base: > weekly)			
Weekly	0.346*	0.178	0.244
	(0.189)	(0.175)	(0.257)
2–3/month	0.488**	0.130	0.592**
	(0.231)	(0.221)	(0.290)
≥1/month	−0.212	−0.076	0.042
	(0.445)	(0.448)	(0.565)
Fridge Cleaning History (Base: Within 7 days)			
8–30 days	−0.080	0.131	−0.197
	(0.237)	(0.248)	(0.322)
>30 days	0.225	−0.115	−0.212
	(0.277)	(0.266)	(0.360)
Not Applicable	−0.928**	0.506	0.158
	(0.431)	(0.392)	(0.489)
Freezer Cleaning History (Base: Within 7 days)			
8–30 days	0.452*	0.067	0.019
	(0.234)	(0.228)	(0.287)
>30 days	0.075	0.281	−0.118
	(0.222)	(0.220)	(0.278)
Not Applicable	0.073	0.013	−0.393
	(0.311)	(0.308)	(0.412)
Pantry Cleaning History (Base: Within 7 days)			
8–30 days	−0.108	−0.086	0.401
	(0.217)	(0.211)	(0.265)
>30 days	−0.144	−0.018	0.188
	(0.197)	(0.194)	(0.255)
Not Applicable	−0.225	0.007	0.508
	(0.278)	(0.279)	(0.362)
Employment Status (Base: Full time)			
Part time	0.152	0.017	0.226
	(0.223)	(0.210)	(0.252)
Other	0.236	−0.104	−0.053
	(0.203)	(0.182)	(0.249)
Age (Base: <45)			
45–64	0.111	0.383**	−0.160
	(0.174)	(0.164)	(0.220)
65+	0.335	1.025***	0.313
	(0.253)	(0.240)	(0.309)
Household Size (Base: 1)			
2	0.359*	0.217	0.143
	(0.197)	(0.191)	(0.243)
3+	0.373*	0.507**	0.065
	(0.218)	(0.205)	(0.269)
Household Income (Base: <50k)			
50-99k	−0.358*	−0.197	−0.554**
	(0.183)	(0.176)	(0.218)
100k+	−0.633***	−0.089	−0.713***
	(0.194)	(0.188)	(0.238)

Table 4.
Logit models for frozen food and freezing behaviours

(*continued*)

	(1) Frequently purchase frozen foods (vs Sometimes, rarely or never)	(2) Freeze food not purchased as frozen (yes vs no and unsure)	(3) Frequently purchase frozen food to reduce waste (vs Sometimes, rarely or never
Racial Identification (Base: White)			
Black	0.513*	0.308	0.308
	(0.293)	(0.275)	(0.339)
Asian	−0.642**	0.471	−0.071
	(0.324)	(0.294)	(0.396)
Other	0.128	0.380	−0.262
	(0.325)	(0.335)	(0.396)
Latino or Hispanic	−0.687*	0.406	0.518
(Yes = 1)	(0.354)	(0.350)	(0.404)
Region (Base: Midwest)			
Northeast	0.415**	0.370*	−0.060
	(0.207)	(0.201)	(0.253)
South	0.192	0.125	0.023
	(0.215)	(0.210)	(0.271)
West	0.132	0.367*	−0.108
	(0.221)	(0.216)	(0.287)
Female (Yes = 1)	−0.002	0.172	0.928***
	(0.177)	(0.169)	(0.246)
% of Adult Males in	0.060	0.100	0.239
Household	(0.396)	(0.424)	(0.504)
% of Adult Females	−0.033	0.191	−0.396
in Household	(0.389)	(0.423)	(0.490)
% of Children	1.484**	0.540	0.343
<5 Years in	(0.733)	(0.692)	(0.843)
Household			
Constant	−1.240***	−1.012**	−2.123***
	(0.477)	(0.502)	(0.654)
Observations	1,067	1,067	1,063
Pseudo R^2	0.056	0.039	0.065

Note(s): Standard errors are below coefficients. *, **, *** denote that parameter estimate is significantly different from zero at the 10%, 5%, 1% levels. Frequently Purchased Frozen Food to Reduce Waste was only asked of those who purchased at least some frozen foods

Source(s): Authors' own work

Table 4.

new recipes, and expired items purchased on sale or in bulk being the reasons that were significantly more likely to be mentioned than the group with no frozen discards.

4. Discussion

We confirm that freezing is a popular technology among our sample of 1067 US consumers who participated in the summer 2022 wave of the National Household Food Waste Tracking Survey. Our sample includes participants who have similar characteristics as the US average, such as the household size and income. More than 80% sometimes or frequently purchase commercially frozen foods, and a majority sometimes or frequently purchase commercially frozen foods specifically as a way to reduce food waste. A majority of the sample also reports home freezing of foods. Our findings align with those of the 2022 Frozen Food Waste Study conducted by the American Frozen Food Institute (AFFI). The AFFI collected data from 1,548 US households, revealing that 97% of respondents purchase frozen food at least once a year, and 92% freeze food at home, including leftovers. Furthermore, 71%

	(1) Total household food waste	(2) Frozen food waste	(3) Waste purchased as frozen	(4) Waste frozen after purchase	(5) Waste discarded from freezer	(6) Waste discarded from fridge
Frequently purchase frozen food (vs sometimes rarely or never)	37.49	43.31*	76.00**	2.021	−25.11	73.42
	(34.64)	(22.94)	(34.44)	(41.85)	(66.59)	(47.22)
Freeze food by yourself (yes = 1, no or unsure = 0)	−101.9***	−43.93*	−55.81	52.45	27.98	−20.57
	(36.80)	(22.51)	(34.69)	(32.16)	(57.67)	(37.91)
Shopping Frequency (Base: ≥2/week)						
Weekly	24.29	8.204	10.68	−10.18	−131.2*	20.73
	(38.70)	(25.51)	(43.81)	(43.14)	(69.61)	(46.75)
2–3/month	23.47	−30.51	−7.434	26.04	−185.7**	14.69
	(45.87)	(27.41)	(49.44)	(48.78)	(85.29)	(49.49)
≤1/month	−189.7**	−52.56	39.25	26.14	−1883.9***	−320.1**
	(87.70)	(52.04)	(92.38)	(84.88)	(290.4)	(162.7)
Fridge Cleaning History (Base: Within 7 days)						
Fridge 8–30 days	−308.0***	54.88	121.8*	49.73	236.9**	24.20
	(72.48)	(52.17)	(71.14)	(64.87)	(91.83)	(89.37)
Fridge >30 days	−589.7***	−45.17	108.2	−34.76	320.9**	−211.0
	(85.39)	(45.29)	(77.72)	(78.43)	(133.5)	(133.2)
Fridge Not Applicable	−482.2***	−46.99	−29.81	−168.9	256.7	−157.6
	(152.7)	(47.02)	(94.55)	(105.5)	(291.9)	(101.7)
Freezer Cleaning History (Base: Within 7 days)						
Freezer 8–30 days	−45.20	−187.1***	−252.5***	−236.5***	−300.7***	−88.69**
	(58.28)	(38.15)	(63.61)	(71.03)	(95.69)	(44.87)
Freezer >30 days	−148.7***	−312.4***	−427.7***	−437.2***	−617.1***	−288.1***
	(49.24)	(54.63)	(86.79)	(103.8)	(143.6)	(104.4)
Freezer Not Applicable	−333.0***	−301.0***	−411.9***	−363.2***	−2071.7***	−268.9**
	(61.22)	(61.43)	(107.1)	(96.75)	(343.2)	(117.4)
Pantry Cleaning History (Base: Within 7 days)						
Pantry 8–30 days	−171.4***	−8.778	16.73	28.40	15.09	−91.08
	(53.56)	(35.20)	(51.41)	(42.50)	(74.38)	(79.39)
Pantry >30 days	−256.0***	−51.89	−12.50	−12.85	−100.5	−81.35
	(46.02)	(31.58)	(44.09)	(45.92)	(89.28)	(69.64)
Pantry Not Applicable	−173.4***	21.84	18.17	−0.322	−270.4	93.52
	(58.87)	(35.47)	(83.08)	(64.20)	(210.7)	(60.29)
Employment Status (Base: Full time)						
Part time	4.437	40.54	107.6**	27.93	−110.5	83.23
	(45.95)	(28.87)	(51.67)	(49.15)	(88.04)	(56.57)
Other	−36.85	7.310	−72.36	3.406	−24.96	51.40
	(40.68)	(25.49)	(45.49)	(41.69)	(77.48)	(51.54)
Age (Base: <45)						
45–64	−28.79	46.56**	18.11	31.44	−57.62	46.36
	(32.76)	(23.51)	(44.37)	(45.58)	(72.09)	(45.46)
65+	−42.65	67.44	138.5**	97.14*	29.77	119.4
	(60.38)	(41.66)	(61.79)	(55.21)	(94.43)	(100.7)
Household Size (Base: 1)						
2	−232.2***	19.66	160.3***	97.03*	77.00	59.93
	(49.23)	(30.02)	(58.52)	(53.83)	(86.93)	(59.95)

Table 5.
Tobit model for freezing behaviour on food waste

(*continued*)

	(1) Total household food waste	(2) Frozen food waste	(3) Waste purchased as frozen	(4) Waste frozen after purchase	(5) Waste discarded from freezer	(6) Waste discarded from fridge
3+	−359.4***	9.762	215.0***	77.56	82.06	69.05
	(50.11)	(28.90)	(60.84)	(47.28)	(88.69)	(58.20)
Household Income (Base: <50k)						
50-99k	63.95	24.91	−3.194	24.28	−56.26	80.15
	(42.99)	(24.89)	(42.21)	(42.13)	(69.77)	(55.85)
100k+	−4.162	−43.17*	−26.35	−81.98	−127.4	56.04
	(35.93)	(24.94)	(48.61)	(51.62)	(81.61)	(46.44)
Racial Identification (Base: White)						
Black	47.56	90.81***	142.7**	75.01	227.0**	120.5*
	(50.63)	(28.20)	(61.16)	(76.91)	(94.39)	(64.95)
Asian	−27.29	62.47	105.8	112.1	−227.0	52.34
	(63.31)	(39.78)	(71.30)	(73.58)	(140.0)	(80.37)
Other	17.68	−14.76	−35.32	−0.878	−117.9	−89.08
	(67.24)	(35.13)	(77.36)	(66.82)	(141.7)	(75.23)
Latino or Hispanic (Yes = 1)	−96.43*	48.79	140.9	92.39	203.3*	−12.65
	(51.40)	(36.83)	(98.02)	(66.90)	(108.5)	(75.82)
Region (Base: Midwest)						
Northeast	34.14	−3.349	10.32	−16.91	53.33	−30.46
	(50.35)	(29.13)	(50.55)	(43.88)	(75.29)	(55.67)
South	−6.282	−13.54	13.83	0.836	−18.39	−27.02
	(54.11)	(28.56)	(49.79)	(43.71)	(92.45)	(54.37)
West	18.02	1.628	8.253	−9.304	95.46	−20.51
	(56.32)	(35.91)	(55.58)	(52.96)	(103.5)	(61.70)
Female (Yes = 1)	−15.37	8.572	51.15	6.480	−96.00	44.94
	(43.02)	(23.07)	(44.79)	(39.77)	(70.36)	(36.79)
Percent of Adult Males in Household	−57.97	−55.26	4.927	24.58	101.3	−78.30
	(89.63)	(52.84)	(119.4)	(90.69)	(157.1)	(90.15)
Percent of Adult Females in Household	111.6	−75.09	9.348	−152.2*	88.48	−20.31
	(91.06)	(46.03)	(98.53)	(92.02)	(157.7)	(79.42)
Percent of 0–5 Children in Household	−43.12	74.76	68.52	282.8*	373.4	23.49
	(131.4)	(97.18)	(192.3)	(160.6)	(249.4)	(170.9)
Constant	968.7***	85.13	−389.9**	−206.8*	−303.2	−350.1*
	(115.3)	(65.80)	(163.6)	(111.0)	(231.7)	(184.4)
Observations	1,067	1,067	1,067	1,067	1,067	1,067
Pseudo R^2	0.026	0.051	0.078	0.075	0.127	0.040

Note(s): All dependent variables expressed in grams other than % Food Waste as Frozen. Standard errors are below coefficients. *, **, *** denotes coefficients are statistically different from zero a the 10%, 5%, 1% levels. Pseudo R^2 is an indicator of how well the model fits the data when traditional R^2 is not applicable, such as logistic regression

Source(s): Authors' own work

Table 5.

of respondents purchasing frozen food reported consuming frozen food at least weekly (AFFI, 2023).

Our study also contributes by comparing the waste outcomes from two types of freezing, commercially freezing and home freezing. While both types of freezing are popular in our sample, the profile of those who embrace commercially frozen food for waste reduction

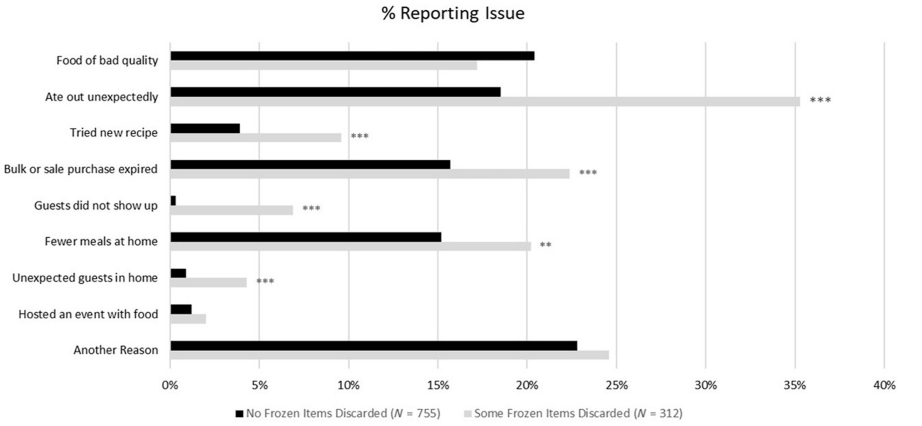


Figure 3.
Reasons for unexpected waste levels during reporting week by amount of frozen food discarded

Note(s): ** and *** represent that the reporting issue is statistically different between two groups (no frozen discarded vs. some frozen discarded) at 5% and 1% significance level

Source(s): Authors' own work

(female, lower income respondents who shop less frequently for food) is distinct from those who turn to home freezing (older respondents from larger households). The findings may imply that commercially frozen foods are viewed as a value proposition for households of limited means and flexibility (lower income who are unable to shop on a weekly basis) while home freezing may be a better fit for those with more experience (older respondents) and are responsible for feeding larger groups (households of three or more people).

Despite the popularity of frozen foods within this sample, we find that very little of the discarded food was ever commercially frozen or home frozen (~6%). The survey does not collect information concerning the amount of food that was purchased as frozen or frozen at home, so we are unable to estimate the fraction of frozen food that is wasted. Hence, we cannot directly compare our results to the extant literature that derives ratios of fresh to frozen waste rates which compares between the amount of food waste generated from fresh produce versus frozen produce (Martindale, 2014; Martindale and Schiebel, 2017; Neff *et al.*, 2021; Janssen *et al.*, 2017; Canals *et al.*, 2008; Withanage, 2020). However, we can compare the fraction of waste in three categories (vegetables, potatoes and fruit) to national statistics from 2019 that estimate the fraction of food in each category that is processed as frozen. We find that our estimate of the fraction of waste that is frozen is lower than or similar to the fraction that is nationally available as frozen for potatoes (10% of sample's waste vs 45% of commercial production), non-potato vegetables (6 vs 7%) and fruit (3 vs 3%). Given that potatoes and other vegetables are among the most wasted categories in the Tracking Survey data (Li *et al.*, 2023), the lower rate of waste as frozen compared to national production figures for frozen processing supports the idea that the ratio of fresh to frozen waste rates exceeds one. The finding implies that more food waste is generated from fresh produce than from frozen produce. This aligns with findings in the existing literature and suggests that frozen foods are less likely to be wasted due to their longer shelf life compared to fresh foods.

The richness of the tracking survey data allows us to directly assess if respondents who frequently use commercial and home freezing tend to waste more or less than other respondents while controlling for other factors such as household size and respondent age that are typically associated with waste levels. Those respondents who frequently undertake

home freezing have significantly less total food waste than other respondents, but those who frequently buy frozen foods waste a similar amount as those who rely upon commercially frozen foods less often. The act of freezing an item that was purchased as fresh (or freezing items prepared in excess) implies a level of food management involvement that is greater than simply purchasing commercially frozen foods and may indicate that these respondents have skills and motivation that spill over to other actions that also lead to less overall food waste (Rohm *et al.*, 2017).

The observed correlation between home freezing practices and the reduction of food waste highlights the great potential of targeted interventions in refrigerator and freezer management to minimize household food waste. Achieving reductions in food waste requires behavioural changes in domestic routines, which include food planning, food storage, and the reuse of leftovers. While adopting food planning skills can lead to waste reduction, this necessitates households prioritizing their money and time for food, planning food intake, making feasible food decisions that balance food needs with available resources, and navigating uncertainties within their planning frameworks (Vidgen and Gallegos, 2014). The learning curve associated with these practices may deter long-term commitment among households. Similarly, the reuse of leftovers involves a sophisticated sequence of actions—classifying, selecting, storing, and reusing (Cappellini, 2009). This process demands a significant investment of time and skill development to repurpose perceived waste into appealing meals. In contrast, the principles of fridge/freezer management are universally applicable and straightforward, offering an accessible way for households to gain essential food preservation skills through clear guidance on optimal storage conditions. This approach not only extends the shelf life of food, thereby giving households more time to utilise food effectively and minimize waste, but also bolsters the process of leftover reuse, further mitigating waste.

Of the frozen items that were discarded, meats, vegetables and potatoes are the most common categories, while discard is more likely to occur among commercially frozen rather than home frozen items and from frozen items that had been thawed and were being stored in the refrigerator rather than directly from the freezer. The fact that more commercially frozen food is discarded than home-frozen items suggests that some consumers may benefit from additional guidance on how to effectively incorporate purchased frozen items into fully utilised meal components. This could include providing clearer thawing and preparation instructions on frozen food packaging, offering tips on meal planning that integrates frozen ingredients, and creating educational resources that demonstrate various ways to use frozen foods in everyday cooking. By enhancing the information available to consumers, it is possible to reduce food waste by helping individuals make the most of their frozen food purchases and ensuring these items are used efficiently and effectively.

The structure of the survey question assessing the discard pathway and the commercial vs home frozen nature of the discarded items does not permit an exhaustive cross tabulation as participants were able to check all that apply rather than being pressed to articulate which pathway (from refrigerator or freezer) and which origin (home or commercial freezing) applied to discarded items. Implementing such a question structure would permit isolating if the discard of frozen items is due to issues encountered during the thawing and utilization of commercially frozen items or whether it may have to do with improper home freezing of fresh items, which would lead to different modes of intervention (e.g. improving printed directions on packages vs broad-based culinary education on home freezing processes).

Compared to the previous studies, our study also contributes by identifying some novel and significant predictors of frozen food waste. The strongest predictor of the amount of frozen items that are discarded is whether the respondent cleaned their freezer during the reporting period, which is not surprising nor informative, as we do not elicit from respondents why they felt it necessary to clean their freezer in the past week. Indeed, those

who cleaned their freezer during the reporting week have significantly more frozen items that were purchased as frozen, home frozen, discarded from the freezer and, less intuitively, discarded from the refrigerator. When focusing only on the reported frozen waste that was purchased as commercially frozen food, those who frequently purchase such items are significantly more likely to discard frozen items, which would seem to be a logical outcome for households with a larger stockpile of frozen food items.

5. Conclusions

This study offers a comprehensive analysis of frozen food waste across a diverse range of commonly purchased food categories, providing new insights that contribute to the existing literature on food waste. Distinct from most previous studies, we provide a granular view of the food waste process, assess the share and amount of frozen food waste across various categories, and identify the last location of wasted food prior to discard—whether directly from the freezer or from the refrigerator. Our study also goes beyond traditional factors by considering the impact of household food shopping frequency and the household's recent history of cleaning the fridge, freezer, and pantry when assessing both total and frozen food waste. Including these factors provides a novel understanding of frozen foods' dynamics within the household food waste generation process.

Our analyses yield results that are consistent with the idea that commercial and home freezing of food can limit the amount of food that was wasted in US households. The significant negative association between the use of home freezing and the total amount of waste supports the idea that home freezing as an intervention that can support waste reduction, though we must caution that this is a correlative rather than a causative finding due to the limitations of the study. To more definitively support the efficacy of home freezing, future studies should assess waste prior to and after an intervention that teaches and encourages home food freezing. Future studies might also explore if the relationship between freezing practices and food waste reduction holds across different populations through expanding the sample size and diversity of participants and by comparing the effectiveness of home freezing as a waste reduction strategy in different contexts.

Another of our findings is that only 10% of potato waste is reported to have been frozen while recent data suggests that 45% of potatoes are processed into frozen formats. This can imply that commercial freezing is a mechanism to support waste reduction, though we must provide the caveat that we do not have data from our tracking survey households on the fraction of home food inventories that were commercially or home frozen and that our data shows no significant association between frequent purchasing of commercial frozen foods and overall food waste.

Unlike previous studies that primarily establish a connection between purchased food and subsequent waste—often by estimating waste rates for fresh and frozen foods—our study takes a more comprehensive approach. We focus not only on quantifying total and frozen food waste but also on examining the relationship between overall food waste and waste within specific food categories. By doing so, our research provides a deeper understanding of how different types of food contribute to total waste, offering a more nuanced perspective on the dynamics of food waste generation.

Future work should also address other limitations of our study, including our reliance upon data from a single season (summer), our lack of food purchase and inventory data, and our reliance on surveys (rather than, e.g. audits of household waste streams) to assess home food waste. Future work should also explore issues surrounding differences in inedible food waste (i.e. food scraps) that might arise when shifting from fresh to frozen food purchases. Future studies would also benefit from documentation of respondent food skills, especially those related to food freezing and thawing.

References

Alinovi, M., Mucchetti, G., Wiking, L. and Corredig, M. (2021), "Freezing as a solution to preserve the quality of dairy products: the case of milk, curds and cheese", *Critical Reviews in Food Science and Nutrition*, Vol. 61 No. 20, pp. 3340-3360, doi: 10.1080/10408398.2020.1798348.

AlTarrah, D., AlShami, E., AlHamad, N., AlBesher, F. and Devarajan, S. (2021), "The impact of coronavirus COVID-19 pandemic on food purchasing, eating behavior, and perception of food safety in Kuwait", *Sustainability*, Vol. 13 No. 16, p. 8987, doi: 10.3390/su13168987.

American Frozen Food Institute(AFFI) (2023), "2022 frozen food waste study", available at: https://frozenadvantage.org/wp-content/uploads/2023/05/Consumer-Food-Waste-Survey.pdf (accessed 30 May 2024).

Baker, S.R., Farrokhnia, R.A., Meyer, S., Pagel, M. and Yannelis, C. (2020), "How does household spending respond to an epidemic? Consumption during the 2020 COVID-19 pandemic", *The Review of Asset Pricing Studies*, Vol. 10 No. 4, pp. 834-862, doi: 10.1093/rapstu/raaa009.

Beard-Knowland, T. (2020), "The impact of COVID-19 on how we eat", available at: https://www.ipsos.com/en/impact-covid-19-how-we-eat (accessed 9 August 2023).

Bender, K.E., Badiger, A., Roe, B.E., Shu, Y. and Qi, D. (2022), "Consumer behavior during the COVID-19 pandemic: an analysis of food purchasing and management behaviors in US households through the lens of food system resilience", *Socio-Economic Planning Sciences*, Vol. 82, 101107, doi: 10.1016/j.seps.2021.101107.

Brown, T., Hipps, N.A., Easteal, S., Parry, A. and Evans, J.A. (2014), "Reducing domestic food waste by freezing at home", *International Journal of Refrigeration*, Vol. 40, pp. 362-369, doi: 10.1016/j.ijrefrig.2013.12.009.

Canals, L.M., Muñoz, I., Hospido, A., Plassmann, K. and McLaren, S. (2008), "Life cycle assessment (LCA) of domestic vs. imported vegetables. Case studies on broccoli, salad crops and green beans", CES Working Paper. Centre for Environmental Strategy, University of Surrey.

Cappellini, B. (2009), "The sacrifice of re-use: the travels of leftovers and family relations", *Journal of Consumer Behaviour: International Research and Review*, Vol. 8 No. 6, pp. 365-375, doi: 10.1002/cb.299.

Evans, D. (2012), "Binning, gifting and recovery: the conduits of disposal in household food consumption", *Environment and Planning D: Society and Space*, Vol. 30 No. 6, pp. 1123-1137, doi: 10.1068/d22210.

Gunders, D. (2022), "Freeze more, waste less", *Natural Resources Defense Council*, available at: https://www.nrdc.org/stories/freeze-more-waste-less (accessed 8 August 2023).

Gundersen, C., Strayer, M., Dewey, A., Hake, M. and Engelhard, E. (2023), "Map the meal gap 2023: an analysis of county and congressional district food insecurity and county food cost in the United States in 2021", Feeding America, available at: https://www.feedingamerica.org/research/map-the-meal-gap/overall-executive-summary (accessed 8 August 2023).

Hebrok, M. and Heidenstrøm, N. (2019), "Contextualising food waste prevention - decisive moments within everyday practices", *Journal of Cleaner Production*, Vol. 210, pp. 1435-1448, doi: 10.1016/j.jclepro.2018.11.141.

Intergovernmental Panel on Climate Change (IPCC) (2023), *Climate Change 2022 - Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, doi: 10.1017/9781009157926.

Janssen, A.M., Nijenhuis-de Vries, M.A., Boer, E.P. and Kremer, S. (2017), "Fresh, frozen, or ambient food equivalents and their impact on food waste generation in Dutch households", *Waste Management*, Vol. 67, pp. 298-307, doi: 10.1016/j.wasman.2017.05.010.

Li, R., Shu, Y., Bender, K.E. and Roe, B.E. (2023), "Household food waste trending upwards in the United States: insights from a national tracking survey", *Journal of the Agricultural and Applied Economics Association*, Vol. 2, pp. 306-317, doi: 10.1002/jaa2.59.

Martindale, W. (2014), "Using consumer surveys to determine food sustainability", *British Food Journal*, Vol. 116 No. 7, pp. 1194-1204, doi: 10.1108/BFJ-09-2013-0242.

Martindale, W. and Schiebel, W. (2017), "The impact of food preservation on food waste", *British Food Journal*, Vol. 119 No. 12, pp. 2510-2518, doi: 10.1108/BFJ-02-2017-0114.

Mattila, M., Mesiranta, N., Närvänen, E., Koskinen, O. and Sutinen, U.M. (2019), "Dances with potential food waste: organising temporality in food waste reduction practices", *Time and Society*, Vol. 28 No. 4, pp. 1619-1644, doi: 10.1177/0961463X1878412.

Neff, R.A., Love, D.C., Overbey, K., Biehl, E., Deutsch, J., Gorski-Steiner, I., Pearson, P., Vigil, T., Turvey, C. and Fry, J.P. (2021), "Consumer seafood waste and the potential of a 'direct-from-frozen'approach to prevention", *Foods*, Vol. 10 No. 11, p. 2524, doi: 10.3390/foods10112524.

Rethink Food Waste through Economics and Data (ReFED) (2023), "Data insights engine", available at: https://insights.refed.org/ (accessed 8 August 2023).

Rohm, H., Oostindjer, M., Aschemann-Witzel, J., Symmank, C., Almli, V.L., De Hooge, I.E., Normann, A. and Karantininis, K. (2017), "Consumers in a sustainable food supply chain (COSUS): understanding consumer behavior to encourage food waste reduction", *Foods*, Vol. 6 No. 12, p. 104, doi: 10.3390/foods6120104.

Shu, Y., Roe, B.E. and Bender, K. (2021), "Adapting, refining and expanding a validated questionnaire to measure food waste in US households", *MethodsX*, Vol. 8, 101377, doi: 10.1016/j.mex.2021.101377.

US Department of Agriculture (USDA) (2023), "Food availability (per capita) data system", available at: https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/ (accessed 8 August 2023).

van Holsteijn, F. and Kemna, R. (2018), "Minimizing food waste by improving storage conditions in household refrigeration", *Resources, Conservation and Recycling*, Vol. 128, pp. 25-31, doi: 10.1016/j.resconrec.2017.09.012.

Vidgen, H.A. and Gallegos, D. (2014), "Defining food literacy and its components", *Appetite*, Vol. 76, pp. 50-59, doi: 10.1016/j.appet.2014.01.010.

Withanage, S.V. (2020), "Food waste generation at households and the resulting life cycle environmental impacts: a case study of fresh and frozen broccoli", unpublished master thesis, University of Waterloo, available at: https://uwspace.uwaterloo.ca/handle/10012/16207 (accessed 8 August 2023).

Yu, Y. and Jaenicke, E.C. (2020), "Estimating food waste as household production inefficiency", *American Journal of Agricultural Economics*, Vol. 102 No. 2, pp. 525-547, doi: 10.1002/ajae.12036.

Supplementary material

The supplementary material for this article can be found online.

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