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Examining Food Loss and Food Waste in the United States

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JEL Classifications: D12, Q12, Q18

Keywords: Food loss, Food waste, Supply chain, Fresh produce, Packaged foods

Food that is lost before it reaches the consumer, and food that is wasted by consumers, has been estimated to account for as much as 40% of the total food produced in the United States (Buzby, Wells, and Hyman, 2014; Hall et al., 2009). This represents losses of important resources—including water, chemical inputs, and labor—as well as unused nutrients for consumers. Stakeholders along the supply chain are increasingly interested in developing improved approaches to measuring food waste, understanding its determinants, and devising strategies to ultimately reduce it.

To date, a majority of food waste studies have focused on household-level waste; fewer studies have examined waste in food distribution and retail settings, and very little work has been conducted to understand the economic causes and consequences of food loss at the farm level. This *Choices* theme presents a collection of articles that explore food loss and food waste in the context of the U.S. food supply chain. The behavior and incentives of a variety of food system stakeholders including producers, market intermediaries (including retailers), and consumers are considered. The articles are organized along the supply chain, beginning with upstream issues of food loss proceeding through downstream topics such as household decisions concerning when to discard food. Taken together, this collection offers intriguing insights into current frontiers of the myriad private and public efforts to better characterize, quantify, and reduce food waste.

The contribution by Dunning, Johnson, and Boys provides a novel framework for assessing the value of food lost on farms. They focus on six vegetables grown in North Carolina and use farm-level data to estimate the potential profits associated with additional harvests of marketable and edible crop that would ultimately reduce field-level food loss. Their results indicate that, under some conditions, additional harvests and subsequent sales would lead to modest yet nontrivial increases in per acre profits (notably for cucumbers and sweet potatoes). The framework developed here allows us to better understand the economic tradeoffs associated with reducing food loss in the fields and nudges us toward thinking more carefully about potential markets for foods, notably vegetables, which currently are not harvested.

Capps Jr., Ishdorj, Murano, Field, Hutto, and Storey describe a pilot study examining the nature of vegetable plate waste in two elementary school districts in Texas during the 2012–2013 academic year. Results from this work showcase the level of waste of vegetables in this setting: Plate waste for all vegetables and all subgroups of vegetables exceeded 35%, and in many cases was greater than 60%. Waste levels across vegetable subgroups varied widely, with the least waste associated with potatoes and beans and the most waste with dark green and red-orange vegetables. This work provides additional evidence that not all food is wasted in the same amount and has implications for generic efforts that attempt to decrease total plate waste.

Bolos, Lagerkvist, and Nayga Jr. consider the impact of visual appearance, information effects, and goals in consumer food choices. The implications of these literature-based observations are then used to consider purchase decisions of cosmetically imperfect produce in retail settings. Examples of retailer initiatives to reduce food waste drawn from both the United States and Europe are highlighted. The authors suggest that future research into cognitive and behavioral nudges concerning the consumption of cosmetically imperfect produce may yield concrete actions that retailers could implement to encourage consumers to purchase these products.

Grant, Gallardo, and McCluskey shed new light on how consumers may adjust food waste patterns in the presence of innovations designed to replace or complement other package information about food quality and food safety. This work develops a choice experiment with options involving raw ingredients and ready-to-eat meals as a way to evaluate one dimension of consumers' willingness to pay for reduced food waste. The authors find evidence that consumers are willing to pay more for initiatives that increase food shelf life which may lead to a reduction in food waste. This work offers insights into consumer acceptance of new technologies that might provide better information about the freshness and quality of food and has implications for the generation of food waste in household settings.

Wilson, Miao, and Weis tackle the issue of consumer confusion regarding packaged food date labels. With no standards or regulatory requirements in place, food processors currently use a variety of terms to indicate a suggested date by which a food should be consumed. Consumers, however, are often confused as how to interpret these labels and frequently infer incorrect information about a product's quality and/or safety. This study examines consumer response to an industry-led recommendation to use a simplified "use by" date for food safety and a "best if used by" date label to reflect product quality. These authors find that, even with the proposed labels, consumers' willingness to consume (or discard) products that are past the posted date on the label varies by type of product. These findings indicate that the proposed date labelling approach is unlikely (at least in the short run, when consumers are not yet educated about the meaning of these labels) to generate widespread decreases in unnecessarily wasted food.

In the final article, Minor, Hitaj, Kuchler, Raszap Skorbiansky, Roe, and Thornsbury draw upon a workshop hosted by the U.S. Department of Agriculture Economic Research Service to introduce and review current U.S. discussions concerning the concepts of food loss and food waste, and constraints to addressing it. The authors offer a discussion of the concepts of "food waste" and "food loss," which are sometimes used interchangeably, and explore competing definitions of both terms. Explicit in this discussion is the recognition that how one defines food loss (or food waste) has implications for the magnitude and scope of the issue. It is acknowledged that while generating food loss would never be an intended outcome, agri-food business efforts to manage their risk can contribute to it. The importance of a nuanced understanding of the supply chain characteristics and market opportunities for a given type of produce are recognized as needed in developing strategies to address food loss. This work offers insight concerning some of the tradeoffs that must be considered in developing food loss reduction strategies.

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Putting Dollars to Waste: Estimating the Value of On-Farm Food Loss

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JEL Classifications: Q11, Q13, Q18

Keywords: Alternative markets, Food bank, Food loss, Food waste, Produce, Profitability

Fruit and vegetables that never reach the consumer represent losses of water, chemical inputs, and labor, in addition to the loss of nutrient dense, recoverable food (Hall, et al., 2009; Kummu, et al., 2012). Actions that reduce loss may increase supplies of nutritious food for those who are currently food insecure and contribute to global food needs without additional or more intensive land use and its associated negative environmental impacts (Tilman et al., 2011; Garnett et al., 2013; Royte, 2016; Fan, 2017). U.S. food waste estimates of 40%—estimates that do not include on-farm food loss (Gunders et al., 2017)—have motivated stakeholders across the supply chain to develop improved approaches to measuring food waste, understanding the determinants, and devising waste-prevention strategies. To date, a majority of food waste studies have focused on post-consumer waste and to a lesser extent waste in food distribution and retail settings; very little attention has been given to understanding food loss at the farm level.

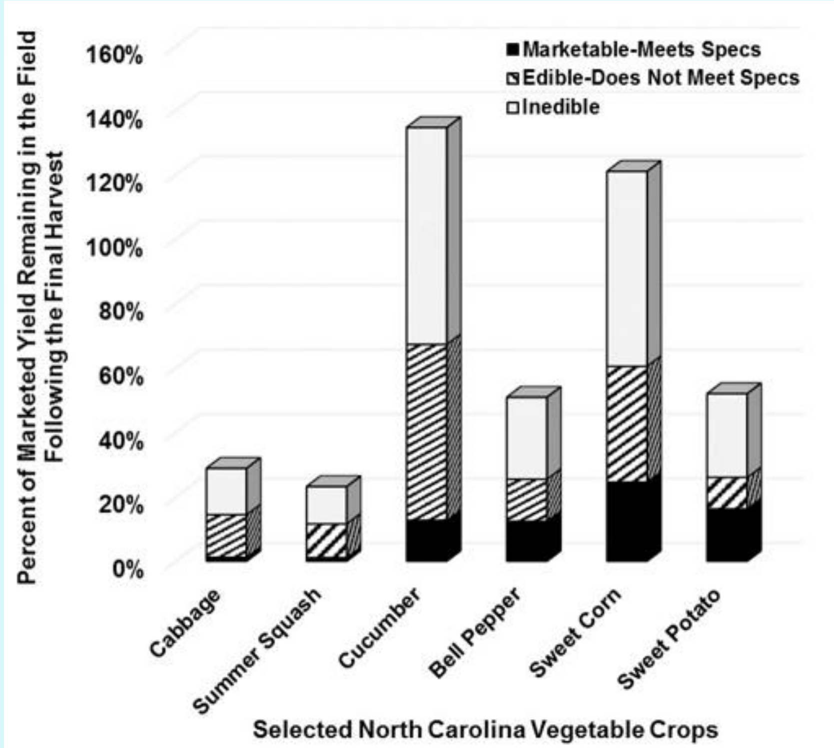
Information on the volume and value of food that never leaves the field is important from both the perspective of farmers making harvesting decisions and, on an aggregate level, for informing policy decisions related to food loss. For most farming businesses, utilizing produce that is currently "lost" on-farm, however, is only a reasonable option when revenues earned by harvesting and selling this produce exceed the costs of doing so. Recently, careful estimates have been made of the volume of selected vegetables left unharvested in fields on mid- and large-scale farms in North Carolina (Johnson, 2018; Johnson et al., 2018a,b), which have informed our understanding of growers' decision-making processes at harvest (Johnson and Dunning, forthcoming). Extending these studies, we explore the costs and potential revenue that could be generated from selling this unharvested produce. We estimate the value of food loss on a per acre basis and aggregate it to a state level using North Carolina as a case example. To the best of our knowledge, this study is the first to offer estimates of monetized values of food loss based on post-harvest field data.

Field Measurement of On-Farm Loss

Existing estimates of on-farm loss in the United States have been based on grower self-reports (Berkenkamp and Nennich, 2015; Neff et al. 2018) or derived from unharvested acreage data from the U.S. Department of Agriculture (2017). The latter comparison of planted relative to harvested acreage does not include produce from fields that were harvested once or several times yet not completely harvested of product meeting market standards. Actual field measurement is rare due to the time-consuming nature of data collection.

The field loss values in this paper are based on estimates of the volume of product remaining unharvested for a set of southeastern U.S. crops in 2017. Johnson et al. (2018b) evaluate in-field produce loss on 68 fields of eight vegetable crops on nine commercial farms in eastern North Carolina. These operations market primarily fresh whole product to wholesale channels and represent 6.8% of the state's production acreage of vegetables, melons, and sweet potatoes. Samples were collected from randomly selected areas of fields shortly after each farmer reported that the field had been harvested for the last time and before any remaining product was either incorporated into the soil or destroyed to plant another crop. The collected field samples were sorted into categories of *marketable*, *edible* (but not marketable), and *inedible* using USDA quality indicators and equipment for produce inspection. *Marketable* product met specifications for U.S. No. 1 grade or higher (such as U.S. Fancy), which is commonly used in conventional fresh produce trade. *Edible* product was in good condition but did not meet U.S. No. 1 grade due to size, shape, coloring, healed scarring, or other types of cosmetic imperfections. *Inedible* product was past maturity, bruised, cracked, or had evidence of decay or other progressive conditions. Johnson (2018) provides additional details about the approach used to quantify field loss.

Figure 1. Volume of Recovered Produce as a Percentage of Sold Produce for Select Southeastern Vegetable Crops in North Carolina



Note: These values reflect the per acre produce recovered following the final harvest in 2017 relative to the 3-year average (2014–2016) of per acre yield for select southeastern crops in North Carolina.
Source: Johnson et al. (2018b).

Figure 1 illustrates the distribution of marketable, edible and inedible produce for six commonly grown southeastern crops left in fields after the final harvest. For additional context, Table 1 summarizes the annual harvested weight for these crops. Combined across the considered crops, the volume of marketable product left unharvested reflects 11% of the average per acre volume harvested in North Carolina. (Estimates are relative to the 3-year average [2014–2016] of volume per acre, U.S. Department of Agriculture 2016, 2017). Including edible weight increases this volume to 34% of the average per acre harvest. Thus, on average across these six crops, the loss of edible food (which does and does not meet grading specifications) reflects one-third of the annual volume of North Carolina sales of these products.

Table 1. Estimated Food Loss on Select North Carolina Vegetable Crops (lb per acre)

Crop	Marketable	Edible	Inedible	Marketed Yield
Bell pepper	2,866	3,028	2,198	23,167
Cabbage	274	3,040	3,057	23,000
Cucumber	1,684	7,249	7,135	13,267
Summer squash	79	777	5,438	7,400
Sweet corn	1,864	2,735	3,319	7,600
Sweet potato	3,191	1,921	326	19,667

Note: All values measured in lb/acre.
Source: Johnson et al., 2018b.

Field Loss and Growers' Harvest Decisions

Each crop in Figure 1 is harvested progressively, with three to five harvests occurring in the same field over a period of several weeks. For each field, the first or second harvest is typically of the best quality; when plants are young and healthy, yield is high and of high quality. As plants age, they lose vigor, and harvest traffic causes minor damage. As a result, harvesting efficiency decreases as the season progresses; it becomes more time consuming to identify the preferred blemish-free product. The exception to this approach to harvesting is sweet potato, which occurs as a single event.

Farmer decisions to continue the harvest—to return to a field to harvest what otherwise will be "lost"—are based on the marginal cost and benefit of harvesting and packing that product given their marketing opportunities. In making this decision, growers are typically not concerned with the sunk costs of production; instead, they compare available sale options to the "pick and pack out" costs to harvest, grade, and pack the product. These costs, and farmer decisions made in response to them, can vary considerably due to buyer requirements that impact the costs of packing and packaging (such as size and type of containers) and farm management conditions, including current and projected labor conditions, remaining "shelf-life" for perishable products, the opportunity costs of reharvesting a particular field relative to other options, and the probability of harvested product being rejected based on quality standards that are fixed in principle but flexible in practice (Johnson and Dunning, forthcoming). For southeastern vegetable crops, farm enterprise budgets indicate that "pick and pack out" costs can account for 50% or more of variable costs (e.g., University of Kentucky, 2017).

Conventional sales channels into retail and food service markets typically require that products meet specified standards related to quality (attributes such as size and shape) and condition (type and extent of blemishes of a progressive nature that can reduce shelf-life). Standards for produce grades developed by the USDA Agricultural Marketing Service commonly serve as a baseline requirement. In practice, however, produce buyers (e.g., wholesaler intermediaries) often apply more stringent standards. While the term "standards" suggest these are fixed across time and space, in practice what is deemed to meet a given standard can change based on market conditions. In a market with less supply, what is considered a secondary-quality produce item can be graded as first-quality, and the opposite is true during times of surplus. The price differential between quality grades can be substantial, with growers reporting that slight differences in quality translate to differences of 50% or more in market price. The flexibility of applying standards increases the risk of rejection later in the season, as the last-harvest crops from a grower in one region compete with the higher quality crops newly available from a competing region.

A small but growing number of alternative markets exist for lower-grade products, such as "ugly produce" programs at grocery retailers and subscription box home delivery programs. Food banks are another potential market for lower-quality produce; they may offer tax deductions for charitable donations and in some cases compensate growers for the "pick and pack out" costs of product. While these alternative channels do mitigate on-farm food loss, it is not clear whether these prices are sufficient to offset harvest and packing costs.

Monetizing On-Farm Produce Loss

A farmer can justify returning to the field to harvest additional product when there is a financial incentive to do so. Using estimates of the mean amount of product left unharvested (reported in Johnson et al., 2018b), we generate estimates of the profit or loss that a farmer would incur by harvesting and selling this product. We consider four scenarios, which reflect differences in sales price and packing requirements of different types of buyers.

As noted above, alternative markets for products not meeting USDA grading specifications do exist in some locations. We account for these possible markets with four alternative scenarios: Scenario 1 reflects the case where marketable and edible categories of product are offered for sale in "ugly produce" markets such as produce-box programs or retail, which pay farmers 50% of the value of USDA No. 1 grade products. Scenario 2 reflects the case of selling the marketable and edible recovered produce to a food bank at $0.07/lb. These sales prices reflect those received by farms in the study region. Scenario 3 reflects the case where marketable product is sold at 100% of the value of USDA No. 1 grade products, while the edible portion of the harvest is sorted and sold to "ugly produce" channels at 50% of this value. Scenario 4 reflects the case where marketable product is sold at

100% of the value of USDA No. 1 grade products, while the edible portion of the harvest is sold to a food bank at $0.07/lb. Inedible produce is assumed to have zero value and thus not included as a source of revenue in these scenarios.

While it is assumed that only marketable and edible product would be harvested, the cost of harvest labor is calculated by pound for the total amount of product (marketable, edible, and inedible) remaining in the field. This approach accounts for the loss of harvest labor efficiency later in the season due to (potentially) large volumes of inedible product (Figure 1). Packing labor is included only for grading and packing that occurs in the packing house and is assumed to vary by the total marketable plus edible volume because growers can ascertain these labor needs by the harvested volume and adjust accordingly. Marketable product is packed in cartons and edible "ugly produce" product is packed in wooden bins. Field pack into wooden bins for sales to the food bank market does not include an additional packing labor cost, as food bank staff or volunteers typically sort this product when packing it into smaller volumes for distribution. The cost of wooden bins is included in the food bank estimates (Scenarios 2 and 4), but it is worth noting that food banks increasingly supply plastic bins for growers to use.

A few caveats of this analysis are worth highlighting. First, it is important to note that these field losses do not include product that is sorted out in the packing house (culls). As such, this analysis reflects the potential profitability of returning to the field for an additional harvest rather than the incentive to sell or donate product that has already been harvested. Secondly, these estimates reflect the marketing opportunities and costs available in the study region (North Carolina) and may not apply in other locations. For example, North Carolina has a large sweet potato processing sector, and local processing is available for some bell pepper growers. This approach further assumes that the labor needed for the additional harvest is available and can be hired at the same wage rates as during the regular harvest period. Thirdly, this analysis implicitly assumed that there is a buyer for the recovered volume of produce and that the increased market supply would not impact market price. These volume and value estimates thus offer insight into the extent of loss for the examined crops in North Carolina but would require reconsideration of several assumptions to be relevant in other settings.

Table 2. Estimates of per Acre Profitability of Harvesting and Selling Recovered Volume, Selected North Carolina Vegetable Crops

	Returns ($/acre)					
Harvest Scenarios	Bell Pepper	Cabbage	Cucumber	Summer Squash	Sweet Corn	Sweet Potato
Scenario 1: Packed in bins at 50% of wholesale price	466	(557)	823	(137)	(178)	88
Scenario 2: Field packed, sold in bins at $0.07/lb	(97)	(338)	38	(277)	(155)	106
Scenario 3: Packed in cartons for marketable and bins for edible; wholesale price for marketable and 50% of this for edible	1,059	(538)	1,135	(116)	5	515
Scenario 4: Packed in cartons for marketable and bins for edible; wholesale price for marketable and $0.07/lb for edible	580	(580)	211	(289)	(111)	364

Data sources and assumptions: Wholesale prices: USDA AMS Custom Average Pricing Tool for USDA No.1 FOB product shipped from North Carolina in 2017.
Harvest and packing labor requirements: Enterprise budgets, University of Kentucky, 2017.
Labor cost: $14/hour based on total costs associated with H2A labor as reported by North Carolina growers.
Packaging: $1.50 per cardboard box; $20 per wooden bin.

Table 2 summarizes the results of the scenario analysis for each crop. Given the processing opportunities available in North Carolina, and assuming there is demand for the produce, only cucumbers and sweet potatoes offered consistently positive returns across each of the examined scenarios. These results do, however, vary considerably depending on the quality of the unharvested produce and the market opportunities.

An additional harvest of bell peppers and sweet corn may be profitable dependent upon the available market opportunities. In only the most conservative scenario (Scenario 2) was it unprofitable to reharvest bell peppers. For sweet corn, at best, a small, $5/acre return is offered in circumstances where the recovered product is sorted and separately sold to marketable and edible "ugly produce" channels (Scenario 3). Partially due to the relatively high proportion of inedible relative to edible produce, harvesting abandoned cabbage and summer squash was found to be unprofitable under any of the examined scenarios.

State-Level Estimates of On-Farm Produce Loss

While these farm-level results are useful, examining these results in aggregate offers further insight into the magnitude of this issue. Multiplying the total production areas in North Carolina for each crop by their estimated recoverable marketable and edible volume offers state-level estimates of the loss of potentially useable produce. Table 3 presents estimates of both the volume and the value of food loss for each of the considered vegetable crops. At the low end, for summer squash it is estimated that more than 2 million pounds of marketable and edible product remains unharvested in the fields. Sweet potato production, which in North Carolina has a larger area under production than the other considered crops combined, annually leaves an estimated 460 million pounds of marketable or edible product unharvested in fields.

In the lower portion of Table 3, the per acre profitability results (from Table 2) are extended to estimate the aggregate monetized value of food loss for North Carolina. For brevity, results of only two of the considered scenarios are presented. Again, Scenario 1 (all marketable and edible product is sold to wholesale markets at 50% of standard prices) is akin to selling to "ugly produce" markets. These estimates indicate that the unharvested values of bell pepper, cucumber, and sweet potatoes reflect $1.1, $8.6, and $7.9 million, respectively, in forgone income to North Carolina growers. Paying to harvest and pack abandoned cabbage, summer squash, and sweet corn is not profitable. Scenario 3 considers the case of better market opportunities, where marketable and edible product is sorted and sold to standard wholesale and "ugly produce" channels, respectively. By these estimates, compared to Scenario 1, the annual value of North Carolina's food loss increases between two- and six-fold, and it becomes profitable to harvest sweet corn.

In Summary

Recent, careful field measurement studies indicate that previous reports have underestimated the volume of on-farm produce loss (Johnson et al., 2018b). Capturing this food loss may offer a means to increase production yield with minimal additional environmental impact and generate additional farmer profits. This study pairs field estimates of the volume of unharvested produce with sale price and cost data to estimate the market value of produce left unharvested in North Carolina fields. Potential returns to harvesting abandoned produce were found to vary considerably among the six southeastern crops examined. Under the examined scenarios, some crops (cucumber, sweet potato) offered consistently large and positive returns to reharvesting, while for other crops (cabbage, summer squash) under none of the examined scenarios was it advantageous to do so. Other crops (bell pepper, sweet corn) varied in their outcomes; under some, but not all, market circumstances it would make good business sense to conduct another harvest of these fields.

A few generalizable insights can be gleaned from this analysis. Most importantly, the mix of marketable, edible, and inedible produce varies considerably by crop and significantly affects the profitability of strategies to recapture food loss. Having more edible relative to marketable crop in the field leads to a preference for selling to an alternative wholesale market. In the same vein, the larger the proportion of inedible produce remaining in a field, the more product there is to examine during harvest and the less profitable it will be to recover any marketable and edible product. These findings have important implications for efforts to reduce food loss. Regardless of the type of crop, the significant volumes of unharvested but edible produce suggest that should opportunities exist to at least reduce or compensate growers for their packaging and labor costs a significant volume of food is available to be recaptured and could be streamed into food assistance channels. These results, however, suggest that no single food recovery strategy will be most appropriate across all crops. Rather, among other considerations, recovery strategies would do well to consider targeting limited food recovery resources to the crops which offer the highest proportion of edible relative to inedible produce.

Table 3. Estimated Volume and Value of North Carolina Food Loss for Selected Vegetables

		Bell Pepper	Cabbage	Cucumber	Summer Squash	Sweet Corn	Sweet Potato
NC Total Production Area (planted acres)[1]		2,400	2,600	10,500	2,400	5,276[2]	90,000
NC Marketed Volume (1000 lbs)[1]		62,100	70,000	168,000	22,300	NA	1,969,000
NC Total Sales ($1000)[1]		27,914	10,570	28,699	10,112	NA	346,544
Estimated Food Loss (1000 lbs)							
Marketable		6,878	712	17,678	191	9,833	287,223
Edible		7,268	7,903	76,116	1,865	14,428	172,882
Inedible		5,276	7,947	74,917	13,051	17,511	29,309
Total Volume of Marketable and Edible Loss		14,145	8,616	93,793	2,056	24,261	460,108
Volume of marketable and edible food loss relative to total NC marketed volume (%)		22.8%	12.3%	55.8%	9.2%	NA	23.4%
Estimated Unrealized Farm Income ($1000)							
Scenario 1							
Revenue		3,225	694	18,524	601	2,728	68,325
Harvest Labor + Packing Labor + Packaging ($)		2,106	2,087	9,883	931	3,670	60,422
Revenue Less Labor and Packaging Expenses	$	1,119	(1,394)	8,647	(329)	(941)	7,904
	% of NC Total Sales	4%	(13%)	30%	(3%)	NA	2%
Scenario 3							
Revenue		4,793	751	22,016	657	3,834	110,979
Harvest Labor + Packing Labor + Packaging ($)		2,251	2,096	10,100	936	3,808	64,665
Revenue Less Labor and Packaging Expenses	$	2,542	(1,344)	11,915	(279)	26	46,319
	% of NC Total Sales	9%	(12%)	42%	(3%)	NA	13%

Note: NA = Not Available.

[1] U.S. Department of Agriculture (2017).

[2] U.S. Department of Agriculture (2012).

These findings are instructive in offering both insight into the magnitude of this problem (or, if perceived otherwise, opportunity) and a process through which the value of unharvested produce in other regions could be monetized. This approach to monetizing the value of food loss, however, comes with several important caveats. These results are reflective of food-loss volume estimates based on a set of mid- and large-scale growers in North Carolina. In practice, farm-level decisions should be based on growers' own estimates at harvest and be made using a tested measurement protocol (Johnson, 2018). Additionally, the results are based on North Carolina processing and marketing opportunities and costs and assume that demand for these products is large and stable enough to absorb a potentially substantial increase in produce volume without adversely affecting market prices (see Table 3).

These results have implications for farm decision making, regional food access strategies, and tax and regional development policies that affect incentives for recapturing abandoned food. At the farm level, these findings can be used to inform growers' farm management plans. This may mean a reconsideration of harvesting decisions and more intentionality in identifying sales channels for surplus and lower-quality product. Extension personnel and others can be important catalysts by identifying and circulating buyer lists to interested growers and facilitating these connections. (For an example, see the Whole Crop Harvest initiative at North Carolina State University, 2019). Improved understanding of the potential volume of unharvested produce may also encourage conversations with produce growers about the value of food donation.

At the state or regional level, the volumes and associated value revealed in our state-level estimates of food loss offer valuable information to the ongoing work to prevent food waste and loss. By way of example, Feeding America and its national network of over 200 food banks has an online match-making system to arrange regional transportation of surplus food products among member food banks and, more recently, has become active in aggregating and distributing product. This information would allow these groups to better understand the type and scale of potentially available produce and, when estimated by county, product location. Doing so will enable these organizations to make better use of their food infrastructure and to potentially more effectively target farmer recruitment or donation efforts and partnerships.

To the extent that one might want to incentivize the recapture of abandoned produce through policy incentives, this information could also inform federal and state policy provisions and implementation. Currently, tax deductions for donations are available to farm operators who are not incorporated and who opt to itemize their tax deductions. The tax benefits of these donations, however, are limited (van der Hoeven, 2017). A different and expanded federal or state tax treatment of food donations could provide further incentive to harvest abandoned product (Harvard Food Law and Policy Clinic, 2016). Alternatively, states and government agencies could initiate programs that encourage and facilitate food access and other social support programs to purchase surplus and lower-grade products (see Kentucky's Farm to Food Bank program, KAFB, 2019). Improved information about food loss can also inform economic development initiatives and industry recruitment focused on food processing and manufacturing, which could provide reliable alternative markets for the significant volumes of produce currently left on-farm.

This article illustrates the income opportunities for farmers that can accompany growth in alternative produce markets. If demand for lower-quality produce increases for "ugly produce" programs in retail settings and subscription box home delivery, and from food banks able to compensate farmers for their "pick and pack out" costs, growers of some vegetables could increase their income. This reduction in on-farm food loss also reflects an increase in yield that does not come at the expense of additional land conversion, water and other natural resource use, or application of chemical inputs.

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Waste Not Want Not: Examining Plate Waste of Vegetables in Elementary School Lunches

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Total loss and waste of food produced in the United States may be as high as 40% and cost $218 billion a year (Gunders et al., 2017; ReFED, 2016). In addition to food wasted by households at home, institutions such as universities, schools, hotels, healthcare facilities, and other locations with cafeterias and catering contribute to total food waste. On January 26, 2012, the Food and Nutrition Service (FNS) of the U.S. Department of Agriculture (USDA) issued final regulations to align the School Breakfast Program (SBP) and National School Lunch Program (NSLP) with the most recent Dietary Guidelines for Americans (U.S. Department of Agriculture, 2012). The proposed school meal regulations originally included a limitation on starchy vegetables, but this limitation was later removed. Nevertheless, the proposal to limit starchy vegetables in school meals raised questions concerning vegetable intake or plate waste as well as costs and nutritional values of school meals. Despite the elimination of this proposal by FNS, questions dealing with the ramifications of plate waste in general remain largely unanswered.

Motivated by the FNS proposal, we center our attention on plate waste from vegetables offered in school lunch menus. The principal objectives are twofold: (i) to measure plate waste for vegetables from school lunches over the period of April 2012 to January 2013 and (ii) to document the value associated with plate waste of various types of vegetables in school lunches. The topic is important from several perspectives. Evidence shows that diets emphasizing vegetables, fruits, whole grains, and low-fat dairy products are not only beneficial for health but also help prevent obesity. We hypothesize that plate waste from starchy vegetables, particularly white potatoes, is lower relative to plate waste from nonstarchy vegetables. As such, concerns arise from nutritionists because children may not be getting the level of some nutrients from school lunches that alternative vegetables offer. Besides potential differences in plate waste, prices of nonstarchy vegetables are typically higher relative to prices of white potatoes; consequently, costs to school districts in providing nutritious meals may be higher than previously considered.

To keep research costs manageable, we focus on three elementary schools in Bryan, Texas, hereafter referred to as Independent School District 1 (ISD 1) and three elementary schools in Dallas, Texas, hereafter referred to as Independent School District 2 (ISD 2). As such, this work essentially constitutes a pilot study. The respective schools in each district were matched based on the percentage of students receiving free or reduced-price school meals and comparable numbers of student enrollment. Besides geographic location, the sociodemographic composition of the students from these school districts was not the same. On the basis of ethnicity, the students were predominantly white, black, and Hispanic in each school district. Students of Asian and Native American descent represented very small percentages of the populations in the respective school districts.

Buzby and Guthrie (2002) estimated that costs of food waste annually at elementary schools were on the order of $600 million. However, these analysts only had access to aggregate school meal costs and consequently were unable to examine costs of food waste specific to vegetables. Cohen et al. (2013) examined nutrient losses and economic costs associated with school meal waste among middle school students (grades 6–8) in Boston public schools in 2010–2011, estimating the average cost per vegetable item to be $0.21, the average percentage waste for vegetables to be 73%, and the average waste cost per student for vegetables to be $0.09. Our research permits this examination for various types of vegetables for elementary schools in two distinct independent school districts in Texas.

Plate Waste

A registered dietitian selected the vegetables to ensure variety. However, the list of vegetables was restricted to the school lunch calendar and menu cycle. All school principals, teachers, and food service and custodial staff were notified of the study objectives, the dates of collection, and the plate waste study protocol. Teachers explained the protocol to their students before lunch on days of collection and instructed students that they were not obligated to participate. Study participants were kindergarten through fifth grade students who selected at least one vegetable as part of the NSLP. Lunch periods were scheduled by grade (K–5), and 30 minutes were allocated for lunch. Menu items and serving sizes were consistent throughout all lunch periods. Each school had complete control over when and what students were served; the research team had no control over menus or any competitive foods offered before or during the lunch periods.

In this study, we define plate waste as the quantity of edible portions of vegetables served that students discarded. Plate waste in school lunches traditionally has been measured using several methods, including physical measurements such as weighing discarded food (Comstock, St. Pierre, and Mackiernan, 1981; Chu et al., 2001; Glueson et al., 1994); visual estimates made by trained observers (Martin et al., 2007; Parent et al., 2012; Taylor, Yon, and Johnson, 2014; Williamson et al., 2003; Kropp et al., 2018); and combinations of methods that include weighing discarded food and photographing and analyzing contents of full and discarded plates (Adams et al., 2005; Marlette, Templeton, and Panemangalore, 2005).

Accurate measurement of school children's food consumption and waste is challenging. Though labor intensive and time-consuming compared to other research protocols, we utilized a comparison of pre- and post-consumption plate weights as a basis for plate waste estimation. The study design was modeled after the aggregate plate waste method of Chu et al. (2001) and Cohen et al. (2013). For each data collection day, five to ten servings of each sampled vegetable were obtained on "test trays," which were used to gather preweights for each vegetable item in which plate waste was collected to obtain an average weight in grams (g). The key measure was the percentage of plate waste of the respective vegetable items. To arrive at this measure, the total amount of plate waste was obtained and this total was divided by the number of children who chose the vegetable in question. The ratio provided the plate waste per child. Finally, the percentage of plate waste was calculated by dividing this ratio by the preweight of the vegetable item, also measured in grams. Hence, plate waste was measured on a standardized basis (percentage).

Research assistants affixed coded data tags to eligible student lunch trays after the selection of vegetables in the cafeteria line. Lunch trays were included in the study if the student (i) participated in the NSLP on the day of the data collection; (ii) chose at least one vegetable serving that was sampled on the day of collection; and (iii) returned their tray with the data collection tag to a field worker after the lunch period. In each school district, roughly one of every two school lunches served was sampled.

Data tags identified the vegetables selected as well as student gender and grade. Students received a small incentive—such as a sticker, pencil, or eraser—if their tray and data tag were returned after the lunch period. Plate waste stations were located in the cafeteria to collect the sampled vegetables. Plate waste was collected from each eligible tray, while all other tray contents were discarded. The method was repeated for each lunch period to determine plate waste differences by grade and lunch period. Three trial runs were conducted to familiarize each research assistant with the movement of students through the cafeteria and the mechanics of labeling trays, obtaining samples, and collecting and weighing plate waste.

All plate waste was separated in a labeled and dedicated trash container lined with a plastic bag for each specific item at each given lunch period. Aggregated plate waste for each item was recorded and divided by the number of children that selected the item. In addition, the waste was segregated according to grade level within each of the participating schools. In sum, aggregate plate waste was measured for each vegetable by elementary school and by grade level using a Denver Instrument food balance with maximum capacity of 5,000 g. Percentage plate waste was calculated as follows:

(1) % plate waste = [(aggregate vegetable plate waste for each vegetable/total number of children selecting the vegetable)/weight of the mean serving size for each vegetable] * 100

Calculating plate waste as a percentage allows for comparisons among types of vegetables as well as for comparisons by elementary school and by grade.

Additionally, the respective school districts provided the following public information essential for our analysis: (i) district food costs (excluding labor costs) per menu item and per serving; (ii) school lunch production sheets for the days of plate waste collection that include the number of servings per item served and nutrient information; and (iii) meal counts (free, reduced, paid, and “other” meals served on days of plate waste collection. Information was recorded on the particular school, grade, type of vegetable, number of students consuming particular vegetables, the vegetable preweight, the vegetable plate waste in terms of percentage, the total number of students (male and female) who bought or received a school lunch, the total number of lunches served, the number of free lunches served, the number of reduced lunches served, and the number of paid lunches.

This study adds to the existing literature by providing plate waste measurements for various types of vegetables collected from representative elementary schools from two independent districts of Texas. No previous study has focused on the detail of the plate waste of different types of vegetables.

The respective vegetables in school lunches fell into seven categories:

1. dark green vegetables (i.e., steamed broccoli, garden salad, broccoli florets, spinach salad, broccoli salad, turnip greens, and cooked spinach);
2. red/orange vegetables (i.e., sweet potato fries, glazed carrots, sweet potatoes; cooked baby carrots, veggie dippers, raw sweet potato sticks, and raw baby carrots and celery);
3. beans (i.e., baked beans, pinto beans, ranch-style beans, and pork and beans);
4. starchy vegetables excluding white potatoes (i.e., green peas, corn on the cob, and whole kernel corn);
5. white potatoes (i.e., potato wedges, mashed potatoes, French fries, and tater tots);
6. “other” vegetables (i.e., green beans and whole dill pickles); and
7. “additional” vegetables (i.e., tomato and cucumber salad; Italian vegetables; Asian vegetables; mixed Normandy vegetables; and Sonoma vegetables).

Table 1 reports average plate waste for vegetables in ISD 1 and in ISD 2. On average, plate waste for vegetables was 59.3% in ISD 1 and 48.5% in ISD 2. Based on statistical tests of equality of means and medians, statistically significant differences were evident for vegetable plate waste by vegetable subgroups. Plate waste for vegetables was significantly higher for ISD 1 than for ISD 2. This finding is attributed to differences in regions of Texas, differences in race/ethnicity of the respective student populations, and differences in the percentages of free lunches across the respective schools. The Welch (1951) *F*-test was chosen to test the equality of means due to the fact that this statistic takes into account unequal variances. The nonparametric Kruskal–Wallis (1952) test was chosen to test the equality of medians.

As measured by the median number of students who selected various vegetables, white potatoes in various forms were the most popular vegetables. On average, plate waste was lowest for white potatoes and beans in both districts and highest for red/orange vegetables. In both districts, significant differences were not evident in mean vegetable plate waste by grade.

Increasing vegetable consumption of children has been a challenge for decades. Reger, O’Neil, and Nicklas (1996) showed that vegetable plate waste, excluding potatoes, was 54% among children in a low-socioeconomic elementary school in southern Louisiana; potato plate waste was 37%. Our study revealed similar results. Our study, like others, shows that vegetable waste remains a notable problem for schools, despite new USDA regulations requiring schools to offer students a greater variety of vegetables. Plate waste of most vegetables was high and similar to that shown in other studies (Adams et al., 2005; Cohen et al., 2014; Cohen et al., 2016; Byker, Farris, and Marcenellel, 2014; Gase et al., 2014; Handforth et al., 2016; Ishdorj et al., 2015; Niaki et al., 2017; Schwartz et al., 2015).

Table 1. Mean/Median Plate Waste for all Vegetables and by Vegetable Subgroup by ISD

Vegetable Subgroups[a]	% Vegetable Plate Waste Mean	% Vegetable Plate Waste Median
ISD 1		
Beans	53.68	53.98
Additional vegetables	77.44	79.87
Dark green vegetables	56.34	56.30
Other vegetables	59.72	60.81
White potatoes	44.23	43.73
Red/orange vegetables	64.19	65.63
Other starchy vegetables	59.33	75.56
All vegetables	59.33	60.21
ISD 2		
Beans	38.21	33.23
Additional vegetables	53.47	54.71
Dark green vegetables	57.69	60.00
Other vegetables	41.87	35.65
White potatoes	35.24	35.81
Red/orange vegetables	60.29	64.10
Other starchy vegetables	50.04	53.16
All Vegetables	48.46	47.18

Note: [a] Test for equality of means; Welch *F*-statistic 12.20, *p*-value 0.0000. Test for equality of medians; Kruskal-Wallis statistic 80.34, *p*-value 0.0000. *Source*: Computations by the authors using EVIEWS 9.5. The level of significance chosen for all statistical tests was 0.05.

Lost or Wasted Dollars

We turn attention to the consequences associated with plate waste for vegetables. Specifically, in this study, our interest centers on lost or wasted dollars per serving of vegetables and the percentage of dollars lost or wasted, and the total amount of lost dollars for vegetables. As exhibited in Table 2, the average waste value per serving on all vegetables in ISD 1 was slightly more than $0.08, and the average waste value per serving was slightly more than $0.05 per serving. In ISD 1, the average waste value per serving of vegetables ranged from $0.0411 (white potatoes) to $0.2206 (additional vegetables). In ISD 2, the average waste value per serving ranged from $0.0254 (white potatoes) to $0.1237 (red/orange vegetables). Notable differences in the lost or wasted dollars were evident across the respective vegetable subgroups for ISD 1 and ISD 2.

As exhibited in Table 2, for the respective vegetable subgroups across the two school districts, average waste costs per serving were lower for ISD 2 than for ISD 1, except for red/orange vegetables. For each school district, white potatoes had the lowest average waste value per serving among the respective vegetable subgroups.

Results from our study suggested that there were nonnegligible costs associated with vegetable plate waste. The variation in plate waste by vegetable type was considerable. Plate waste was lowest for white potatoes compared to plate waste for other starchy vegetables and for nonstarchy vegetables. White potatoes were the most popular vegetables, and they were wasted the least, resulting in cost savings. In addition, white potatoes are relatively inexpensive compared to other vegetables. Indeed, schools serve a variety of vegetables because of their nutritional content. But when vegetables are wasted, schools lose money; we found that 44%–59% of the total value of vegetable preparation (exclusive of labor costs) was wasted. On average, the lost dollars per serving of potatoes was less than $0.04 compared to $0.06–$0.09 for beans, $0.07–$0.09 for dark green vegetables, and $0.07–$0.12 for red/orange vegetables. On average, the percentage of lost dollars for white potatoes was 35%–44%, compared to 31%–54% for beans, 53%–56% for dark green vegetables, and 58%–64% for red/orange vegetables. As such, we find evidence of a tradeoff between nutritional content and the dollar value associated with waste of vegetables.

Actual dollars lost due to vegetable plate waste averaged $9.37 per day per school in ISD 2 and $20.06 per day per school in ISD 1. If we assume a 180-day school calendar, then actual dollars lost attributed to vegetable plate waste alone amounted to $1,687 per school in ISD 2 and $3,610 per school in ISD 1.

Table 2. Costs of Waste for Vegetables by Subgroup and by ISD

Vegetable Subgroup	Average Cost per Serving	Total Number of Servings	Total Cost of Preparation	Total Lost Dollars	% Lost Dollars	Average Waste Value per Serving
ISD 1						
Beans	$0.17	364	$60.03	$32.22	53.68	$0.09
Additional vegetables	$0.29	267	$76.07	$58.91	77.44	$0.22
Dark green vegetables	$0.15	268	$39.99	$22.53	56.34	$0.08
Other vegetables	$0.17	522	$86.89	$51.89	59.71	$0.10
White potatoes	$0.09	1,930	$179.52	$79.40	44.23	$0.04
Red/orange vegetables	$0.11	506	$55.19	$35.43	64.19	$0.07
Other starchy vegetables	$0.19	845	$159.00	$114.24	71.85	$0.14
All vegetables	$0.14	4,708	$676.17	$401.17	59.33	$0.09
ISD 2						
Beans	$0.18	599	$112.91	$34.60	30.65	$0.06
Additional vegetables	$0.11	76	$8.08	$4.64	57.45	$0.06
Dark green vegetables	$0.14	228	$29.77	$15.82	53.13	$0.07
Other vegetables	$0.15	344	$50.74	$21.45	42.28	$0.06
White potatoes	$0.07	2,827	$198.56	$71.94	36.23	$0.03
Red/orange vegetables	$0.22	637	$134.59	$78.77	58.52	$0.12
Other starchy vegetables	$0.19	562	$106.65	$53.89	50.53	$0.10
All vegetables	$0.15	5,273	$641.31	$281.11	43.83	$0.05

Implications

Our findings are limited to the six schools from the two independent Texas school districts that participated in the study; therefore, the results may not apply to other regions of the state or other regions of the country. We did not control food menu decisions or vegetable selection, and we did not influence the vegetable choices of children participating on collection days. The schools had control over the menus and foods served as well as any competitive foods served. Purchase of à la carte foods such as ice cream and popsicles may have reduced hunger, leading to decreased consumption of vegetables, especially among older children.

The information gleaned from our study is useful to policy makers, food service professionals, and perhaps other federal, state, or local program staff in addressing the overarching question of how to encourage children who attend elementary schools to eat more diverse and nutritionally beneficial vegetables, while still staying within a reasonable budget. In any research scenario, where it is found that food items are being wasted, particularly those designated as healthy, strategies must be developed and implemented to increase consumption. These strategies could include conducting taste tests, providing nutrition education, and implementing health promotion interventions. Alternatively, the availability of "offer versus serve" (OVS) in school cafeterias makes it possible for schools to save on the preparation of various vegetables. When the OVS policy is in place, students are only required to take a fruit or a vegetable.

The results from this research suggest that plate waste of vegetables differs due to geographic location and diversity of sociodemographic composition of student populations. Importantly, our research efforts have the potential not only to be conducted on a larger scale but also to be implemented at relatively low cost. In essence, this work served as a pilot study. Future research should center on replicating this project in other areas of Texas and elsewhere around the country. In addition, research centered on establishing factors linked to vegetable plate waste as well as the financial and nutritional implications associated with plate waste is needed.

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Consumer Choice and Food Waste: Can Nudging Help?

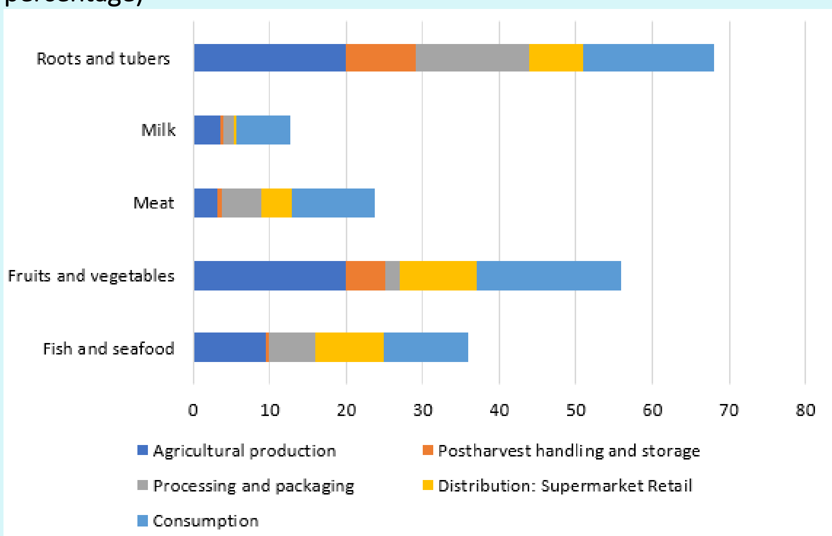
Laura Andreea Bolos, Carl Johan Lagerkvist, and Rodolfo M. Nayga, Jr.
JEL Classifications: D11, D12, Q01
Keywords: Food waste, Goal setting, Information framing

Food waste—to a large extent a result of people's consumption and purchase habits—is increasingly recognized as a challenge facing both developed and developing economies (Aschemann-Witzel et al., 2017b; Ellison and Lusk, 2018). Therefore, investigating opportunities to shift retail practices and influence consumers at point of purchase is important if food waste is to be reduced, which could have an impact on food security, nutrition, household budgets, the environment, and public health (Hall et al., 2009; Neff, Spiker, and Truant, 2015; Spiker et al., 2017).

Importantly, consumers' propensity to not accept food that visually deviates from the norm because of cosmetic imperfections—such as being misshapen, off-color, or slightly damaged—contributes to consumer food waste (Aschemann-Witzel et al., 2015, 2017a,b; de Hooge et al., 2017). Products and produce not meeting ideal visual standards are disposed as waste downstream in the value chain and discarded at the point of purchase or at home.

According to the U.S. Department of Agriculture, a substantial amount of food waste occurs in retail and consumer settings (Buzby, Farah-Wells, and Hyman, 2014). In 2010, around 31% of food was wasted at the retail and consumer level in the United States, corresponding to approximately 133 billion pounds and $161 billion worth of food (Buzby, Farah-Wells, and Hyman, 2014). Figures 1 and 2 summarize food waste across Europe, North America, and Oceania; with roots and tubers as well as fruits and vegetables (Gustavsson, Cederberg, and Sonesson, 2011). Some food waste is inevitable, but food waste at the current scale indicates inefficient resource use. For example, about 24% of total water and cropland use are, in fact, used to produce waste (Kummu et al., 2012). Importantly, food waste contributes to the environmental burden of food production owing to resources spent in vain (Kummu et al., 2012; Aschemann-Witzel, 2016).

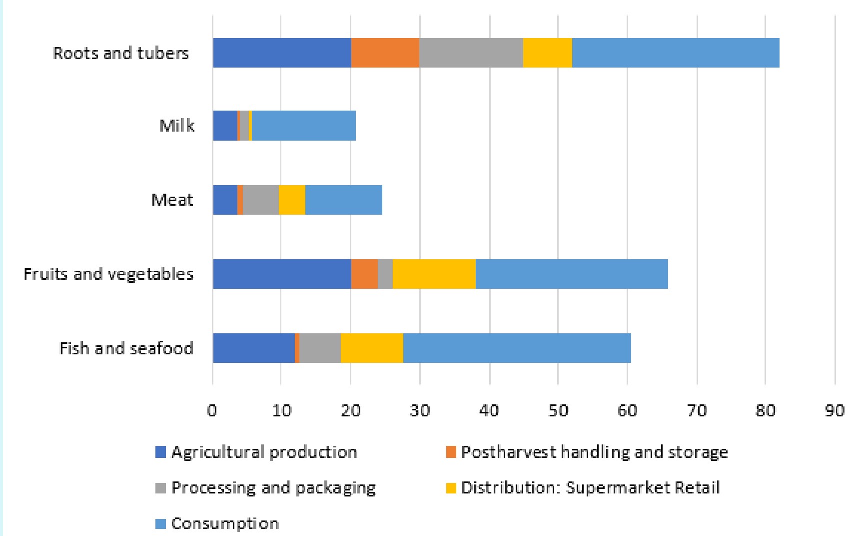
Figure 1. Food Wasted in Europe across the Entire Supply Chain (in percentage)



Source: Gustavsson, Cederberg, and Sonesson (2011, p. 26).

While recent studies show that U.S. consumers perceive themselves to be knowledgeable and engaged with the issue of food waste (Ellison and Lusk, 2018; Neff, Spiker, and Truant, 2015), many consumers do not purchase imperfect or blemished food in retail stores due to food safety misconceptions (Aschemann-Witzel, 2016). Since supermarkets remain the main purchase point for food, they have the ability to influence which products make it on the shelves and the types of food consumers purchase (Escaron et al., 2013). Supermarkets also have the power to decide what happens to unsold food and how to encourage consumers to buy visually imperfect food to reduce food waste. Box 1 lists examples of recent retailer, nonprofit organization, and government agency initiatives to reduce food waste in Europe and the United States.

Figure 2. Food Wasted in North America and Oceania across the Entire Supply Chain (in percentage)



Source: Gustavsson, Cederberg, and Sonesson (2011, p. 26).

A number of studies have focused on food waste, but we argue that there remains a need for studies that examine the effectiveness of different strategies or initiatives that retailers can implement to increase consumers' acceptance of food with cosmetic imperfections. Retail initiatives (see Box 1) can only work as long as they relate to consumers' needs and wants and therefore instill sustained behavioral changes in favor of greater degrees of acceptance of visually imperfect food. Hence, an assessment of the effect of specific initiatives on consumer information processing, acceptance, and motivation is important.

The Inquisitive Eye: The Impact of Visual Appearance of Food on Decision Making

Before touching or tasting, consumers generally first analyze food visually (Lee et al., 2013), resulting in a first impression about the product's quality. According to the literature, consumers assess three characteristics of the visual appearance of fruit and vegetable relevant: (i) color, (ii)

Box 1. Examples of Initiatives to Reduce Food Waste in the US and Europe

United States:

Imperfect Produce works to reduce food waste by taking food with cosmetic imperfections (which would otherwise be wasted) from farmers and delivering it to customers for about 30% less than grocery store prices (Imperfect Produce, 2019).

Rethink Food Waste through Economics and Data (ReFED)—a multi-stakeholder nonprofit comprising experts from leading businesses and nonprofit, foundation, and government agency leaders—uses a data-driven approach to identifying concrete solutions to reducing U.S. food waste (ReFEd, 2019).

In 2019, grocery chain Kroger announced the launch of Peculiar Picks, a brand of food with cosmetic imperfections (Pomranz, 2018).

Europe:

More to Do More (Sweden) is an initiative from the Swedish National Food Agency—in collaboration with the Swedish Environmental Protection Agency and the Swedish Board of Agriculture—to provide concrete suggestions and solutions for reducing food waste (Swedish National Food Agency, Swedish Board of Agriculture, and Swedish Environmental Protection Agency, 2018).

Retailer Matsmart (Sweden) sells food that, for example, has been mislabeled, has a short or has already passed best-before date, or has other imperfections and could not have been sold in regular stores (Matsmart, 2019).

Inglorious Fruits and Vegetables is a marketing campaign conducted by the French supermarket Intermarché. Foods with cosmetic imperfections are sold at a 30% discount (Intermarché, 2019).

shape, and (iii) physical form (Blasco et al., 2007; Loebnitz, Schuitema, and Grunert, 2015; Salvador, Sanz, and Fiszman, 2007; Seppä et al., 2013). These attributes affect customers' purchase intentions, but only if they deviate significantly from the norm (Loebnitz, Schuitema, and Grunert, 2015). Since fresh fruit and vegetables are often not packaged, or are packaged in a way that allows the produce to be seen (Deng and Srinivasan, 2013), they offer an appropriate product to study consumers' preferences for food with cosmetic imperfections (see Table 1).

Table 1. Examples of Cosmetic Imperfections

Category	Picture	Category	Picture
Perfect		Imperfect shape	
Imperfect color		Imperfect physical form	

Examining visual appearance (with or without imperfections) fits with the established multi-attribute utility perspective, which implies that consumers derive their utility (or happiness) not from the item itself (e.g., the tomato) but from the attributes contained in that particular item, such as color, flavor, etc. (Lancaster, 1966). However, even though the multi-attribute perspective has come to play a significant role in understanding the decision-making process, there is a need for a more multifaceted understanding; hence, recent research has moved away from the Lancaster utility model (Marley and Swait, 2017; van Osselaer and Janiszewski, 2012). Studies that examine the effect of information related to food waste and goal setting could help bring about a better understanding of how consumers can be nudged to accept food with cosmetic imperfections.

The Contribution of Information Nudges and Goals on Decision Making

Many factors can influence decision making, and nudging is one of them. A nudge is a change in the way in which choices are presented, altering behavior in a predictable way without forbidding any options or significantly changing economic incentives. According to a recent meta-analysis by Cadario and Chandon (2017), nudging interventions can be divided into three categories:

1. An *attention-focused intervention* uses descriptive information of the product (e.g., pictures with information) or influences the visibility of certain types of food in the store (such as building a pyramid of fruits to make them more visible) to attract consumer attention.
2. An *interest-focused intervention* captures consumers' interest by targeting their emotions with messages (such as "How about grabbing a piece of fruit?" or "Make an environmentally friendly choice") or by boosting the appeal of a product with vivid sensory descriptions, beautiful packaging, or photographs.
3. Finally, the *action-focused intervention* is more hands-on and often implements techniques that consumers are not aware of, such as making it easier to select certain types of food products by placing them more strategically (e.g., a "grab and go" line where only a few products are presented, making them a more obvious choice).

The effectiveness of the intervention increases significantly as the focus shifts from attention to interest to action (Cadario and Chandon, 2017).

While many studies focus on the impact of nudges on consumers' perceptions about and willingness to buy certain types of food (Cadario and Chandon, 2017; McFadden and Huffman, 2017; Nayga, Aiew, and Nichols, 2005; Valente and Chaves, 2018) and whether information can guide consumers to make better-informed choices or change behavior (Qi and Roe, 2017), there is scant literature on the impact of nudges in relation to food waste in retail settings.

Based on previous studies, we suggest that cognitive nudges could be used at the point of purchase. For this purpose, we need more research to determine whether providing information about the amount and consequences of food waste would change purchase behavior and increase acceptance of food with cosmetic imperfections. Whether framing the information in a positive or negative way might influence consumer behavior could also be evaluated. While information nudges have shown good results, it is behavioral nudges (such as convenience enhancements) that have been shown to have the greatest effects (Cadario and Chandon, 2017). Therefore, studies are needed on ways to assist retailers with developing business and marketing actions that can reduce food waste at their stores.

In addition to nudges, goals can also play an important role in decision making as we illustrate with this example inspired by Dellaert et al. (2018): Assume a person is buying a takeaway meal. Two personal goals play an important role in making this decision: (i) to avoid gaining weight and (ii) to eat something tasty. The person may set some minimum requirements for each goal to be fulfilled and choose a meal that satisfies these requirements (e.g., tasty and low in calories). Or, the person may decide to focus on fulfilling only one of the goals (e.g., choose a tasty meal that may be high in calories). At this stage in the decision-making process, the person only decides (reasoned or unreasoned) which goal to pursue without assigning any utility value to either of the two meal alternatives; hence, the person chooses a strategy without considering the two options. However, according to the established multi-attribute utility perspective, both meals have a utility value based on their attributes. Then, the person makes a decision based on which meal has the highest utility value without considering the trade-off between the two goals. Not considering the trade-offs between the two goals offers an incomplete picture about how consumers make decisions and what it might take to actually make them change those decisions (Dellaert et al., 2018).

According to goal-based theory, goals are seen as (i) drivers of choice, (ii) able to explain the choice of strategy, (iii) included in the constraint set, and (iv) able to help explain the effect of the decision context in the allocation of the decision maker's cognitive resources (van Osselaer and Janiszewski, 2012; Marley and Swait, 2017). Therefore, goals serve as reference points for consumers and direct the selection of means to their attainment—meaning that forming personal goals related to food waste will direct the means used by consumers to reduce waste (Lagerkvist et al., 2015). Research to develop and test behavioral nudges that target such goal-setting as well as the selection of "means to an end" is therefore needed. There are also reasons to expect that goal-setting relates to the affective and emotional post-purchase experiences. Hence, whether consumers are satisfied with their choice of a particular food product has to do with whether one or more goals can be attained (Lagerkvist et al., 2017). Future research on food waste behaviors using a goal-based approach can therefore contribute to a better understanding of consumer food waste behavior. Decision making can be difficult due to time or money limitations or due to too many food products being available. Personal goals can therefore help direct consumers to make choices in the presence of scarce resources, such as money or time (Dellaert et al., 2018).

In summary, we posit that a combination of cognitive and behavioral nudges should be tested in food-waste reduction campaigns that aim to encourage consumers to become more aware of the extent and consequences of food waste and how some behavioral changes, such as accepting food with cosmetic imperfections, can contribute to reducing food waste. This information will help retailers tailor actions to support consumers to consider or buy fruits and vegetables with cosmetic imperfections, thereby reducing food waste. Advertising imperfect or blemished fresh fruits and vegetables as safe and as something that should not be discarded could also work as goal priming that could potentially shift consumer motivation (Aschemann-Witzel, 2016). The hope is that by finding ways to encourage consumers to purchase fresh fruits and vegetables with cosmetic imperfections, food waste at the retail level can be significantly reduced.

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Are Consumers Willing to Pay to Reduce Food Waste?

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JEL Classifications: Q11, Q18, Q53

Keywords: Food waste, Shelf life, Willingness to pay

Food waste is an environmental, economic, and social problem, but defining and measuring the problem has proved a struggle (Roodhuyzen et al., 2017). Definitions to date have depended on the nature of the project. For example, Buzby, Wells, and Hyman (2014) define food waste as a component of food loss; that is, any edible item discarded at different levels of the supply chain (e.g., food discarded at the retail level due to external blemishes or at the consumer level for various reasons). Meanwhile, Wilson et al. (2017, p. 37) define premeditated food waste as "the expected amount of food waste consumers create based on the influence of date labels which affect consumers' perceptions of a product's quality and safety."

Several studies (Bellamare et al., 2017; Buzby and Hyman, 2012; Gustavsson et al., 2011; Kummu et al., 2012; Stefan et al., 2013) attempt to measure food waste and food loss, but they are not consistent in their approach. For example, Gustavsson et al. (2011) use FAO food balance sheets from 2007 and find that food waste in North America and Europe amounted to 95–115 kg/person/year. Buzby and Hyman (2012) find that approximately 123.9 kg/person were lost in the U.S. food supply chain in 2008. This measurement problem often results from the lack of a clear definition of food waste. In this study, participants' food waste was characterized as the quantity disposed as a share of ingredients or meals bought.

If it were integrated into CO_2 emissions by various countries, food waste would rank third behind the United States and China as the largest CO_2 emitters (FAO, 2013b). The U.S. Environmental Protection Agency (2018a) estimates that in 2015, 39.7 million tons of food waste were generated in the United States, and 30.3 million tons of that were sent to landfills. At the retail and consumer level, roughly 31% of food available for human consumption went uneaten in 2010, amounting to $161.6 billion in 2010 retail prices (Buzby, Wells, and Hyman, 2014).

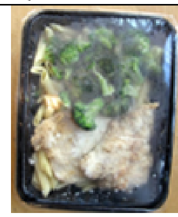
While researchers can document the problem, a feasible solution to reducing food waste might be difficult to implement. Retailers focus on keeping shelves fully stocked and disposing of products that go bad. If they do not stock shelves, they face a potential shortage of certain products or a lack of variety for consumers, negatively impacting their business (Peterson, 2018). Consumers prefer variety in their food choices (Dixit and Stiglitz, 1977; Spence, 1976) and typically fail to plan grocery trips effectively (FAO, 2013b; Schanes, Dobernig, and Gözet, 2018). Consumers' desire for convenience and struggle to plan for future food consumption contribute to the food waste problem. As a result, grocery store stocking decisions are complex, with much uncertainty about demand.

In this article, we assess consumer willingness to pay for foods prepared using a new food-processing technology, a pasteurization process based on microwave treatments called Microwave Assisted Pasteurization Systems (MAPS), which can improve the appearance, texture, and flavor of ready-to-eat meals and extend shelf life compared to other equivalent processing technologies (Tang, 2015). We also examine whether there are linkages between stated shelf life dates and estimated premeditated food waste for the different ingredients used in the choice experiment. We collected data using an online survey via Qualtrics in which we asked questions about premeditated food waste according to different shelf life dates and conducted a discrete choice experiment to compute willingness to pay for reduced food waste.

Willingness to Pay for Reduced Food Waste

In the discrete choice experiment included in our survey instrument, we presented respondents with eight scenarios, each of which mimicked a shopper facing a choice at the grocery store to either purchase ingredients to make a recipe or purchase a ready-to-eat meal. We presented respondents with pictures of the two choices: a bundle of raw ingredients and a ready-to-eat meal. This bundle of raw ingredients (chicken, basil, garlic, cherry tomatoes, and broccoli) closely matched the ingredients in the ready-to-eat meal (chicken piccata with penne rigate and broccoli). For both choices, we used three attributes: price, expected food waste percentage, and shelf life. The price levels were $12, $14, and $16. These prices were based on both the estimated cost of the bundle of raw ingredients to feed a family of four and the cost of ready-to-eat meals with four servings, as displayed in grocery stores.

Figure 1. Example of a Scenario from the Choice Experiments

Option A	Option B	Option C
 Recipe for 4	 Serves 4	None of the two options
Prep. Time: 45 minutes	Prep. Time: 5 minutes	
Will last 2 days in refrigeration	Will last 6 weeks in refrigeration	
Food waste: 42% of net weight	Food waste: 29% of net weight	
$16.00 for 32 oz. (Serves 4)	$14.00 for 32 oz. (Serves 4)	
I would choose this one	I would choose this one	I would choose this one

The percentages of expected food waste were 29%, 42%, and 61%. These percentages were based on findings from Wilson et al. (2017) of estimated premeditated waste for products such as salad, cereal, and yogurt with far, middle, and near expiration dates. The shelf-life levels were 2 days, 4 days, and 6 weeks. The 2 and 4 days of shelf were based on the shelf life of the most perishable ingredient in the bundle of raw ingredients, obtained from the Foodkeeper App (U.S. Department of Health and Human Services https://www.foodsafety.gov/keep/foodkeeperapp/index.html). The six weeks of shelf life was selected because it is the level obtained by using a food preservation technology based on microwave pasteurization. The food preservation technology is applied to ready-to-eat-meals that should be kept in refrigeration. Figure 1 depicts an example scenario comparing the bundle of raw ingredients in option A to the ready-to-eat meal in option B. We also gave respondents a no-buy option. All combinations of scenarios follow a fractional factorial design.

We found that consumers need to receive a discount of $5.82 to buy products that have the highest expected food waste percentage (61%) compared to products with the lowest expected food waste percentage (29%). Even the products with an expected food waste percentage of 42% needed to be discounted by $2.38, on average, for the consumer to buy that product over one with less food waste. Our findings suggest that respondents were willing to pay a premium for reduced food waste and for a product with a few more days of shelf life. Respondents were willing to pay around $2.27 more for products that had a shelf life of 4 days compared to 2 days. However, we found that the shelf life of 6 weeks is insignificant. This could be due to respondents associating long shelf life with a lack of freshness and reduced quality.

Premeditated Food Waste under Different Shelf-Life Lengths

Our survey instrument included questions related to premeditated food waste. Similar to Wilson et al. (2017), we suggest a connection between food waste and shelf life. Date labels are a way for retailers to convey shelf life to consumers. However, date labels can be misleading and ambiguous (Newsome et al., 2014; Wansink and Wright, 2006; Wilson et al., 2017; WRAP, 2011). For example, one product may provide a “use by” date while another uses a “sell by” date. To prevent confusion, our survey calculates premeditated waste based on “use by” dates exclusively. Using the same ingredients as in the choice experiment section of the survey, we asked consumers what percentage of a given food product they would likely consume given various “use by” dates.

Figure 2 shows an example where we use chicken breast as the product and three separate “use by” dates. Each product had an associated close, middle, and far date in terms of its expiration date relative to the day it was purchased. The close, middle, and far dates were selected based on each product’s expected shelf life. For example, for a more perishable item like chicken, the three dates were close together (1 day, 3 days, and 5 days after purchase), but for less perishable products like garlic the dates were further apart (3 days, 2 weeks, and 1 month after purchase). We asked respondents about six products: chicken breast, cherry tomatoes, garlic, basil, broccoli, and the ready-to-eat meal. The first five products correspond to the bundle of raw ingredients in the discrete choice experiment, and the premeditated waste for the ready-to-eat meal is included for consistency. Once we knew what percentage of the product a respondent would consume, we were able to ascertain how much they would waste by assuming that the unconsumed portion would be wasted.

Figure 2. Example of a Premeditated Waste Question

Suppose you are grocery shopping today (5/21/2018) and purchase the product below. What percentage of the following product are you (or your household) likely to consume before it expires, based on your recent consumption habits?

Chicken Breast

(stored in your refrigerator)

0 10 20 30 40 50 60 70 80 90 100

Use by 5/22/2018

Use by 5/24/2018

Use by 5/26/2018

Table 1 reports that products with "use by" dates closest to the purchase date had the highest premeditated waste across all the products. Chicken, with the closest expiration date, had one of the lowest premeditated waste of all the products presented, while garlic had the highest premeditated waste at the nearest expiration date. Our findings suggest that proteins such as chicken tend to have lower premeditated waste at the nearest expiration dates compared to products like basil and garlic. Another potential explanation is that there are often greater food safety concerns associated with chicken as opposed to a product like garlic. The amount consumers perceived wasting at the furthest expiration date was lower than the closer dates, suggesting that they would be less likely to waste it if there were more time before a product's expiration date.

Table 1. Mean Percentage of Premeditated Waste

Food Product	Closest Expiration Date	Middle Expiration Date	Farthest Expiration Date
Garlic (3d, 2w, 1m)	71.78% (27.2329)	58.54% (27.8570)	40.12% (33.1650)
Basil (1d, 1w, 10d)	65.59% (31.2476)	56.28% (31.5881)	46.10% (35.5149)
Tomatoes (1d, 3d, 1w)	58.43% (30.2875)	46.21% (30.5464)	31.07% (33.5553)
Broccoli (1d, 3d, 5d)	55.47% (31.7610)	45.36% (31.1830)	32.33% (33.4929)
Chicken (1d, 3d, 5d)	50.89% (34.3922)	42.91% (33.2293)	31.62% (35.2646)
Ready-to-eat meal (1d, 4d, 2w)	41.56% (36.2048)	35.21% (35.9425)	33.08% (39.7626)

Note: Standard deviations are in parentheses.

In estimating the average premeditated waste across each product for a particular date label (close, middle, far), we found that the average food-waste percentage for the furthest date is 36%. If we compare this with our lowest waste percentage in the choice experiment (29%), our survey respondents, on average, expect to waste 7 percentage points more at the furthest expiration date compared to percentages used in the choice experiment. Similarly, for the middle date, the average expected waste percentage was 47%, 5 percentage points higher than what was used in the choice experiment. Whereas, the average expected waste percentage for the closest date was 57%, 4 percentage points lower than what was used in the choice experiment. This information increases the reliability of our choice of 29%, 42%, and 61% levels for food waste used in the choice experiment portion.

Policy Implications

Consumers are often confused about how to interpret date labels (Newsome et al., 2014; Wansink and Wright, 2006; Wilson et al., 2017; WRAP, 2011). Some freshness is lost over time, but it can take much longer for food to spoil and be unsafe to eat. Consumers may waste a lot of food if they confuse when a product is spoiled with when quality diminishes. Several food processing technologies exist commercially or are under development to help reduce food waste; one example is smart packaging with bio-sensors that change colors based on freshness or spoilage (Newsome et al., 2014). Making it easier for consumers to interpret food quality and safety will make it potentially easier for them to plan and reduce the amount they waste. While this packaging is more expensive, companies may be able to afford to invest in technologies conducive to reduce food waste if consumers are willing to pay a premium for lower-waste products.

From our findings on premeditated waste, we found that consumers would waste products like garlic and basil more when they are sold in larger quantities; grocery stores could therefore work to sell these products in smaller quantities. Retailers could also offer discounts on single-serving products as opposed to offering sizable discounts for buying in bulk. Single-person households tend to waste more food per person than bigger families (Schanes, Dobernig, and Gözet, 2018). As a potential solution, the government may be able to subsidize retailers for some single- or small-serving food items to make discounting single-serving products more worthwhile for retailers.

Before implementing any of the suggested solutions, it is vital that companies perform detailed cost–benefit analyses to determine whether the extra effort to reduce food waste is worth the undertaking.

Another measure could consist of educating consumers on ways to reduce food waste. Institutions such as schools, hospitals, and retirement homes often generate much food waste as well. Comprehensive education programs could help younger generations develop habits that reduce overall food waste. One example of food-waste education is the "Love Food Hate Waste" campaign enacted by grocery stores in the United Kingdom, which has been quite successful at reducing food waste (Newsome et al., 2014). However, any education programs on the consumer side should be carefully crafted. To reduce food waste, we need to ensure that it also coincides with smaller portion sizes. Otherwise, if consumers take too much food on their plate and—to prevent waste—consume everything on their plate it could contribute to a different problem, obesity. Education on plate waste reduction would then have to also coincide with education on proper nutrition.

Along with education programs, the government could potentially tax food waste disposal (Katare et al., 2017). However, this is challenging due the government's ability to monitor food disposal. The government could also subsidize companies that take strides to reduce food waste in their products. Likewise, they could provide awards or additional funding for institutions that meet certain food waste goals. Raising awareness and providing incentives may be a strategic way to reduce consumer-generated food waste.

In Summary

Overall, consumers express concern with food waste and are willing to pay more for products with lower food waste and with longer shelf life. These findings hint at some potential benefits for grocery stores, food companies, and policy makers who take measures to reduce food waste. Some potential measures could include improved food packaging, increased awareness, and discounted food items with smaller portion sizes. However, before implementing such measures, it is essential that the costs associated with food waste reduction do not outweigh the benefits.

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When in Doubt, Throw It Out! The Complicated Decision to Consume (or Waste) Food by Date Labels

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Have you ever walked into your kitchen, opened the cabinet, found a jar of spaghetti sauce with a "use by" date label, and the date printed on it has passed? What would you do? You may say this product has "expired," and it is no longer safe to consume. You may worry that the spaghetti sauce may taste bad, and you do not want to eat it. Either way, you end up throwing out the product, unopened. Alternatively, you may say that the product is fine and proceed to eat it. Which of these options would you choose if the date label stated, "best if used by"? Would you dispose of the spaghetti sauce and say, "When in doubt, throw it out"? Would your responses differ if the product were a carton of eggs?

If you would opt to throw out a product in any of these scenarios, you are not alone. We have had this question in our own homes. When presenting related research to academic and nonacademic audiences, we are often asked what these date labels really mean. Is the product safe? After stating that we are not food scientists, we proceed to explain the limited regulatory environment of date labels. We frequently hear of stories of domestic squabbles where one partner is perfectly content to consume the "expired" product, while the other believes that product will inflict harm or is unwilling to take the risk given uncertainty about the meaning of the label and the posted date.

Groups like ReFED (https://www.refed.com/) and the Harvard Food Policy Law Clinic have suggested that the confusion around date labels is a contributing factor to food waste in the United States. This argument appears in the preamble of the May 18, 2016 U.S. Senate bill S.2947: "Confusion over the meaning of date labels is estimated to account for 20% of consumer waste of safe, edible food, leading to approximately $29,000,000,000 of wasted consumer spending each year." As of May 19, 2016, U.S. House bill H.R.5298 states that "date labeling practices on food packaging cause confusion with 'sell-by,' 'best-by,' 'use-by,' and 'best before' dates, leading up to 90% of individuals in the United States to occasionally throw out still-fresh food." Recent publications suggest that consumers are confused about or uncertain of the meaning of the labels or ascribe meaning to the labels beyond what is legally required (Broad Leib et al., 2013; Wilson, Miao, and Weis, 2018). Roe et al. (2018) presented evidence that participants anticipated wasting more milk when a date label was present relative to no date label. However, they did not look at differences across date labels.

The confusion comes in part from the lack of federal policy that clearly defines the meaning and proper use of date labels (Broad Leib et al., 2013). In response, public and private entities—including the U.S. Department of Agriculture (USDA), Food Marketing Institute (FMI) with the Grocery Manufacturers Association (GMA), and Congress—have suggested moving toward two date labels: one for quality and another for safety. However, the bills in Congress suggest "best if used by" for quality and "expires on" for safety. The GMA and FMI suggest "best if used by" for quality and "use by" for safety (GMA, 2018). The Food Safety and Inspection Service of the USDA suggests simply using "best if used by" (U.S. Department of Agriculture, 2016). Using a survey, we explore consumption responses to date labels about safety and quality, and we describe the policy implications of these labels.

The current study is inspired by Ellison and Lusk (2018), who used a vignette study to evaluate food waste. We draw mostly from the "expired" milk example. In their study they asked participants:

> Imagine this evening you go to the refrigerator to pour a glass of milk. While taking out the carton of milk, which is [one quarter; three quarters] full, you notice that it is one day past the expiration date. You open the carton and the milk smells [fine; slightly sour]. [There is another unopened carton of milk in your refrigerator that has not expired; no statement about replacement]. Assuming the price of a half-gallon carton of milk at stores in your area is [$2.50; $5.00], what would you do? (Ellison and Lusk, 2018, p.623)

Ellison and Lusk (2018) found that smell was the only factor that contributes to increased waste, though differences exist given the demographics of the participants. In their analysis, they did not explicitly look at the role that date labels may have on waste. Our study explores how participants respond to a trio of products based on date labels, given prices.

Quality versus Safety Labeling

We evaluate how date labels and prices affect the probability of consuming a product that has "expired", or passed its posted date. We hypothesized that when we expose study participants to a product 1 day after the posted date, they are more likely to consume (i.e., not waste) the product if the product has a date label about quality than if it has a date label about safety. Following policy proposals discussed by the GMA and FMI, we used "best if used by" to indicate quality and "use by" to indicate safety. We expected this result to hold across multiple products. Given that the value of the product may matter, we controlled for the price of the product as well. We also considered the effect on anticipated consumption. We hypothesized that more participants would consume the product if the product were of greater value. Further, we assessed how the date label and price effects may differ by product.

We conducted a survey as part of a larger food experiment on date labels. In the larger experiment, we brought 206 participants into laboratories in Auburn, AL (104 participants), and Ithaca, NY (102 participants), to evaluate deli meat and spaghetti sauce under different date label treatments. Five respondents were dropped from the sample due to incomplete data. Table 1 provides sociodemographic variables of our sample. We attracted a random sample of participants to the laboratories in university communities. Our sample is not nationally representative, with a heavier representation of college educated and higher income participants than the U.S. population.

To the participants, we posed three vignette questions about anticipated consumption for the two experimental products (deli meat and spaghetti sauce) and eggs. We asked participants

> "You find in your refrigerator a carton of 12 eggs marked ("best if used by"/"use by"), which is yesterday. You paid ($3/$4) for the eggs. Do you use the eggs or throw out the eggs?"

All respondents saw this question for eggs and the same questions for deli meat and spaghetti sauce. All respondents saw the products in this order. Typically, we would have randomized the order of the products, but because this survey was part of a larger experiment that focused on spaghetti sauce and deli meat, we began this part of the survey with the different product, eggs. In the experiment, the participants evaluated spaghetti sauce and deli meat with the date labels "best by" and "use by." Thus, we anticipated the participants would evaluate eggs similar to how they evaluated the other two products. However, we randomized respondents into one of four settings for each product in the survey portion. These settings are four possible combinations of two date labels ("best if used by" and "use by") and two prices ($3 and $4).

Participants were asked whether they would consume or waste the product. If they stated that they would consume the product, they indicated the number (eggs) or percentage (deli meat and spaghetti sauce) that they would consume. In this article, we focus only on the choice to consume. We first test whether the responses under one date label differ from those under the other date label. In this test, we compare whether the date label leads to greater consumption of the "expired" product. We further test whether the date label makes a difference by product. Lastly, we explore whether the chances of consumption differ by the price or the date labels by estimating a model for each product. We include a group of sociodemographic variables as well.

Table 1. Summary Statistics of the Sample

	N	Mean	Std. Dev.	Minimum	Maximum
Share of Participants Who Would Consume the Product 1 Day After Posted Date					
All products					
Best if used by	201	0.894		0	1
Use by	201	0.821		0	1
Summary Statistics of Demographic Variables					
Age (in years)	193	40.472	14.203	20	73
Income groups					
Lower income	184	0.348		0	1
Middle income	184	0.429		0	1
Higher income	184	0.223		0	1
Female	198	0.700		0	1
White	201	0.662		0	1
Married/partner	194	0.634		0	1
College educated	201	0.856		0	1

Note: The income groups are divided as follows: lower income (<$85,000), middle income ($85,000–$115,000), and higher income (>$115,000).

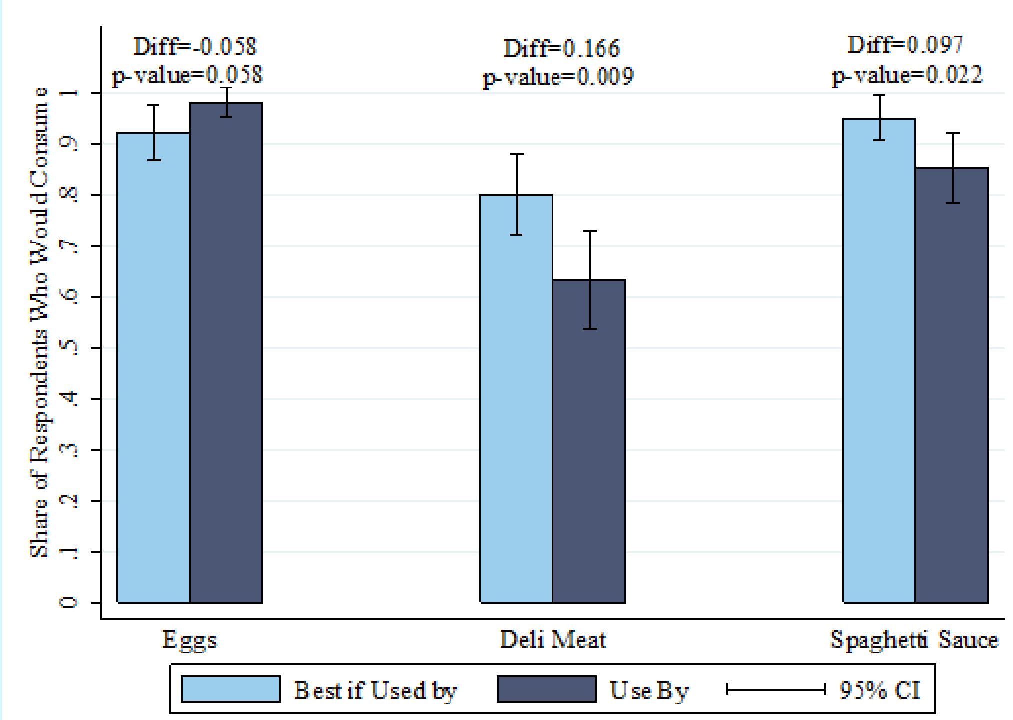
In Table 1 and Figure 1, we provide evidence that participants respond differentially to the date labels. Overall, 89% of respondents would consume the products labeled "best if used by," compared to 82.1% when labeled "use by" (see Table 1). However, by product we see differences (see Figure 1). For eggs, 92.2% of respondents would consume eggs labeled "best if used by," while 98% of respondents would consume eggs labeled "use by," a reversal of the general pattern. The difference of 5.8 percentage points, which is relatively small and statistically insignificant, suggests that the response to the date labels for eggs is not meaningful. For deli meat, 80% of respondents would consume meat labeled "best if used by," compared to 63.4% who would consume meat labeled "use by." The 16.6 percentage point difference is large and statistically significant, suggesting a meaningful difference in the response to the date labels for deli meat. Lastly, 95% of respondents would consume spaghetti sauce with "best if used by," compared to 85.3% of respondents when the sauce has "use by." Though smaller, the 9.7 percentage point difference is sufficiently large to suggest that participants respond differently to the date labels for spaghetti sauce. This summary suggests that consumers may have different interpretations of date labels across products.

While these findings are compelling, we consider a fuller analysis. Since date labels appear to have differential effects across products, we estimate models for each product separately. To control for potential price effects, we assess consumption of products given high ($4) and low ($3) prices. We include a series of sociodemographic variables in the models because participant characteristics may matter.

We estimated a linear probability (ordinary least squares) model of the date labels, prices, and sociodemographic variables. Figure 2 illustrates the estimated effect of each factor. The value of the estimated effect is denoted by the dot; lines (95% confidence intervals) that extend from the dot represent the range of values of the estimated effect. An effect greater than 0 means that the presence of the factor (e.g., the high price) contributes to a greater chance of consumption than the alternative (e.g., the low price). An estimated effect of less than 0 means that the factor is associated with a lower chance of leading to consumption, while an estimated effect of 0 suggests that the factor has no meaningful effect on consumption. If the line crosses the reference line, we argue that the factor has no effect on consumption; this is true regardless of the length of the line or the distance of the dot from the reference line.

This analysis confirms results of the earlier comparisons: Participants stated that they were less likely to consume post-dated eggs if the date label was "best if used by" relative to "use by" (the estimated effect is to the left of the reference line). However, participants were more likely to consume deli meat and spaghetti sauce if the date label was "best if used by" relative to "use by" (the estimated effect is to the right of the reference line, see Figure 2). The effect of high relative to low price did not have a meaningful effect for any of the products. Most of the sociodemographic variables did not influence consumption. However, white participants were more likely to state that they would consume eggs and spaghetti sauce past the date on the labels than nonwhite participants. College-educated participants stated that they were less likely to consume eggs past the date on the labels relative to participants without a college degree. Thus, regardless of product, the key factor affecting consumption was the date label rather than price or characteristics of the participants.

Figure 1. Share of Participants Who Would Consume 1 Day after the Date, by Product

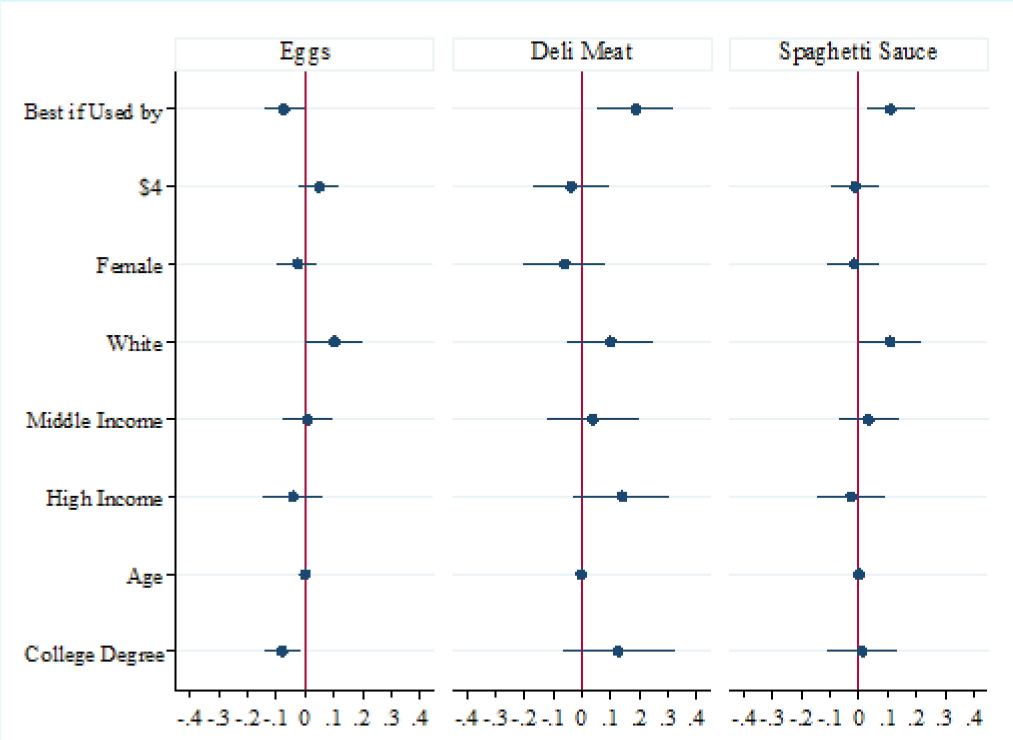


Discussion

These results suggest that date labels have the power to influence anticipated consumption of products. As suggested by Wilson, Miao, and Weis (2018), who used survey data from the same sample, participants have some level of confusion concerning the meaning of the date labels. This point is made clear, as the effects of the label differ by product. As noted by Broad Leib et al. (2016), no national product labelling standard exists. Further, as Wilson, Miao, and Weis (2018) point out, the survey participants can see at least two different date labels for the same product. Our evidence indicates that consumers respond to date labels differently depending on the product. Even in the case of deli meat and spaghetti sauce, where the response to date labels follows the hypothesized pattern, the two labels yield a difference in the magnitude of response. While we include price as a factor, it does not have a substantial effect.

In this study, we consider the consumption decision after product expiration date when the product is in the home. This differs from Wilson et al. (2017), who considered future consumption at the point of purchase. Interestingly, the findings of this study suggest higher consumption after the product has expired compared to future consumption in an experimental auction with exchange of real products and money. Since this survey was hypothetical, respondents’’ consumption response could be biased upward because the responses had no real consequences.

Figure 2. Factors that Influence Whether Participants Would Consume Products 1 Day after the Date, by Product



Note: We used the linear probability model to assess respondents’ choice to consume. For each product, we assessed the chance of consumption based on the experimental factors (date label, price, and product) and sociodemographic variables. Dots to the right of the reference line (0), indicate a greater chance of consuming the product, while values less than 0 indicate a lower chance of consuming (thus a greater chance of wasting) the product. Lines that extend from the dots represent the likely ranges of the estimated effect (95% confidence interval). Lines that cross the reference are no different than 0, regardless of the line length. Thus, the factors have no effect on consumption if the estimated value is 0 or if the likely range includes the reference line. The range of possible estimated effects for age in all three models is too small to detect in this figure, but they include the reference value 0.

The reason for the opposite response pattern to date labels for anticipated consumption of eggs relative to the other products is unclear. A potential explanation is that eggs are typically cooked before being consumed, whereas the other two products are typically “ready to eat” (though most consumers warm the spaghetti sauce before use). We hypothesized that the difference would be the same across products as we assumed that participants would waste more product when faced with a concern about safety relative to quality (Wilson et al., 2017). We find that the participants in this study did not adjust their anticipated consumption based on the price of the product. While not a formal hypothesis, we expected participants to anticipate consuming more (wasting less) when the product has a higher price, despite the 0-price effect found be Ellison and Lusk (2018). A potential explanation for this result is that participants do not see a large enough difference in the price beyond the typical market value, so that the high or low price is not perceived to be sufficiently different to warrant a differential response. If this point holds, it could reflect evidence against the sunk cost fallacy, which suggests that consumers continue consuming a product after it is of little use to the consumer (past date). Further, participants may overstate their consumption and avoidance of waste to avoid the stigma of being identified as a "food waster," though no one could be identified, in accordance with the study protocol.

Beyond these points, we acknowledge other issues that this study may have. The contradictory response to the date labels by product may be an artifact of the study design. Our sample includes only 201 participants. A larger sample might have given us more refined results. We collected data in the context of an experiment focused on spaghetti sauce and deli meat. However, we asked the egg question first; thus, we expected responses to the deli meat and spaghetti sauce to follow eggs. Another issue is that we used a study design such that individuals did not see all possible date labels and prices for each product; rather, we randomly placed participants into one of four possible combinations of date labels and price conditions for each product. With this study design, we may have inadvertently assigned more participants to a date label group for a product who will consume that product regardless of the date label. These findings suggest that a larger study is needed to confirm these results.

If these results hold with a larger dataset and a different design, we will have evidence that a simplified date label system (a label for quality and another for safety) may not lead to universal reductions in food waste. Rather, we see under this policy a reduction in waste that is greater for some products while an increase in waste for other products. The net result could be positive or negative. A wider array of products needs to be analyzed to see whether the results hold over a more diverse basket of goods.

Conclusions

Concern over how to manage foods past their posted dates is common in households. This concern may lead to some wasted product, where the magnitude of the waste, as suggested by this study, depends on the date label provided on the product. Unfortunately, labels are not under specific national regulations, and consumers have differential understanding of these labels. As a result, consumers base their responses on limited and often confusing, if not misleading, information.

The current efforts to regulate these labels is a reasonable approach. However, the growing body of evidence about consumer responses to date labels suggests that policy makers need to proceed with care in crafting rules. If this and other work are correct, adjusting date labels may not reduce waste in general—as waste rates for some products rise above the reduction in waste for other products. An important step forward to address this policy question is to conduct careful testing of labels with real evaluation of actual consumption and waste.

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Additional Information

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Exploring Food Loss from Farm-to-Retail in the Produce Industry

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While much of the established literature on food loss in the United States focuses on food retailers and consumers (Buzby, Wells, and Hyman, 2014), understanding of farm-to-retail food loss is more limited. In December 2017, the USDA Economic Research Service (ERS) hosted a workshop titled “Farm-to-Retail Food Loss in Produce: An Exploratory Discussion of the Causes and Economic Drivers of Change.” The focus was on identifying knowledge gaps and discussing underlying economic drivers and mitigators of food loss at earlier stages of the supply chain. This article summarizes the insights and lessons learned from that full-day workshop. Furthermore, we highlight topics where economists might contribute to a growing area of inquiry and illustrate the complexity and interrelated impacts of actions suggested to reduce food loss and waste (FLW).

Language Matters, but There Is Little Consensus

It is widely acknowledged that there is no standard definition of FLW (Hanson et al., 2016; Bellemare, et al., 2017; Ellison, Muth, and Golan, forthcoming). For example, the ERS defines food loss as “the edible amount of food, postharvest, that is available for human consumption but is not consumed for any reason.” By this definition, food waste—“edible items that go unconsumed, as in food discarded by retailers due to color or appearance and plate waste by consumers”—is a subset of food loss (Buzby, Wells, and Hyman, 2014). Table 1 reports four widely used definitions of food loss and how they differ.

Resources spent on competing definitions dividing loss from waste can lead to incorrect assumptions regarding the nature of food loss and can somewhat miss the point. There may be valid economic reasons to over-plant or over-purchase food, such as to avoid penalties from delivering a quantity below the contracted amount. However, these decisions may be rational or even efficient considering all circumstances. Thus, defining food loss by itself does not lead to a deeper understanding of the issue, its importance, or potential mitigators. Similarly, “waste” is often viewed as a pejorative term and linked with finding fault or assigning blame for an outcome (Creamer and Johnson, 2018).

However, language is important because it is associated with quantitative estimates and policy decisions. It is critical to have transparency on the definition of FLW, especially to understand which quantitative measurements can be compared, replicated, and then used.

Measurement Matters (for Some Goals)

While differences in language may serve to muddle the discussion on FLW, measurement has the potential to clarify and focus efforts. As Flanagan et al. (2018) succinctly state: “What gets measured gets managed.”

Large-scale, nationally representative surveys of food loss are relatively rare and extremely expensive (see Table 1). In lieu of this, many researchers rely on small-scale, in-depth studies of food loss for a particular commodity or region (Dusoruth, Peterson, and Schmitt, 2018; WWF, 2018). This type of analysis sheds light on the individual instances studied and may help to inform the larger conversation around food loss generally. However, without some common denominator, it is nearly impossible to tell whether the estimates from one study are comparable to another or are representative of a larger geographic area or longer time frame. Additionally, lack of transparency on some measurements makes replicating a study or specific results nearly impossible.

Table 1. Definitions and Estimates of Food Loss and Waste

Food Loss or Waste Definition	Estimate of Food Loss	Methodology
U.S. Department of Agriculture, ERS (Buzby, Wells, and Hyman, 2014)		
Food loss represents the amount of edible food, postharvest, that is available for human consumption but is not consumed for any reason; it includes cooking loss and natural shrinkage (e.g., moisture loss); loss from mold, pests, or inadequate climate control; and plate waste.	31% (66.5 million tons) of the 195 million tons of the available food supply at the retail and consumer levels in 2010.	Estimates domestic per capita availability for 215 food commodities, based on production, trade, shrink, Nielson Homescan, and retail price data.
U.S. Environmental Protection Agency (2018)		
Food waste describes food that was not used for its intended purpose and is managed in a variety of ways, such as donation to feed people, creation of animal feed, composting, anaerobic digestion, or sending to landfills or combustion facilities.	39.73 million tons generated in 2015, of which 2.10 million tons are composted.	Estimate tonnage of municipal solid waste (trash) products from industry, business, and government data sources.
Food & Agriculture Organization of the United Nations (2018)		
Food loss is the decrease in quantity or quality of food reflected in nutritional value, economic value or food safety of all food produced for human consumption but not eaten by humans. Food waste is part of food loss and refers to discarding or alternative (nonfood) use of safe and nutritious food for human consumption all along food supply chains.	One-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons per year: 30% of cereals, 20% of dairy products, 35% of fish and seafood, 45% of fruits and vegetables, 20% of meat, 20% of oilseeds and pulses, 45% of roots and tubers.	Food lost and wasted for seven commodity groups throughout the food supply chain quantified using available country-level food balance-sheet data, literature, and modeling assumptions.
European Commission (FUSIONS 2016)		
Food waste is the fraction of food and inedible parts of food removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested), anaerobic digestion, bioenergy production, cogeneration, incineration, disposal to sewer, landfill or discarded to sea).	87.6 million tons in EU-28 states in 2012.	Government-collected data on food waste from the 28-member states analyzed, along with filling of data gaps, and two new data collections.

Realizing the importance of transparency across studies, the Food Loss & Waste Protocol (FLWP) released a "Food Loss and Waste Accounting and Reporting Standard" to help researchers globally create measurements of FLW that are consistent, transparent, and comparable across various dimensions (Hanson et al., 2016). The report defines FLW as a combination of what is lost (edible versus inedible) and its (unintended) destination.

Destination is important because it reveals that the diversion of food, even if it is not able to be quantified, can be ranked from highest to least priority, the origins of which can be traced back to the EPA's (2017) Food Recovery Hierarchy. Destinations range from animal feed, where some of the value is recovered, to landfill, where the total value would be lost, with numerous steps in between. Diverting food loss from a less efficient use of materials to a more useful outcome can now be incorporated to the overall understanding and quantification of FLW.

Measurement is critical to understanding and communicating FLW; knowing the underlying mechanisms is essential to progress.

Understanding the Supply Chain Matters

Compared with efforts to measure food loss, there has been less attention to the drivers of food loss, particularly at earlier stages of the supply chain. If growers and processors maximize profit, then it naturally follows that food loss occurs because of factors inherent to the supply chain.

We often like to think of the fresh produce supply chain as moving seamlessly from “farm to fork,” but the reality is much more complex. Supply chains are complicated, with products moving rapidly across the globe. Produce can be sold and resold, packed and repacked, and touch many different hands (figuratively and literally) before reaching the final consumer. In addition, supply chains evolve with technological change. Moving fresh produce, which often has a short shelf life and is highly perishable and sensitive, from the farm to the consumer often involves advanced technology for vacuum cooling, packaging, refrigerated trucking and storage, and other infrastructure to maintain product quality and marketability.

These sections of the supply chain, on-farm through transportation and processing, have largely been omitted from the food loss discussion in the United States (Kitinoja, Tokala, and Brondby, 2018). The omission is partly because initial research suggested losses are relatively smaller near the farm in developed countries (FAO, 2011) and also because loss at these stages may be less visible to the public than post-consumer waste. Incentives and preventive measures taken throughout the supply chain warrant critical examination, as efforts in the middle of the supply chain may shift loss to either end of the supply chain, where there is less consolidation and oversight. Secondary or alternative outlets for a product can alter loss and waste levels, but this adds additional and perhaps redundant steps to the supply chain. Also, while some products may be easily moved to alternative uses, others, such as fresh tomatoes, are not easily sold into other markets, where standards and varieties vary substantially by intended use (e.g., fresh versus processed end products). Understanding why these markets do or do not function effectively can inform our overall understanding of losses.

As suggested previously, food loss research to date has seldom plumbed for a deeper understanding of the market mechanisms that cause food loss. Grades and standards (real or perceived) and consumer preferences (or a lack of understanding between real and perceived consumer preferences) could stop some edible food from moving forward in the supply chain because it is deemed unmarketable. To illustrate, if consumers are unwilling to eat “ugly fruit” (such as an apple with brown streaks on the skin), retailers are unlikely to accept fruit below some cosmetic threshold. In such a case, moving unsalable food forward sinks additional labor, transportation, and storage, which may actually constitute a greater loss than simply abandoning the product or repurposing it for some other use (e.g., compost). On the other hand, there may be an untapped market for ugly fruit, unbeknownst to some retailers, which could be driving some portion of the food loss.

Further examination and disaggregation of food losses that occur prior to consumer or retail levels could dramatically affect the discussion of food loss in its entirety. Currently, our understanding of these issues is severely limited by the data, suggesting that new and different data collection techniques may be necessary to more fully understand FLW in this context.

Managing Risk and Uncertainty Matters

Agricultural production is inherently risky, as it is exposed to multiple weather and pest/disease pressures that come with any biological process. Yields and quality change by year and region and depend on factors outside of the grower’s control. The same planted area, under ideal conditions, may exceed expected yield in one year, where last year it produced a shortfall. This inherent variability may explain some sporadic food losses, as overplanting could occur as part of a risk management strategy to combat uncertainty in the field.

Similar to many other economic agents, growers and processors may exhibit loss aversion (Kahneman, Knetsch, and Thaler, 1991) and would always prefer a surplus to risking a shortage (De Gorter, 2014). While corporate strategies like just-in-time delivery and inventory management are making it easier for retailers and consumers to access a variety of produce year-round, these make forecasting more difficult for growers and make the impacts of underestimating more severe if markets are lost. Some buyers and contracts severely penalize shortages, whereas a surplus may still be bought by the customer (possibly at a lower price) or sold into secondary channels. Keeping additional product on hand may simply be an elegant, privately optimal strategy.

Produce markets are notoriously volatile. Prices can crash suddenly, causing the value of edible product to drop below the marginal cost of harvest, effectively stopping the food from further movement through the supply chain. Depending on where and when the price fluctuations occur, produce could be left in the field (also known as fly-by fields), discarded at a packing shed, or dumped from the back of a truck (De Gorter, 2014). The persistence of food insecurity in the United States makes it tempting to suggest that a more efficient outcome would be to divert lost produce to a food recovery operation. However, perishability, transportation costs, and fragmented infrastructure preclude comprehensive recovery efforts. The number and capacity of food recovery and diversion companies have exploded recently, which may improve landfill diversion rates; however, concerns remain that recovery and diversion efforts, while virtuous short-term responses, distract from addressing the underlying issues for the loss.

Any effort to further understand how growers, suppliers, and processors quantify and act upon risk and uncertainty could help to move the conversation forward. This could include anything from looking at exogenous (weather or food safety) shocks to a particular market or estimating the effect of price volatility on food losses.

Tradeoffs Matter

Reducing food loss is an important goal, but like any singular focus in a complex system, adjustments do not occur in a vacuum and each action has an opportunity cost. Reducing FLW must be considered alongside other, competing factors for the individual grower, processor, retailer, and consumer. If reducing food loss takes away resources devoted to farm profitability or sustainability, it is unlikely that any grower would choose to participate. However, if reducing food loss can be considered alongside more traditional goals that improve farm income, industry adoption of food loss initiatives will be more likely. Additionally, how we frame the issue (e.g., as a distribution problem, as a way to feed hungry people, as a path to increase farm profit) may lead to different outcomes that produce different “winners” and “losers.”

Similarly, single-mindedly pursuing food loss reductions has unintended consequences. For example, a policy that incentivizes growers to send all of their edible produce to a wholesaler could result in defective or imperfect produce being thrown out at the wholesaler or retailer level if consumers reject that produce. This policy does not actually reduce FLW; rather, it simply shifts where the losses occur, possibly requiring more investment in ultimately uneaten produce. A better understanding of how the industry deals with food loss at each point in the supply chain is needed. If food is never produced with an intention of it going to a landfill, then there must be other underlying drivers of loss, which may include supply chain rigidities or competing policies that unintentionally exacerbate food loss. Once the effects, incentives, and competing goals are considered together, one can begin to understand how to effectively balance resources devoted to reducing food loss alongside other goals.

Realizing that there are opportunity costs, spillovers to other segments of the supply chain, and diminishing marginal returns to any activity means an efficient strategy would allocate resources toward the actions with the highest benefit. This may include areas and actions where losses are the greatest and where intervention can have the most positive effect. These two options may not necessarily be the same. For example, getting a diverse and widespread group of consumers to reduce losses individually (the sector where the majority of losses are found to occur in developed countries) may be much more difficult than enacting changes in a largely consolidated, fairly narrow industry. Losses as well as possible interventions should be considered simultaneously to generate the most efficient possible outcome.

Knowing this, the optimum outcome is likely a reduction, rather than a complete eradication of food losses. When balancing the opportunity costs of intervention with the costs of FLW, there will necessarily come a point where it is no longer efficient to devote resources to reducing these losses. Therefore, we need to consider a level of "optimal" food loss. And while that term may be unpopular, the costs associated with eradication of virtually anything, including food losses, would likely be economically enefficient.

While certainly more work is needed here, modeling efforts and threshold analysis may be able to shed some light now on what is theoretically feasible in terms of "optimal" food loss. This of course presumes that modeling will be able to capture the relevant factors, and since there is no definitive list of these as of yet, more qualitative analysis may need to precede.

Looking Forward

The takeaways from a daylong workshop on FLW held at ERS in 2017 read more like an issues paper than a completed path forward. The discussions on individual aspects of FLW primarily serve to highlight how much further our understanding of this issue needs to go to truly have an impact. If there was a single takeaway from the day, it is this: The discussion of FLW could benefit from moving from accurately quantifying and labeling the problem to developing a greater understanding of the economic and financial decisions that lead to the problem in the first place.

FLW remains a complex issue that policy makers and researchers across disciplines are struggling to understand. While researchers have spent a great deal of effort measuring and understanding food losses in the consumer and retail sectors, less has been devoted to understanding food loss at the early stages of the supply chain. Actions must not only address the individual sectors of the supply chain but also the entire food system in all its complexity in the attempt to most efficiently reduce food loss. Certainly, some understanding exists, in the private sector, of modern supply chain management techniques (such as real-time inventory management) which may help address some drivers of food loss in produce. However, only after examining the underlying drivers of food loss in this complete system can we begin to strategize how to properly mitigate these drivers, reduce food losses where they occur, and generate maximum societal benefit.

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