OTHER RESEARCH IN THE CONSUMER INTEREST

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# The Value of Retail- and Consumer-Level Fruit and Vegetable Losses in the United States

**Food loss at the retail and consumer levels in the United States includes 14.8 billion pounds of fruit and 23.4 billion pounds of vegetables, valued at $15.1 billion and $27.7 billion, respectively, in 2008 retail market prices. The total value of these losses is $42.8 billion per year, or roughly $141 per capita. To most efficiently reduce the annual food loss, it may be beneficial to focus efforts on the four fruits (fresh apples, grapes, peaches and strawberries) and four vegetables (fresh and canned tomatoes and fresh and frozen potatoes) that have the greatest amount of loss.**

Food loss at the retail and consumer levels represents significant amounts of money and other resources invested in food production, including land, fresh water, labor, energy, agricultural chemicals (e.g., fertilizer, pesticides) and other inputs to produce food that does not ultimately meet its intended purpose of feeding people. Examples of food loss include fresh oranges thrown out after harvest and orange juice poured down the drain. A recent study estimated that the production of wasted food required the expenditure of around 300 million barrels of oil and over 25% of the total freshwater used in the United States (Hall et al. 2009). According to the US Environmental Protection Agency (EPA), food waste accounted for 31.75 million tons (12.7%) of the 250 million tons of municipal solid waste in the United States in 2008 (EPA 2010a), and cost roughly $1.3 billion to landfill (Schwab 2010). Less than 3% of food waste was recovered and recycled in 2008, with the remainder going to incinerators or landfills (EPA 2010a). These disposal methods

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negatively impact the environment through the emissions from incinerating food waste and the methane gas generated when food waste decomposes anaerobically in landfills. Methane is twenty-one times more powerful in accelerating global warming than $CO_2$ (EPA 2010a). Landfills account for 34% of all human-related methane emissions in the United States (EPA 2010a). In addition to methane, landfills produce leachate (a mixture of liquid waste, organic degradation by-products and rainwater), which may contaminate groundwater if the landfills are not properly maintained.

A large multidisciplinary project sponsored by the British Government found that reducing food waste across the entire food chain will be a critical part of any strategy to sustainably and equitably feed the rapidly growing world population (Foresight 2011). The Food and Agriculture Organization of the United Nations predicts that the world population will reach 9.1 billion by 2050 and that will require a 70% increase in food production, net of crops used for biofuels (FAO 2009) (the world population was 6.8 billion in mid-2009). Although most of this growth will occur in developing countries, developed countries also face issues of food insecurity. Households are considered “food insecure” when, at some time during the year, they have difficulty providing enough food for all of their members because of a lack of resources. In 2008, 49.1 million people lived in food-insecure households in the United States out of a total population of 300 million (Nord, Andrews, and Carlson 2009). Some parts of the world face critical food shortages. For example, there were riots in response to soaring food prices in 2007–2008, and in Thailand and Pakistan, soldiers were deployed to prevent hungry people from seizing food from fields and warehouses (Hodges, Buzby, and Bennett 2010).

Stuart (2009) makes the case that in global food markets, food wasted in developed countries means that less is available for others to buy and that wasting less food could liberate agricultural land and resources for other uses, such as growing food for the world’s hungry. On the other hand, Stuart acknowledges that a certain amount of surplus food is needed to prevent shortages and that the demand for food in developed countries, including that which is wasted, stimulates production and helps raise revenue for farmers, including those in developing countries. Reducing food loss would likely reduce food prices in the United States and the rest of the world, although the effects depend on the nature of supply. If food loss reductions led to reduced food prices, then food insecurity might be alleviated in the United States and some other parts of the world. Food insecurity could also be alleviated if consumers, industry and governments increased donations to charitable feeding programs.

Growing populations, increasing pressures on agricultural land and other limited resources, and the negative effects of food loss on the environment mean that it is becoming increasingly important to estimate the amount and value of food loss, including food waste, as a baseline for future efforts to minimize food waste, conserve resources and improve human health worldwide (Hodges, Buzby, and Bennett 2010). Here, our study's unique contribution is that we estimate the baseline dollar values of the fruit and vegetable losses at the retail and consumer levels in the United States. Baseline values for other food groups will be estimated in subsequent analyses. The value of fruit and vegetable losses are estimated using national retail prices from Nielsen Homescan data and loss estimates derived from the US Department of Agriculture's Economic Research Service's (ERS) Loss-Adjusted Food Availability data (ERS 2010a). These value estimates highlight the importance of food loss in the United States by putting the size of the loss into perspective.

Although consumers are affected by the negative externalities associated with food loss,[1] the impact and relevance of food loss is currently not apparent to most consumers as they plan meals and purchase, eat and discard food. The literature suggests that recycling by US consumers is influenced by both monetary (e.g., bottle deposit refund, pay as you throw) and nonmonetary incentives (e.g., perceived effectiveness of recycling, concern about the environment and social pressure) as well as by barriers to recycling (e.g., inconvenience, lack of knowledge about what and how to recycle) (Massachusetts Department of Environmental Protection 2002). The monetary estimates for fruit and vegetable loss provided here, combined with a discussion of the nonmonetary factors (e.g., negative externalities of food loss), may motivate some consumers to reduce food waste, patronize food stores and other businesses that have good track records of donating food to charity, or, at a minimum, to become more socially mindful of the amount of food they waste.

Additionally, baseline estimates can help identify whether and where reducing food loss will be cost-effective. For example, estimates of the value of food loss to society could be helpful when weighed against the costs of reducing these losses. Strategies and technologies used to reduce food loss will vary at the different points along the food production, marketing and consumption chain, such as sophisticated packaging of food sold at retail to reduce spoilage and gleaning (i.e., food recovery) unsold food at restaurants to feed those who are food insecure. The *Journal of Consumer*

1. Negative externalities are the indirect negative spillover costs to others not involved in a transaction, such as the release of greenhouse gases or water contamination.

*Affairs*' audience is consumer affairs professionals. Thus by sensitizing these professionals to the issue of food loss, and through information multipliers, consumers will be exposed to the issue as well. The baseline estimates provided here are from the most detailed study of the value of fruit and vegetable losses in the literature to date for the United States.

## BACKGROUND

"Postharvest losses" are the measurable quantitative and qualitative losses of a specific food product after harvest (de Lucia and Assennato 1994). Quantitative losses include decreased weight or volume, such as may occur from poor handling. Qualitative losses include adversely altered physical condition or characteristics, such as undesirable color changes and reduced nutrient value. In this article, "food loss" is a subset of postharvest loss and represents the amount of food that is available for consumption at either the retail or the consumer levels but is not consumed; it includes natural shrinkage (e.g., moisture loss), loss from mold, pests or inadequate climate control and food waste. "Food waste" is a subset of food loss. According to Bloom (2010, p. xii), food waste occurs when an edible item goes unconsumed as a result of human action or inaction and is often the result of a decision made farm-to-fork by businesses, governments and individual consumers. As an example of food loss, an estimated 8.6% of the retail weight of fresh apples is lost at the retail level and after removing that amount from the food supply, an additional 20% is lost at the consumer level (ERS 2010b). Some unknown portion of each of these fresh apple loss amounts constitutes food waste, such as apples thrown out by supermarkets because of minor discoloration or soft spots (despite still being edible) and fresh apple slices discarded by children. In this paper, we do not specifically assign a value for the inedible portions, such as the core and stem of apples, because they are not considered available for consumption.

Postharvest losses can occur anywhere in the postharvest chain of interconnected phases or associated activities, from the time of harvest on the farm all the way through the food manufacturing, processing, marketing (e.g., retail) and consumption chain to the final decision by the consumer to eat or discard the food. The nature of the activities in the postharvest chain varies considerably according to the type of food (e.g., refrigeration and misting for leafy greens vs. room temperature and a relatively dry atmosphere for sweet potatoes). The remainder of this section provides examples of postharvest food loss at the different phases, and subsequent sections focus on the estimates of the quantity and value of food loss for fruits and vegetables at the retail and consumer levels. These food loss estimates can serve as a reasonable proxy for food waste in the United States. This is because loss of the edible share due to natural shrinkage, pest infestation, mold and other spoilage factors outside of people's control has not been quantified, but may account for a relatively small share of food given technologies available to prevent them.

### Farm-Level Food Losses

Postharvest losses at the farm level can arise for several reasons. For example, crops can become more prone to disease and spoilage during storage and transport if, prior to harvest, they are subject to unseasonable freezing, hail, disease, mold or pests. Crop damage can also occur by mechanized harvesters. Crops that remain unharvested and are plowed back into fields as fertilizer are losses to the producers yet are not counted as postharvest losses. Harvested crops and other food shipments may also be rejected because they fail to meet minimum quality standards set by the major supermarket chains that buy the shipments.

### Processing and Retail-Level Losses

At the processing and marketing stage, losses may occur due to natural deterioration and shrinkage, transportation and handling damage (e.g., crushed or dented cans), improper packaging, expired sell-by dates, mold and pest infestations. Where economically feasible, fruit and vegetable trimmings and other by-products of processing, such as broccoli stalks and lemon peels, are diverted for use as ingredients in other foods for human consumption or in nonfood products (e.g., cosmetics) or for animal feed. Despite available cold chain technologies, temperature abuse occurs in a small portion of food held in storage, resulting in faster deterioration and increased potential for microbial growth. Retailers may also discard food due to overstocking, improper stock rotation, quality that does not meet the retailer's specifications and additional trimming of edible parts, such as for precut produce.

At the retail level in the United States, new food product introductions are common but have high failure rates, often leading to their removal from grocery shelves. In 2005, there were a record 18,722 new food and beverage products introduced in US supermarkets and other retail outlets (Martinez 2007). Most were variations of existing products (e.g., new packaging) rather than new innovations (Martinez 2007). Nonetheless, failure rates may exceed 90% for some food categories, suggesting that firms must struggle to develop products that appeal to enough consumers to merit continued production (Connor and Schiek 1997). New product introductions that fail may be returned to the manufacturer and may ultimately end up discarded, representing food loss. However, if failed new products are donated to charities or sold in one of the growing number of stores for resaleables so that the food is ultimately consumed by humans, this does not count as food loss. An unquantified, but likely small, share of surplus perishable foods from restaurants, schools and other institutions is recovered for feeding programs, composting or animal feed.

## Consumer-Level Losses

At restaurants and other dining-out venues, expanded menu choices are common sources of food loss, as well as unexpected fluctuations in food sales, overpreparation (e.g., cooking more French fries than needed), cooking loss, plate waste and product spillage and breakage. Food loss in households occurs for many of the same reasons. Plate leftovers from restaurants are sometimes taken home by patrons for later consumption, but an unknown portion of this food ends up being fed to pets or discarded. Different consumer tastes and preferences also play a role.

The widespread and growing intolerance of consumers for substandard foods (e.g., undersized or with cosmetic defects) has likely led to an increased rejection rate by both consumers and the food industry, which aims to satisfy consumer demand for a continuous supply of a wide variety of high-quality, fresh foods, including convenience foods. Overtime, food merchandising in the United States has changed with greater emphasis on coupons, discount offers and supersized portions and on meals at retail stores, restaurants and other dining-out venues. In response to these and other factors, consumers have increased their expectations of serving sizes and are often encouraged to buy more than they need, increasing the potential for food loss.

Some food loss is inevitable because food is inherently perishable. For example, some unsold or uneaten food at restaurants, supermarkets or in homes is not suitable for consumption. Some losses—like the discard of moldy fruit from the produce shelf at the supermarket and the condemnation of diseased animals at the slaughtering house—are necessary to ensure the safety and wholesomeness of the US food supply. Such foods are not recoverable for human use. Likewise, at eating establishments, plate scraps not taken home by patrons are appropriately discarded out of health considerations. Legal liability and strict food safety rules, such as those in the wake of the Bovine Spongiform Encephalopathy (BSE) scare, inhibit food recovery and redistribution in some cases. For society as a whole, investments to reduce these losses may be economically attractive because the available food supply can be increased without incurring additional production resources.

## Previous Estimates of Food Loss and Waste

In 1997, Kantor et al. published a seminal study on food loss in the United States that estimated that in 1995, roughly 96 billion pounds of food was lost, or 27% of the 356 billion pounds of food available for human consumption. Kantor et al.'s conversion factors for food losses serve as the foundation for what is now called the Loss-Adjusted Food Availability (LAFA) data series, which was first posted on the ERS' website in 2005 (ERS 2010a). In the present study, this data series is used to value fruit and vegetable losses. It is more fully described in the data and methods section.

Table 1 is a food loss summary table that has similar column and row headings as a table in Kantor et al. (1997) but updated with the US population count on July 1, 2008 (304.06 million) and the data and loss assumptions currently used in the hundreds of spreadsheets in the LAFA data series. Table 1 shows that in the United States in 2008, 29% or 126 billion pounds of the 428 billion pounds of the food supply were lost at the retail and consumer levels. Relevant for this study, these losses include 14.8 billion pounds of fruit and 23.4 billion pounds of vegetables. The current loss assumptions in the LAFA data differ from Kantor et al.'s in that they include updated retail loss estimates for each fresh fruit, vegetable, meat, poultry and seafood item documented in Buzby et al. (2009), among other updated loss assumptions. For example, Kantor et al. uniformly assumed that each fresh fruit and vegetable loss estimate was 12% at the retail level. Now, using Buzby et al. (2009), each fresh fruit and vegetable in the LAFA data series has its own retail-level loss estimate (e.g., fresh bananas, 8%; fresh artichokes, 19.3%). Most of the differences between the total amounts of loss in Kantor et al. and the new estimates in Table 1 are due to the increased US population, because the net effect of all of the loss assumption updates is small. Losses on farm and between the farm and retailer were not estimated due to data limitations for some of the food groups. Had these losses been included, total postharvest loss in the United States would be over 29%.

Also in the late 1990s, there was heightened interest by the US Department of Agriculture (USDA) in gleaning (i.e., food recovery at all levels, including the farm), which resulted in a conference and a publication titled "A Citizen's Guide to Food Recovery" (ARS 1997). Since then, plate waste studies have focused on certain demographic groups, primarily school children. For example, Buzby and Guthrie

TABLE 1
*Estimated Food Loss in the United States, 2008*

| | | Losses from Food Supply | | | | | |
|---|---|---|---|---|---|---|---|
| | Food Supply[a] | Retail Level | | Consumer Level | | Total Retail and Consumer Level | |
| Commodity | Million Pounds | Million Pounds | % | Million Pounds | % | Million Pounds | % |
| Grain products | 59,757 | 7,171 | 12 | 10,517 | 18 | 17,688 | 30 |
| Fruit | 61,832 | 5,742 | 9 | 9,040 | 15 | 14,782 | 24 |
| Fresh | 36,599 | 4,228 | 12 | 6,668 | 18 | 10,896 | 30 |
| Processed | 25,233 | 1,514 | 6 | 2,372 | 9 | 3,886 | 15 |
| Vegetables | 82,463 | 6,886 | 8 | 16,483 | 20 | 23,369 | 28 |
| Fresh | 52,735 | 5,102 | 10 | 11,730 | 22 | 16,832 | 32 |
| Processed | 29,728 | 1,784 | 6 | 4,754 | 16 | 6,538 | 22 |
| Dairy products | 83,455 | 9,360 | 11 | 14,025 | 17 | 23,385 | 28 |
| Fluid milk | 54,463 | 6,541 | 12 | 9,584 | 18 | 16,125 | 30 |
| Other dairy products | 28,992 | 2,819 | 10 | 4,441 | 15 | 7,260 | 25 |
| Meat, poultry, and fish | 59,861 | 2,724 | 5 | 20,370 | 34 | 23,094 | 39 |
| Meat | 32,920 | 1,471 | 4 | 11,009 | 33 | 12,481 | 38 |
| Poultry | 22,087 | 856 | 4 | 8,167 | 37 | 9,022 | 41 |
| Fish and seafood | 4,854 | 397 | 8 | 1,193 | 25 | 1,591 | 33 |
| Eggs | 9,690 | 872 | 9 | 1,323 | 14 | 2,195 | 23 |
| Tree nuts and peanuts | 3,175 | 190 | 6 | 298 | 9 | 489 | 15 |
| Added sweeteners | 41,440 | 4,558 | 11 | 7,376 | 18 | 11,935 | 29 |
| Added fats and oils | 26,458 | 5,430 | 21 | 3,645 | 14 | 9,075 | 34 |
| Total | 428,131 | 42,934 | 10 | 83,078 | 19 | 126,012 | 29 |

[a]Food supply at the retail level, which is the foundation for the retail- and consumer-level loss stages in the loss-adjusted data series.
[b]Totals may not add due to rounding.
Source: This table uses similar column and row headings as a table in Kantor et al. (1997). It was computed by authors using assumptions in the ERS Loss-Adjusted Food Availability data as of March 7, 2010 (ERS 2010a) and the US population on July 1, 2008 (304.06 million). Per capita losses at the retail and consumer levels for each commodity (not shown) were estimated by multiplying the quantity of that commodity available for consumption by the appropriate loss assumption. Individual loss estimates were then multiplied by the US population and summed up into their respective food groups and retail or consumer levels.

(2002) reviewed plate waste in US school nutrition programs. A literature review by Muth et al. (2007) identified a need for peer-reviewed and published national estimates of food loss at the retail or consumer levels in the United States.

There have been four recent studies in the United States that have emphasized the need to quantify food loss and waste. Hall et al. (2009) used a mathematical model of human energy expenditure to calculate the energy content of food waste in the United States and estimated that food waste on average is equivalent to 1,400 kcal per person per day or a total of 150 trillion kcal per year (almost 40% of the available food supply).

Buzby et al. (2009) estimated that annual losses from waste and spoilage at the retail level (i.e., in supermarkets) for 2005 and 2006 averaged 11.4% for fresh fruit, 9.7% for fresh vegetables and 4.5% for fresh meat, poultry and seafood. Cuéllar and Webber (2010) focused on the embedded energy in food waste in British Thermal Units (BTUs), and Muth et al. (2011) proposed a set of consumer-level loss estimates developed from expenditure and food consumption data. The studies by Muth et al. and Hall et al. suggest that the 29% share of retail- and consumer-level food loss out of the total food supply shown in Table 1 is conservative.

In general, food waste measurements in the United States rely on structured interviews, measurement of plate waste, direct examination of garbage and application of inferential methods using waste factors measured in sample populations and applied across the food system (Hall et al. 2009). Food loss, particularly at the consumer level, is by nature difficult to measure accurately. Participants in household food waste studies tend to be highly "reactive," changing their behavior and wasting less when they know they are being observed during the survey period (Gallo 1980) or tend to be biased when estimating waste (Buzby and Guthrie 2002). Studies that observe food loss by inspecting landfill garbage are also prone to errors. Such studies are not nationally representative and may not account for food fed to pets and other animals, put in garbage disposals or composted at home. Plate waste studies, such as for schoolchildren at lunchtime, often target only a slice of the total US population, meaning that the findings cannot be easily extrapolated to all other demographic categories.

There has been more recent research on consumer-level food loss in the United Kingdom than in the United States, and some of this research estimates the value of food loss. The Waste & Resources Action Programme (WRAP) study of households and their rubbish in England and Wales estimated that UK consumers discard roughly one-third of the food they buy each year (WRAP 2008a). The estimated cost to the UK of this avoidable food waste is £10 billion ($15.8 billion) of food each year (WRAP 2008b). Local authorities spend an additional £1 billion ($1.58 billion) annually to collect and dispose of this food waste.

## DATA AND METHODS

The LAFA data series is an extension of the ERS core Food Availability data series, which has been continuously maintained by the USDA since 1941 when the data was compiled back to 1909 for many foods (ERS 2010b). This long-respected and popular core series has over a hundred years of data and calculates the supply of each commodity for a given year by adding annual production, imports and existing supplies from the previous year's production and subtracting exports, nonfood uses (farm, industrial and other) and the remainder of current crop production that carries over into the next crop year. The data on these components are collected directly from producers, distributors or importers using techniques that vary by commodity or point in the food production and marketing chain (e.g., industry surveys, marketing agency reports and US Customs Service trade data). Both the LAFA and the core data series measure the supply of over 200 food commodities, such as beef, dried plums and eggs.

The LAFA data series was originally designed by Linda Kantor at ERS in the late 1990s to estimate per capita calories and serving equivalents consumed daily by the average American for individual foods and food groups. There are three main types of loss assumptions used in the LAFA data series that extend the core series: (1) loss from primary (e.g., farm) to retail weight, such as damage during harvesting and processing, (2) loss at the retail level (e.g. supermarkets, megastores such as Walmart and other retail outlets) and (3) loss at the consumer level (Figure 1). This consumer-level loss includes food no longer available for consumption, both at home and away from home (e.g., restaurants, fast-food outlets), and has two components: (1) nonedible share of a food (e.g., asparagus stalk and peach pit), using data from the National Nutrient Database for Standard Reference (ARS 2008) and (2) cooking loss and uneaten food, such as extra tomato sauce poured down the drain, plate waste from the edible share (e.g., broccoli served to children who dislike the taste) and fresh strawberries that are lost from spoilage. Greater detail on the data series can be found on the ERS website (http://www.ers.usda.gov/Data/FoodConsumption/FoodGuideDoc.htm).

This article extends Kantor et al. (1997) by estimating the value of fruit and vegetable losses at the retail and consumer levels in the United

FIGURE 1
*Loss Adjustments for Each Commodity in the Loss-Adjusted Food Availability Data*


[a]Available commodity food supply is generally calculated as (production + imports + beginning stocks) − (nonfood uses + exports + ending stocks).
[b]Loss at the consumer level includes food loss both at home and away from home.
Source: Adapted from Figure 1 in Muth et al. (2011).

States by using prices consumers would have paid, on average, for those foods if bought at retail. The analytical method consisted of four key steps. First, we identified 61 fresh and processed fruits and 60 fresh and processed vegetables in the LAFA data for our analysis.

Second, we estimated national annual average retail prices using Nielsen Homescan data for fruits and vegetables consumed at home in 2008. This method for determining average prices was used in previous research (Reed, Frazão, and Itskowitz 2004; Stewart et al. 2011). Members of the Homescan consumer panel in 61,440 households reported the foods they purchased, the quantities they bought and the prices they paid. The data include purchases at supermarkets, grocery stores, farmers' markets, mass merchandisers and drugstores but not at restaurants and other foodservice outlets. This means that fruits and vegetables consumed away from home are not included in our estimated prices. Nielsen further provides projection factors that allow data users to estimate what all households across the contiguous United States paid for foods and the quantities they bought. The intricacies of the price estimation are described more fully in Box 1.

BOX 1 *Calculation of Fruit and Vegetable Retail Prices*

For each fruit and vegetable in the ERS Loss-Adjusted Food Availability data series, we used Nielsen's 2008 Homescan data and projection factors to estimate total expenditures and quantities bought by all US households. Following Reed, Frazão, and Itskowitz (2004), for each covered fruit and vegetable, we estimated the average annual retail price per pound (weighted average) by dividing the total dollars spent on that item by the total volume sold. For example, our estimate at retail market prices that Americans spent $265.9 million on 253.2 million pounds of canned peaches led to an average retail cost of $1.75 per pound when also adjusting for each can consisting of 60% solids ($265.9 million/[253.2 million pounds × 0.60]). This retail price per pound represents the weighted-average price for all canned cling and freestone peaches purchased at all types of retail outlets by American households in 2008 in all sizes of cans, jars or cups (e.g., 15 and 29 ounce cans) and packed in water, juice or any kind of syrup. The conversion factors for canned solids are from a USDA handbook on yields (Mathews and Garrison 1975). Estimating the best price for each fruit and vegetable in the LAFA database was an intricate and time-consuming process, particularly because we had to identify and select fairly specific products for pricing. See Stewart et al. (2011) for more detail on the estimation process.

Six fresh products were rarely sold with a Universal Product Code (UPC) (i.e., bar code), so they were poorly represented in the 2008 Homescan data. For these products we used the 2006 Homescan data which, unlike the 2008 data, had detailed information on random weight sales. We then used the Bureau of Labor Statistics (BLS) consumer price index for fresh fruits or for fresh vegetables (all urban consumers, not seasonally adjusted) as appropriate to adjust the 2006 prices to 2008 dollars (BLS 2010a). Specifically, we used 2006 random weight prices for fresh broccoli, corn, cucumbers, romaine and leaf lettuce, and spinach, and we used both 2006 random weight and UPC prices for fresh apricots. Random weight sales are for foods that do not have a manufacturer-assigned UPC code. These food items tend to be sold in loose form so that consumers can make their selection from a display, place their selection in a plastic bag, and pay for the item by the weight of the food.

Third, as a validation step, we compared our estimated 2008 prices with 1999 prices from Reed, Frazão, and Itskowitz (2004) and 2001–2002 prices in the USDA's Center for Nutrition Policy and Promotion prices database (Carlson et al. 2008), both of which used the Homescan data and had a similar range of products. When our estimates fell outside of the expected range, we examined the data more closely to determine if there had been computational errors, and we adjusted our methodology where appropriate. It is likely that some households made mistakes when reporting information to Nielsen or, because the recording process is time-consuming, failed to report some purchases. However, validation studies confirm the suitability of Homescan data. For example, Einav, Leibtag, and Nevo (2008) found that errors in the Homescan data are of the same order of magnitude as reporting errors in major government-collected data sets. Moreover, their findings suggest that errors in Homescan data are unlikely to affect estimates of average prices paid by all households.

Fourth, we multiplied the estimated price by the annual amount of food loss for each fruit and vegetable at the retail and consumer levels. The amounts of loss for each type of produce were calculated by multiplying per capita quantities available at each level by the corresponding food loss assumptions and by the US population on July 1, 2008 (304.06 million). We then estimated the total value of fruit and vegetable losses by summing individual valuations over all fruits and vegetables.

## RESULTS

Estimated at retail market prices, $15.1 billion of fresh and processed fruit were lost from the US food supply in 2008. Of this amount, roughly $5.8 billion occurred at the retail level and $9.3 billion occurred at the consumer level. The amount for each individual fruit was a function of its price per pound and, more importantly, the quantity lost. Fresh apples, strawberries, peaches and grapes each had over one billion dollars worth of losses at the retail and consumer levels—largely because these fruits are among the most commonly purchased and consumed.

Also estimated at retail market prices, $27.7 billion of fresh and processed vegetables were lost from the US food supply in 2008. Of this amount, $9.2 billion occurred at the retail level and $18.5 billion at the consumer level. The top four vegetables in terms of value lost were fresh tomatoes, frozen potatoes (e.g., French fries), fresh potatoes, and canned tomatoes. These products are among the most commonly purchased and consumed vegetables in the United States.

Looking only at the consumer-level losses, the total estimated fruit and vegetable losses in the United States shown in Tables 2 and 3 translate into almost 84 pounds per capita in 2008, including roughly 30 pounds of fruit and 54 pounds of vegetables. The total annual value of these losses at the consumer level averaged around $92 per person, including roughly $31 of fruit and $61 of vegetables. When looking at both the retail- and consumer-level losses, the value of these losses totals roughly $141 per capita, or the sum of around $50 in losses for fruit and $91 in losses for vegetables.

However, consumption of vegetables and, especially, fruit is not evenly distributed among the population (NIH 2011). This implies individuals who buy few fruits and vegetables would likely have little to discard, relative to individuals who buy a lot of fruits and vegetables. This could potentially be an advantage in terms of maximizing the reduction in total fruit and vegetable losses for a given amount of resources (i.e., dollars spent for this goal). For example, those who discard the most could be identified and targeted with educational efforts about food loss or could be provided with a cost-efficient way of disposing of uneaten produce (e.g., curbside collection) so that it does not end up in a landfill or down a drain.

How robust are our results based on the LAFA loss estimates? The LAFA data estimates suggest that the average American consumes 2,674 calories per person per day in 2008, which provides evidence that the loss estimates are likely to be underestimated. This daily calorie level may be appropriate for some physically active adult males, but is too high for Americans in general, even considering the obesity epidemic in the United States. This means that the cumulative effects of the hundreds of loss assumptions in the data system would need to be higher to reduce this calorie total. Additionally, many raw commodities are not in the system, so loss would have been higher had they been included. For example, the data system includes 61 types of fresh and processed fruits, whereas 319 different fruit products were imported into the United States in 2007 (Brooks, Regmi, and Buzby 2009). However, most consumers tend to eat a limited variety of fruits, and the most commonly eaten fruits are included in the data system. Additionally, per capita quantities and the percentage loss assumptions for dried peas, lentils, and beans are for the dry form of these foods in the LAFA data series, so we estimated retail prices and total value of the losses for the dry forms to be consistent. Had we used the cooked form of these foods, a heavier weight for food loss would have been calculated and the total estimated value of food loss would have been slightly higher.

TABLE 2
*Estimated Amount and Value of the Losses of Fresh and Processed Fruit in the United States at the Retail and Consumer Levels, 2008*

| | | Losses from the Food Supply | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Retail Level | | Consumer Level | | Total Retail and Consumer Levels | | |
| Commodity | Price/lb | Million Pounds | Million Dollars | Million Pounds | Million Dollars | Million Pounds | Million Dollars | Percent Loss |
| Fresh oranges | $0.67 | 339 | $226 | 518 | $346 | 857 | $572 | 29 |
| Fresh tangerines | $1.24 | 182 | $226 | 142 | $176 | 324 | $402 | 36 |
| Fresh grapefruit | $0.66 | 120 | $79 | 162 | $107 | 282 | $186 | 30 |
| Fresh lemons | $1.77 | 40 | $71 | 107 | $190 | 147 | $261 | 26 |
| Fresh limes | $1.17 | 60 | $70 | 132 | $154 | 191 | $224 | 27 |
| Fresh apples | $1.07 | 407 | $437 | 862 | $926 | 1,269 | $1,363 | 27 |
| Fresh apricots | $1.86 | 13 | $24 | 5 | $9 | 18 | $33 | 48 |
| Fresh avocados | $2.50 | 104 | $259 | 202 | $505 | 306 | $764 | 27 |
| Fresh bananas | $0.45 | 607 | $274 | 1,403 | $633 | 2,010 | $908 | 26 |
| Fresh blueberries | $3.91 | 12 | $46 | 43 | $167 | 54 | $213 | 24 |
| Fresh cantaloupe | $0.95 | 303 | $287 | 436 | $414 | 739 | $701 | 30 |
| Fresh cherries | $3.51 | 11 | $38 | 54 | $189 | 65 | $227 | 23 |
| Fresh cranberries | $2.74 | 2 | $5 | 6 | $15 | 7 | $20 | 25 |
| Fresh grapes | $1.68 | 179 | $300 | 436 | $730 | 615 | $1,030 | 26 |
| Fresh honeydew | $0.55 | 105 | $58 | 71 | $39 | 177 | $97 | 38 |
| Fresh kiwi | $1.80 | 16 | $29 | 22 | $40 | 39 | $70 | 30 |
| Fresh mangoes | $1.00 | 88 | $88 | 104 | $104 | 192 | $193 | 32 |
| Fresh peaches | $1.69 | 175 | $296 | 452 | $766 | 626 | $1,062 | 43 |
| Fresh pears | $1.04 | 158 | $165 | 148 | $154 | 307 | $319 | 34 |
| Fresh pineapple | $1.04 | 215 | $224 | 251 | $262 | 465 | $486 | 32 |
| Fresh papaya | $2.92 | 155 | $453 | 26 | $74 | 181 | $527 | 64 |
| Fresh plums | $1.24 | 46 | $58 | 44 | $55 | 90 | $112 | 34 |
| Fresh raspberries | $7.29 | 7 | $53 | 13 | $98 | 21 | $150 | 28 |
| Fresh strawberries | $2.28 | 176 | $401 | 326 | $742 | 502 | $1,143 | 28 |
| Fresh watermelon | $0.26 | 709 | $187 | 704 | $185 | 1,413 | $372 | 33 |
| Canned apples and applesauce | $0.77 | 64 | $50 | 101 | $78 | 165 | $128 | 15 |
| Canned apricots | $1.93 | 4 | $7 | 6 | $11 | 10 | $18 | 15 |
| Canned sweet cherries | $3.81 | 0 | $1 | 0 | $1 | 0 | $2 | 15 |
| Canned tart cherries | $4.05 | 2 | $9 | 4 | $14 | 6 | $23 | 15 |
| Canned peaches | $1.75 | 65 | $114 | 102 | $179 | 167 | $293 | 15 |
| Canned pears | $1.79 | 41 | $73 | 64 | $115 | 105 | $188 | 15 |
| Canned pineapple | $1.39 | 47 | $65 | 73 | $101 | 120 | $166 | 15 |
| Canned plums | $1.38 | 0 | $1 | 1 | $1 | 1 | $2 | 15 |
| Canned olives | $3.12 | 17 | $53 | 26 | $83 | 43 | $135 | 15 |
| Frozen blackberries | $3.38 | 2 | $6 | 3 | $10 | 5 | $16 | 15 |
| Frozen blueberries | $3.95 | 31 | $123 | 49 | $193 | 80 | $317 | 15 |
| Frozen sweet cherries | $3.38 | 2 | $8 | 4 | $13 | 6 | $21 | 15 |
| Frozen tart cherries | $2.12 | 9 | $20 | 15 | $31 | 24 | $51 | 15 |
| Frozen raspberries | $2.94 | 7 | $20 | 11 | $31 | 18 | $52 | 15 |
| Frozen strawberries | $2.61 | 7 | $19 | 12 | $30 | 19 | $49 | 15 |

*(Continued)*

TABLE 2
*(Continued)*

| | | Losses from the Food Supply | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Retail Level | | Consumer Level | | Total Retail and Consumer Levels | | |
| Commodity | Price/lb | Million Pounds | Million Dollars | Million Pounds | Million Dollars | Million Pounds | Million Dollars | Percent Loss |
| Other frozen berries | $2.61 | 1 | $2 | 1 | $3 | 2 | $5 | 15 |
| Frozen apples | $3.79 | 1 | $3 | 1 | $4 | 2 | $7 | 15 |
| Frozen apricots | $2.76 | 12 | $33 | 19 | $52 | 31 | $86 | 15 |
| Frozen peaches | $2.61 | 11 | $28 | 17 | $44 | 27 | $71 | 15 |
| Frozen plums | $2.61 | 0 | $0 | 0 | $0 | 0 | $1 | 15 |
| Dried apples | $5.40 | 2 | $11 | 3 | $17 | 5 | $28 | 15 |
| Dried apricots | $3.56 | 2 | $7 | 3 | $11 | 5 | $17 | 15 |
| Dried dates | $3.29 | 3 | $11 | 5 | $18 | 9 | $29 | 15 |
| Dried figs | $4.74 | 1 | $7 | 2 | $10 | 4 | $17 | 15 |
| Dried peaches | $5.79 | 1 | $5 | 1 | $7 | 2 | $12 | 15 |
| Dried plums | $2.78 | 6 | $16 | 9 | $25 | 15 | $41 | 15 |
| Raisins | $2.42 | 27 | $64 | 42 | $101 | 68 | $165 | 15 |
| Grapefruit juice | $0.65 | 57 | $37 | 89 | $58 | 146 | $95 | 15 |
| Lemon juice | $1.19 | 20 | $23 | 31 | $36 | 50 | $60 | 15 |
| Lime juice | $2.69 | 4 | $12 | 7 | $19 | 11 | $31 | 15 |
| Orange juice | $0.61 | 557 | $339 | 873 | $531 | 1,430 | $869 | 15 |
| Apple juice | $0.48 | 344 | $163 | 538 | $256 | 882 | $419 | 15 |
| Cranberry juice | $0.73 | 43 | $32 | 68 | $50 | 112 | $82 | 15 |
| Grape juice | $0.61 | 73 | $45 | 114 | $70 | 188 | $114 | 15 |
| Pineapple juice | $0.66 | 43 | $28 | 68 | $44 | 111 | $73 | 15 |
| Prune juice | $0.96 | 7 | $6 | 11 | $10 | 17 | $16 | 15 |
| Total | NA | 5,742 | $5,795 | 9,040 | $9,340 | 14,782 | $15,135 | 24 |

Source: Calculated by authors using Loss-Adjusted Food Availability data and Nielsen Homescan data.

On the other hand, food loss may be overestimated if a significant share of the food counted as lost was actually either donated to food banks and other charities or sold at discount food stores and eventually consumed. Changes in foods that lose weight during cooking through water evaporation or the melting of fat should already be accounted for in the “cooking loss and uneaten food” estimates. Cumulative errors can also arise if incorrect food waste factors (or loss factors here) are applied in early stages of the food system calculations (Hall et al. 2009). Given the loss assumptions currently used by ERS, 9% of fruit and 8% of vegetables are lost at the retail level compared to 15% of fruit and 20% of vegetables at the consumer level. This suggests that focusing loss reduction efforts on the consumer-level losses could potentially recover greater amounts of food than efforts at the retail level. However, there would be many other factors to consider, such as the greater concentration

TABLE 3
*Estimated Amount and Value of the Losses of Fresh and Processed Vegetables in the United States at the Retail and Consumer Levels, 2008*

| | | Losses from the Food Supply | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Retail Level | | Consumer Level | | Total Retail and Consumer Levels | | |
| Commodity | Price/lb | Million Pounds | Million Dollars | Million Pounds | Million Dollars | Million Pounds | Million Dollars | Percent Loss |
| Fresh artichokes | $1.71 | 85 | $145 | 71 | $121 | 156 | $266 | 35 |
| Fresh asparagus | $1.83 | 31 | $56 | 59 | $108 | 90 | $165 | 28 |
| Fresh bell peppers | $2.13 | 214 | $456 | 508 | $1, 082 | 722 | $1, 538 | 26 |
| Fresh broccoli | $1.16 | 198 | $230 | 292 | $339 | 491 | $570 | 30 |
| Fresh Brussels sprouts | $3.05 | 17 | $52 | 15 | $45 | 32 | $97 | 35 |
| Fresh cabbage | $0.62 | 326 | $202 | 398 | $246 | 724 | $448 | 31 |
| Fresh carrots | $0.77 | 122 | $95 | 452 | $349 | 574 | $444 | 24 |
| Fresh cauliflower | $0.67 | 62 | $42 | 76 | $51 | 137 | $93 | 31 |
| Fresh celery | $0.90 | 90 | $81 | 334 | $300 | 424 | $381 | 24 |
| Fresh collard greens | $0.77 | 42 | $32 | 14 | $11 | 56 | $43 | 50 |
| Fresh sweet corn | $0.97 | 16 | $15 | 819 | $797 | 835 | $812 | 32 |
| Fresh cucumbers | $0.82 | 116 | $95 | 354 | $289 | 470 | $384 | 25 |
| Fresh eggplant | $0.53 | 50 | $26 | 50 | $26 | 100 | $52 | 43 |
| Fresh escarole and endive | $1.86 | 31 | $57 | 7 | $12 | 37 | $69 | 58 |
| Fresh garlic | $2.62 | 51 | $132 | 126 | $330 | 177 | $463 | 26 |
| Fresh kale | $0.92 | 30 | $28 | 9 | $9 | 40 | $36 | 51 |
| Fresh head lettuce | $0.99 | 416 | $411 | 871 | $859 | 1,287 | $1,270 | 27 |
| Fresh Romaine and leaf lettuce | $1.32 | 437 | $576 | 541 | $713 | 978 | $1,290 | 31 |
| Fresh lima beans | $0.69 | 1 | $0 | 1 | $1 | 2 | $1 | 30 |
| Fresh mushrooms | $3.40 | 89 | $301 | 122 | $414 | 210 | $715 | 30 |
| Fresh mustard greens | $1.38 | 58 | $81 | 7 | $9 | 65 | $90 | 71 |
| Fresh okra | $2.55 | 30 | $76 | 18 | $47 | 48 | $122 | 40 |
| Fresh onions | $0.67 | 535 | $360 | 1,732 | $1,164 | 2,267 | $1,524 | 41 |
| Fresh potatoes | $0.48 | 696 | $335 | 3, 003 | $1,444 | 3,699 | $1,779 | 35 |
| Fresh pumpkin | $0.19 | 150 | $28 | 237 | $44 | 387 | $72 | 29 |
| Fresh radishes | $1.45 | 32 | $46 | 24 | $35 | 56 | $81 | 37 |
| Fresh snap beans | $3.23 | 112 | $362 | 108 | $349 | 220 | $711 | 36 |
| Fresh spinach | $1.15 | 62 | $71 | 74 | $85 | 136 | $156 | 32 |
| Fresh squash | $1.86 | 142 | $264 | 200 | $371 | 342 | $635 | 30 |
| Fresh sweet potatoes | $0.90 | 195 | $176 | 366 | $330 | 561 | $506 | 41 |
| Fresh tomatoes | $2.79 | 631 | $1,763 | 831 | $2,323 | 1,462 | $4,086 | 31 |
| Fresh turnip greens | $1.03 | 37 | $38 | 11 | $11 | 47 | $49 | 53 |
| Canned asparagus | $3.03 | 3 | $9 | 5 | $15 | 8 | $24 | 15 |
| Canned snap beans | $1.17 | 36 | $42 | 57 | $66 | 93 | $108 | 15 |
| Canned cabbage (sauerkraut) | $0.95 | 10 | $9 | 15 | $14 | 24 | $23 | 15 |
| Canned carrots | $1.09 | 13 | $14 | 21 | $23 | 34 | $37 | 15 |
| Canned sweet corn | $1.01 | 90 | $91 | 141 | $142 | 231 | $233 | 15 |

*(Continued)*

TABLE 3
*(Continued)*

| | | Losses from the Food Supply | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Retail Level | | Consumer Level | | Total Retail and Consumer Levels | | |
| Commodity | Price/lb | Million Pounds | Million Dollars | Million Pounds | Million Dollars | Million Pounds | Million Dollars | Percent Loss |
| Canned cucumbers (pickles) | $2.18 | 26 | $56 | 41 | $88 | 66 | $145 | 15 |
| Canned green peas | $1.16 | 13 | $15 | 20 | $23 | 33 | $38 | 15 |
| Canned mushrooms | $2.59 | 16 | $41 | 25 | $65 | 41 | $106 | 15 |
| Canned chile peppers | $3.58 | 82 | $293 | 128 | $459 | 210 | $752 | 15 |
| Canned potatoes | $1.03 | 12 | $13 | 19 | $20 | 32 | $33 | 15 |
| Canned tomatoes | $1.21 | 503 | $607 | 788 | $951 | 1,291 | $1,559 | 15 |
| Other canned vegetables | $1.96 | 34 | $67 | 54 | $106 | 88 | $173 | 15 |
| Frozen asparagus | $3.79 | 1 | $3 | 4 | $16 | 5 | $19 | 34 |
| Frozen snap beans | $1.34 | 33 | $44 | 103 | $138 | 135 | $182 | 25 |
| Frozen broccoli | $1.47 | 37 | $54 | 92 | $136 | 129 | $190 | 21 |
| Frozen carrots | $1.19 | 15 | $18 | 28 | $34 | 44 | $52 | 17 |
| Frozen cauliflower | $1.42 | 5 | $7 | 12 | $18 | 17 | $24 | 22 |
| Frozen sweet corn | $1.40 | 49 | $69 | 108 | $151 | 157 | $220 | 19 |
| Frozen green peas | $1.34 | 31 | $41 | 82 | $110 | 113 | $151 | 22 |
| Frozen lima beans | $1.56 | 6 | $9 | 30 | $47 | 36 | $56 | 36 |
| Frozen potatoes | $1.06 | 488 | $517 | 2,447 | $2,591 | 2, 935 | $3,108 | 36 |
| Frozen spinach | $1.51 | 9 | $14 | 33 | $49 | 42 | $63 | 28 |
| Miscellaneous frozen vegetables | $1.61 | 37 | $59 | 133 | $213 | 169 | $272 | 28 |
| Dehydrated onions | $6.59 | 3 | $19 | 5 | $30 | 7 | $49 | 15 |
| Dehydrated potatoes | $1.84 | 32 | $58 | 50 | $91 | 81 | $150 | 15 |
| Potato chips and shoestring potatoes | $3.51 | 72 | $254 | 113 | $397 | 186 | $651 | 15 |
| Dry edible beans | $0.92 | 115 | $106 | 181 | $166 | 296 | $271 | 15 |
| Dry edible peas and lentils | $0.92 | 13 | $12 | 20 | $19 | 33 | $30 | 15 |
| Total | NA | 6,886 | $9,174 | 16, 483 | $18,493 | 23,369 | $27,667 | 28 |

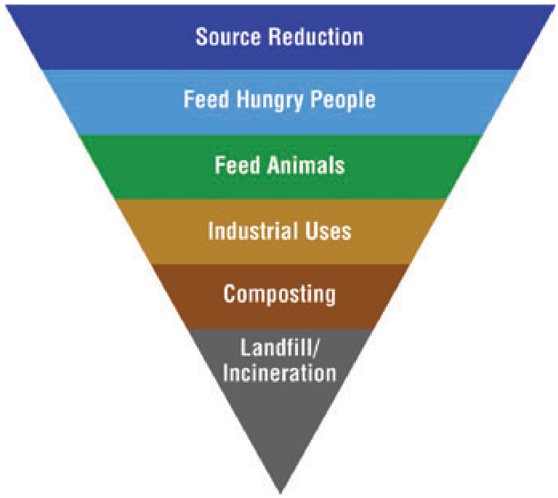
Source: Calculated by authors using Loss-Adjusted Food Availability data and Nielsen Homescan data.

of food loss generated at the retail level compared to food loss dispersed among households.

## DISCUSSION

Currently, in the United States, there is no widespread or visible political or social momentum to reduce food loss and waste. The most active Federal agency in terms of food waste is the EPA, which endorses their "food waste recovery hierarchy" (Figure 2), where the ideal situation would be to reduce the production of food waste at the

FIGURE 2
*EPA Food Waste Recovery Hierarchy*




source. When food waste is generated, the first preference is to recover wholesome food from all points in the food production, marketing and consumption chain to feed people who are food insecure. Providing food for livestock, zoo animals and pets would be the second best option followed by recycling food and food waste for industrial purposes. These three options would help conserve resources and reduce food waste disposal costs. For example, the feasibility of anaerobic digesters that use feedstock, food and agricultural waste and wastewater plant biosolids to produce biogas fuel and other valuable outputs (e.g., compost material) is being explored in developed countries.

Composting food to improve soil fertility is a relatively low-priority option, and its use is not widespread in the United States. However, some cities, counties, and State agencies are investigating the benefits of curbside collection of residential food waste (e.g., in bins or compostable kitchen bags) to compost with collected yard trimmings. According to the EPA (2009), there are around 3,510 community composting programs in operation in the United States in 2008, so expanding these to incorporate food waste might be a viable option. The last resort should be using landfills and incinerators to dispose of food waste because of the negative impacts on the environment.

In the United States, there are several strategies to reduce food waste and help feed the food insecure, including laws that offer tax incentives for businesses to donate food to charitable organizations. Other laws, such as the US Federal and State "Good Samaritan" laws, encourage donors, gleaners and nonprofit organizations (e.g., homeless shelters and soup kitchens) to donate and/or distribute food and grocery products to needy individuals by limiting their liability to instances of gross negligence or intentional misconduct (ARS 1997). Food donations can also help improve corporate image. In theory, industry will minimize food loss when they have positive financial incentives to do so. The leading domestic charity for relieving food insecurity in the United States, Feeding America (2010), secures and distributes more than 2.5 billion pounds of food and grocery products annually to more than 37 million low-income people facing food insecurity. However, this amount is far less than 1% of the 126 billion pounds of estimated food loss at the retail and consumer levels in 2008. Food loss can be prevented or reduced by actions such as routinely maintaining refrigeration equipment to prevent temperature failure and marking down prices or donating products as they approach their sell-by or use-by dates. However, these technologies and other loss-reducing actions may not broadly appeal to consumers' tastes and preferences and they come at a cost—sometimes it makes business sense in terms of labor, time and other resources to discard still-edible food and buy new food.

As of now, most consumers in the United States do not appear to be concerned about food loss, partly because they generally have ready access to an abundance of inexpensive food. Thus, they have only weak monetary incentives to reduce food loss (i.e., the marginal cost of food loss is very low). Per capita in 2008, the estimated average total value of fruit and vegetable losses of $91.54 at the consumer level is less than 2.4% of the average amount spent on food ($3,830) (ERS 2011) and is around one-fourth of 1% of the average disposable income in the US of $34,902 (BLS 2010b). Lack of awareness of the amount of food loss by consumers at home plays a role. In the WRAP study, almost 70% of the 284 households that kept one-week diaries of their discarded food said they were subsequently committed to discarding less food (WRAP 2008b). Follow-up with these households is needed to see if waste reductions actually occurred. Much food loss is preventable through people's actions and decisions if enough resources are expended to do so and if consumer tastes and preferences are flexible enough to accept alternate forms (e.g., decision to buy and consume frozen fish instead of fresh fish, which has a shorter shelf life).

In addition to knowing the amount and direct monetary costs of food loss to their households, consumers might waste less if they were more aware and mindful of the resources used to produce fruits and vegetables and the impact of wasted food on the environment. The total cost of food loss would be substantial if all the resources used and all of the negative externalities incurred were fully accounted for. For example, for fresh tomatoes alone, according to our calculations, 831 million pounds (or 415.7 million tons) were lost or removed from the food supply at the consumer level in 2008. We calculate that this amount of fresh tomatoes would have taken 22,169 acres, 4.4 million to 8.9 million hours of labor and over 15 billion gallons of water to produce.[2] We did not estimate the costs of seed, fertilizer and other chemicals used to grow tomatoes or the fuel, machinery and storage costs. Additionally, it would cost over $17 million to dispose of these tomatoes assuming a landfill tipping fee of $42.08 per ton, not including the fuel and other costs to transport the tomatoes to landfills (Arsova et al. 2008). We used the EPA's Waste Reduction Model (WARM) to estimate that if all of these fresh tomatoes were taken to a landfill and decomposed anaerobically, this would produce 311,845 tons of carbon dioxide equivalent (EPA 2010b). This amount is roughly the same as the greenhouse gas emissions from taking 55,471 passenger cars off the road for a year according to EPA's Greenhouse Gas Equivalencies Calculator (EPA 2010c). The bottom line is that these statistics reflect the amount of resources used to produce food that people do not end up eating and reflect some of the negative externalities associated with wasting fresh tomatoes at the consumer level. Had all other fruits and vegetables and all other associated costs been included, the toll would be substantially greater.

We believe that if consumers were better informed about the monetary and nonmonetary impact of food loss, they would have greater incentives to waste less food. However, consumers have different tastes, preferences, income, etc. and this means that what is important to individual consumers varies and the mix of monetary and nonmonetary factors that might encourage them to reduce food loss will vary. There are different ways that consumers can reduce food loss. Stuart (2009) provides an expanded list of ideas about how consumers, retailers, governments and other groups involved can reduce food waste. For consumers, he suggests writing a shopping list with specific meals in mind prior to shopping, measuring food portions while cooking to avoid overpreparation and freezing items like surplus bread. In the UK,

2. These calculations assume: (1) 1 acre produces an average of 37,500 pounds of fresh tomatoes (Fahs 2010); (2) 1 acre of tomatoes requires 200–400 h of labor (Fahs 2010); and (3) 1 kg of vegetables requires 8 $m^3$ of water to grow (Hoekstra, Chapagain, and Mekonnen 2010).

the Love Food Hate Waste campaign provides tips on how to reduce food waste (http://www.lovefoodhatewaste.com). Food loss reductions by consumers can be direct, such as consumers donating unwanted packaged food to charity, or indirect, such as consumers seeking out and buying from those restaurants and food stores that are known to donate large amounts of food to charitable organizations (a form of corporate social responsibility). For example, some food stores and chains that sell ready-to-eat sandwiches advertise that all unsold food at the end of the day is given to local charities instead of being thrown out or served the next day.

Although reducing food loss at the consumer level is a daunting and seemingly difficult task, some changes in consumer behavior for other issues suggest that inroads can be made overtime. For example, consumers have shown their willingness to change their food choices as evidenced by the recent and rapid rise of the movement toward buying local foods in the United States (Scott-Thomas 2011). Prior to the 1970s, getting consumers to recycle waste seemed like an equally daunting and difficult task, but according to EPA (2009), 48.2% of aluminum beer and soda cans, 28% of glass containers and 27.2% of PET bottles and jars were recycled in 2008. For recycling, three types of legislation have helped create the stable supply of materials needed for recycling to work: (1) container recycling collections (e.g., bottle deposit refund), (2) refuse bans (e.g., against the disposal of old car batteries) and (3) mandatory legislative options, such as preset dates for cities to reach recycling targets. For reducing food loss, some combination of refuse bans and mandatory legislative options may work. In South Korea and Taiwan, it is illegal for retailers, restaurants and households to dispose of food waste in landfills (Stuart 2009, p. 283). Instead, most food waste is collected and fed to pigs and the remainder is composted. Stuart claims that the Koreans comply with the law on food waste recycling, virtually without exception, largely because they understand that disposing food waste in landfills is not in their interest or that of the planet. In the United States, encouraging consumers to reduce food loss may be easier to achieve than recycling because the direct monetary benefits to consumers are more apparent; that is, they would not have to purchase as much food if less is wasted.

More research is needed to identify which foods, and where along the food production, marketing and consumption chain, the greatest inroads can be made to efficiently minimize food waste and maximize the share of food production that is ultimately consumed by humans. Our data suggest that for fruits and vegetables at the consumer level, the greatest gains, in general, may be in reducing loss of fresh as opposed to processed versions. And, to most efficiently reduce the annual pounds of food loss, it might be beneficial to first focus efforts on the top four fruits (fresh apples, strawberries, peaches and grapes) and four vegetables (fresh tomatoes, frozen potatoes [e.g., French fries], fresh potatoes and canned tomatoes) that have the greatest amount of food loss. This article extends the literature on the monetary and nonmonetary costs of food loss in the United States. Consumer education about both food waste and the number and welfare of those who are food insecure in the United States may encourage consumers to reduce food loss. In short, consumer education campaigns should disseminate information about both the monetary and nonmonetary incentives to reduce food loss.

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