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Total and per capita value of food loss in the United States ☆

Jean C. Buzby [a,b,*], Jeffrey Hyman [a,b,1]

[a] USDA/Economic Research Service, 1400 Independence Ave., SW, Mail Stop 1800, Washington, DC 20250-1800, United States
[b] Economic Research Service of the US Department of Agriculture, 355 E Street, SW, Washington, DC 20024-3221, United States

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ABSTRACT

There are few peer-reviewed or major published studies that estimate the total amount of food loss in developed countries and even fewer attempt to estimate the monetary value. We compiled estimates of the amount and value of food loss for more than 200 individual foods in the United States using the US Department of Agriculture's Economic Research Service's Loss-Adjusted Food Availability data and then aggregated these values to estimate the total value of food loss and the value by food group. The results indicate that in 2008, the estimated total value of food loss at the retail and consumer levels in the United States as purchased at retail prices was $165.6 billion. The top three food groups in terms of the value of food loss at these levels are: meat, poultry, and fish (41%); vegetables (17%); and dairy products (14%). Looking more closely at the estimates for the consumer level, this level of loss translates into almost 124 kg (273 lb) of food lost from human consumption, per capita, in 2008 at an estimated retail price of $390/capita/year. Food loss represents a significant share of household food expenditures: our estimates suggest that the annual value of food loss is almost 10% of the average amount spent on food per consumer in 2008 and over 1% of the average disposable income. This consumer level loss translates into over .3 kg (0.7 lb) of food per capita per day valued at $1.07/day. Our estimates of the total value of food loss in the United States and loss estimates by food group are useful in that they can generate awareness of the issue among the food industry members, governments, and consumers. Potential large-scale approaches and economic incentives to mitigate food loss in developed countries are also discussed.

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Introduction

The Food and Agriculture Organization of the United Nations (FAO) estimates that roughly one-third of all edible food produced for human consumption is wasted or otherwise lost from the food supply per year, or about 1.3 billion metric tonnes (mt) (Gustavsson et al., 2011). Reducing this post-harvest food loss will become increasingly important over the coming decades to help sustainably feed a growing human population. Currently, countries vary in the amount of food they have available for consumption, per capita, and those developed countries with greater surpluses of food beyond the minimum requirements of their populations are also those that tend to waste the most (Stuart, 2009). An analysis of the FAO's food balance sheets for 2007 suggests that food waste in North America and Europe is roughly 95–115 kilograms (kg)/capita/year compared to 6–11 kg/capita/year in South/Southeast Asia and Sub-Saharan Africa (Gustavsson et al., 2011).

Food losses can be qualitative, such as reduced nutrient value and undesirable changes to taste, texture, or color, or quantitative as measured by decreased weight or volume. Here, *food loss* is a subset of *post-harvest losses* (or post-production) and represents the edible amount of food available for human consumption but is not consumed. *Food waste* is a subset of food loss. According to Bloom (2010), 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. Definitions of food loss and waste are not universal worldwide. There is some movement to use a wider definition of food waste to frame the problem within a policy context. For example, the Dutch Ministry of Economic Affairs, Agriculture, and Innovation more broadly defines food waste to include quality considerations and residual and waste flows in addition to the food loss analyzed here (Waarts et al., 2011).

Food loss occurs for many reasons, including natural shrinkage (e.g., moisture loss), mold, pests, inadequate climate control, and food waste. Food safety concerns can also trigger short term spikes

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* Corresponding author at: USDA/Economic Research Service, 1400 Independence Ave., SW, Mail Stop 1800, Washington, DC 20250-1800, United States. Tel.: +1 202 694 5370; fax: +1 202 245 4781.

E-mail addresses: jbuzby@ers.usda.gov (J.C. Buzby), jhyman@ers.usda.gov (J. Hyman).

[1] Tel.: +1 202 694 5382.

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in food waste of implicated foods.[2] Table 1 provides examples of the causes of food loss and waste in developed countries at three broad stages of the food supply chain (i.e., at the farm, retail, and consumer levels). Many of these causes occur at more than one level (e.g., spillage and damage occur at all three levels). And although many of the causes are similar across developed countries, such as food that has past its "use-by" dates, some factors have greater variation, such as the socio-demographic characteristics and cultural traditions manifested through individual behavior.

Reasons why food loss is important

There are several reasons why food loss in general and food waste in particular are important. The first reason is that the world population is growing and we will need more food to feed people. The United Nations predicts that the world population will reach 9.3 billion by 2050 (United Nations, 2011) and this growth will require at least a 70% increase in food production, net of crops used for biofuels (FAO, 2009) [the world population was over 7 billion and growing as of May 29, 2012 (US Census Bureau, 2012)]. And, although most of this population growth will occur in developing countries, the reality is that developed countries also face issues of food insecurity. For example, in 2010, almost 49 million people lived in food-insecure households in the United States out of a total population of 304 million (Coleman-Jensen et al., 2011). *Food insecure* households are defined as having difficulty providing enough food for all of their members at some time during the year due to a lack of resources. These 49 million people are in households comprising over 14% of all households in the United States. Canada also conducted a nationally representative food security survey and found that almost 3 million people lived in food-insecure households in 2004 out of a total population of almost 32 million people and this estimate represents roughly 9% of Canadian households (Health Canada, 2007). More broadly, an estimated 852 million people were food insecure in 77 developing countries in 2011 (Shapouri et al., 2011).

The second reason why food loss is important is that food waste represents significant amounts of money and other resources invested throughout food's entire lifecycle to produce, store, transport, and otherwise handle something that does not ultimately meet its intended purpose of feeding people (Buzby et al., 2011). By lifecycle, we mean all the way from the initial production of food through the disposal of any uneaten food. These resources include arable land, labor, energy, fresh water, agricultural chemicals (e.g., fertilizer, pesticides) and other inputs. Researchers at the US National Institutes of Health estimated that the production of wasted food required the expenditure of over 25% of the total freshwater used in the United States and around 300 million barrels of oil (Hall et al., 2009). A study in Sweden found that food loss in foodservice establishments is equivalent to wasting the amount of food from 1.5% of all land cultivated for food in Sweden (Engstrom and Carlsson-Kanyama, 2004). According to the US Environmental Protection Agency (EPA), food waste accounted for almost 31 million mt (14%) of the roughly 220 million mt of municipal solid waste in the United States in 2008 (EPA, 2011) and cost roughly $1.3 billion to landfill (Schwab, 2010).[3] Less than 3% of food waste was recovered and recycled in 2009, with the remainder going to landfills or incinerators (EPA, 2011). After recycling materials, such as paper and paperboard, food waste was the single largest component of municipal solid waste in 2009, more than plastics, metals, wood, or yard waste.

The third reason why food loss is important is that there are *negative externalities* that arise throughout the entire lifecycle of food (including food waste) and adversely impact society and the environment.[4] In general, food that is produced, regardless of whether it is consumed or wasted, has contributed to pressure on the availability of fresh water and other natural resources (Lundqvist et al., 2008), including land needed for urbanization, forests, and protected areas some of which is necessary for biodiversity and wildlife. In short, food production can result in the co-production of negative externalities. At the beginning of food's life cycle, negative externalities begin to arise when food is produced and these externalities are produced unnecessarily when food is wasted. A few examples of these externalities include: (1) greenhouse gas emissions from cattle production (Lundqvist et al., 2008), (2) air pollution caused by farm machinery and trucks that transport food, (3) water pollution and damage to marine and freshwater fisheries from agricultural chemical run-off during crop production, and (4) soil erosion, salinization, and nutrient depletion that arise from unsustainable production and irrigation practices (Nellemann et al., 2009).

Disposing of uneaten food at the end of food's life cycle also poses negative externalities. For example, incinerating food waste creates emissions that can negatively impact human health and the environment. Landfilling food waste also negatively impacts the environment through the methane gas generated when food waste decomposes anaerobically. Methane has 25 times the global warming potential of CO_2 (over a 100-year time horizon) (IPCC, 2007) and landfills account for 34% of all human-related methane emissions in the United States (EPA, 2011). A study on food waste for the European Commission in 2010 used EUROSTAT data and available national studies to estimate that food waste generated in the EU27 in 2006 had an overall environmental impact from greenhouse gas emissions of at least 170 million mt of CO_2 equivalent per year during the whole lifecycle of food (Bio Intelligence Service, 2010). This represents roughly 3% of all EU27 emissions in 2008 and is similar to the total greenhouse gas emissions of the Netherlands or Romania in 2008 (Bio Intelligence Service, 2010). In addition to methane, landfills may contaminate groundwater with leachate (a mixture of liquid waste, organic degradation by-products, and rainwater) if the landfills are not properly maintained.

Aim and scope of this study

The sobering realities of growing populations, increasing pressures on agricultural land and other limited resources, and the negative externalities of food loss on society and the environment mean that it is now timely to study the economic incentives to reduce postharvest losses, including food waste. It is also becoming increasingly important to estimate the amount and value of food loss, including food waste, as a quantitative baseline for policymakers and the food industry to set targets and develop initiatives, legislation, or policies to minimize food waste, conserve resources, and improve human health worldwide. Understanding where and how much food is lost and the value of this loss is important information that industry and policymakers can use to raise awareness of the issue, reduce food waste, and increase the efficiency of the farm-to-fork food system and food recovery efforts to feed the growing human population. To this end, this study provides information from some of the literature on the magnitude of food loss and waste in developed countries. This study extends the literature

[2] For example, one company destroyed an estimated 270 tons of produce in a single week following the German authorities' initial warning to avoid raw tomatoes, lettuce, and cucumbers in the 2011 *E. coli* outbreak (Pleitgen, 2011).

[3] 1 mt = 2,204.62262 lb and 1 short ton [US] = 2,000 lb. Food waste accounted for more than 34 million tons of the 243 million tons of municipal solid waste in the United States (Schwab, 2010).

[4] *Negative externalities* are transaction costs that spillover from an action (e.g., food production or disposal) and that are not incorporated in market prices (e.g., the price of food).

Table 1
Causes of food loss and waste in developed countries at the farm, retail, and consumer levels in the food supply chain.

Farm or production level
- Consumption or damage by insects, rodents, birds or microbes (e.g., molds, bacteria),[a] and damage by unfavorable or extreme weather (e.g., droughts, floods, hurricanes, and freezes)
- Spillage and damage, such as by equipment malfunction (e.g., faulty cold or cool storage) or inefficiencies during harvesting, drying, milling, transporting, or processing
- Diminishing returns when harvesting additional increments of production and other factors leading to leaving some edible crops unharvested
- Difficulty predicting number of buyers/customers leads to overplanting or over-preparing
- Industry or government food safety regulations or standards may cause some products to be rejected for human consumption (e.g., livestock condemned at slaughter for food safety reasons)
- Byproducts from food processing not diverted to other food uses (e.g., ingredients)
- Out-grading of blemished, misshapen, or wrong-sized foods due to minimum quality standards by buyers, which are the result of consumer demand for high quality, cosmetically-appealing, and convenient foods

Retail level
- Dented cans and damaged packaging. Inappropriate packaging which damages produce.[b]
- Un-purchased holiday foods
- Spillages, abrasion, bruising, excessive trimming, excessive or insufficient heat, inadequate storage, technical malfunction.[a]
- Difficulty predicting number of customers leads to overstocking or over-preparing
- Out-grading of blemished, misshapen, or wrong-sized foods in an attempt to meet consumer demand

Consumer level
- Spillages, abrasion, bruising, excessive trimming, excessive or insufficient heat, inadequate storage, technical malfunction.[a]
- Sprouting of grains and tubers, biological aging in fruit.[a]
- Consumer confusion over "use-by" and "best before" dates so that food is discarded in packaging.[b]
- Lack of knowledge or awareness about food date labeling, the importance of food waste as an issue, the amount of waste generated, appropriate portion sizes, and strategies to reduce waste.
- For example, lack of consumer knowledge of when papaya is ripe, how to prepare it, and how to use it as an ingredient are reasons for high papaya loss[e]
- Industry or government standards may cause some products to be rejected for human consumption (e.g., plate waste can't be re-used at restaurants)
- Psychological tastes, attitudes, and preferences leading to plate waste/scrapings, e.g., human aversion, such as "I don't eat that," or refusal to eat a food for religious reasons."[a] Consumer demand for high cosmetic standards
- Socio-demographic factors: Younger people,[c,f] females,[f,g] and single-person,[c,d] larger,fand higher income[c,f] households tend to waste more
- Seasonal factors: More food is wasted in summer.[g]
- Uneaten or leftover holiday foods

[a] Ziegler and Floros (2011).
[b] Parfitt et al. (2010).
[c] Bio Intelligence Service (2010).
[d] Modin (2011).
[e] Buzby et al. (2009).
[f] Buzby and Guthrie (2002).
[g] Gallo (1980).
[h] Lundqvist et al. (2008), and the remainder was constructed by the authors, 2012.

by providing estimates of the total and per capita value of food loss at the retail and consumer levels in the United States in 2008 and the value of this food loss by food group. This study concludes with a brief discussion of potential large-scale or national strategies to reduce food loss in developed countries and the economic incentives to reduce food loss.

Estimates of food loss and food waste in developed countries

There are few peer-reviewed or major published studies that estimate the total amount of national food loss or food waste in developed countries and even fewer attempt to place a monetary value on food loss or food waste. As previously mentioned, definitions of food loss and waste are not universal and this complicates the comparison of estimates across countries and the identification of trends.

In the United Kingdom (UK), the Waste & Resources Action Programme (WRAP) estimated that in 2010, 7.2 million mt of food and drink was wasted from UK households per year and of this amount, 4.4 million mt was 'avoidable', 1.4 million mt was 'possibly avoidable' (e.g., potato skins), and 1.4 million mt was 'unavoidable' (e.g., peach pit) (Quested and Parry, 2011). The total waste was 19% of all food and drink purchases brought into the home by weight and the avoidable waste was 12% (Quested and Parry, 2011). An earlier WRAP study estimated that the average UK household of 2.4 people generated 270 kg/year of 'avoidable' and 'possibly avoidable' waste in their homes (WRAP, 2009). This translates into 112.5 kg/capita/year. According to WRAP, it would cost UK residents £12 billion/year or £480/household/year [200/capita/year] to purchase this amount of avoidable food and drink waste (Quested and Johnson, 2009). These estimates are roughly equivalent to $18.6 billion annually in total, $745 per household, and $311 per person.

According to a food waste study for the European Commission, food waste generated in the EU27 totaled around 89 million mt in 2006, using EUROSTAT data and available best estimates by member states (Bio Intelligence Service, 2010). This translates into roughly 179 kg of food waste per capita in four sectors (manufacturing, wholesale/retail, food service/catering, and consumer). Of this amount, about 76 kg/capita, is produced by households (Bio Intelligence Service, 2010).

Greater detail on food loss is available in some national studies or sources of data. For example, 2009 supply balance sheet spreadsheets by Statistics Austria provide loss estimates for individual foods available for domestic consumption (e.g., 20.8% for carrots) and for aggregated food groups (e.g., 15.3% for all vegetables) though the data do not reveal what share of these losses represents edible food (Statistics Austria, 2010). Two studies in Sweden estimated that avoidable food waste in Swedish households tallied 56 kg per person per year (Modin, 2011) and that roughly one-fifth of food in foodservice establishments in Sweden are lost (Engstrom and Carlsson-Kanyama, 2004). Neither study estimated the per capita annual cost of food waste in Sweden.

Using Loss-Adjusted Food Availability (LAFA) data from the US Department of Agriculture's Economic Research Service (ERS), Buzby et al. (2011) estimated the amount of food "lost" from the available food supply in the United States in 2008, for several hundred individual food commodities by food group, at both the retail and consumer levels. These foods include some beverages, such as whole and low-fat milks, and foods used as ingredients for beverages, such as oranges, cane and beet sugar, and high fructose corn syrup used in juices and drinks. The foundation of the data is made up of individual "supply and utilization" spreadsheets for individual commodities. Many of these spreadsheets account for non-food uses, such as grains originally or directly intended for animal feed and seed uses, by removing these products at an early stage in the calculations. Edible by-products diverted to animal feed from food processing are not estimated separately but are rather counted as part of food loss.

Note that data limitations and the structure of the ERS food loss data prevent us from being able to estimate what is avoidable waste out of the total food loss estimates. However, we suspect that most of the estimated food loss is avoidable waste because we have already removed the inedible (and thus unavoidable) portions from our estimates for each food in the data system. And from the remaining edible portions, we believe that cooking loss and other unavoidable losses are likely to be relatively small.

In total, 29% or 57.2 million mt of the 194.2 million mt of available food supply were lost from human consumption in 2008. Retail-level losses tallied 10% (19.5 million mt) and consumer level losses totaled 19% (37.7 million mt) of the available, edible food supply.[5] The 10% losses at the retail-level is high relative to that in European supermarkets and further research is needed to determine if this is because US supermarkets generally 'over-stock' or because of other factors. For example, the retail-level loss assumptions used here for individual fresh fruits, vegetables, meat, poultry, and seafood are based on an analysis of 2005–2006 data from over 600 stores from six large national and regional food retail chains (Buzby et al., 2009) though US supermarkets may have become more efficient and reduced food loss in recent years. The 19% consumer-level loss estimate out of the edible food supply in the United States is higher than the new estimate of 12% avoidable waste out of food and drink brought into UK homes in 2010 (Quested and Parry, 2011) but lower than the roughly one-fifth of food lost in Swedish foodservice establishments though this latter study included some inedible or 'possibly avoidable' foods (e.g., potato skins) (Engstrom and Carlsson-Kanyama, 2004).

Losses on-farm and between the farm and retailer were not estimated here due to data limitations for some of the food groups. Had these losses been included, total food loss in the United States would have been well over 29%. For fresh produce alone, an estimated 12% is lost in developed countries from production to retail sites with a range from 2% to 23% for individual commodities (Kader, 2005). Buzby et al. (2011) also estimated the total value of fruit and vegetable losses at the retail and consumer levels in the United States was $42.8 billion in 2008 or roughly $141 per capita.

Data and methods

We extend the literature by estimating the total value of all food loss at the retail and consumer levels in the United States in 2008. In short, we used Buzby et al.'s (2011) estimates of the value of food loss for each fruit and vegetable in the LAFA data and we estimated the value of all of the other individual foods in the LAFA data not covered by Buzby et al. (2011). We used prices consumers would have paid, on average, for those foods if bought at retail. In total, we compiled estimates of the value of food loss for more than 200 individual foods in the LAFA data and then aggregated these values to estimate the total value of food loss at both the retail and consumer levels in the United States in 2008 and the value by food group. The analytical method consisted of five key steps.

First, we identified 83 individual foods in the LAFA data in 2008 for our analysis beyond the 61 fresh and processed fruits and 60 fresh and processed vegetables studied by Buzby et al. (2011). The LAFA data can be accessed online through Excel spreadsheets which provide all of the current loss assumptions and structure of the calculations for each food in the data series. More informa-

[5] Buzby et al. (2011) estimated that in 2008, 126 billion lb of the 428 billion lb of the available food supply were lost at the retail level (42.9 billion lb) and at the consumer level (83.1 billion lb).

tion on the LAFA data is available in Box 1 and is summarized on the ERS website (ERS, 2011b).

Box 1. ERS Loss-Adjusted Food Availability data

The ERS's Loss-Adjusted Food Availability data is a popular proxy for food consumption as it provides estimates of the amount of food available for human consumption in the United States, after adjusting for food spoilage and other losses (ERS, 2011b). This "loss-adjusted" data is converted into daily per capita food intake, which is presented in two forms: the number of calories consumed daily (per capita) and the number of serving equivalents consumed daily (per capita) (as defined by the 2005 *Dietary Guidelines for Americans* and its supporting *MyPyramid Plan* Food Guidance System)(DHHS, 2005). In particular, the LAFA data requires estimates of four different conversion or loss factors in its calculations for each covered commodity at three different levels:

1. Losses at the primary production level (for example, farm to retail weight).
2. Losses at the retail level, such as in supermarkets, megastores like Walmart, and other retail outlets, including convenience stores and mom-and-pop grocery stores. Losses in restaurants and other foodservice outlets are not included.
3. Losses at the consumer level. This includes losses for food consumed at home and away from home (e.g., restaurants and fast food outlets) by consumers and foodservice establishments. There are two components:
   (a) "Nonedible share" of a food, such as an asparagus stalk or apple core. Data on the nonedible share are from the National Nutrient Database for Standard Reference, compiled by USDA's Agricultural Research Service (ARS, 2008).
   (b) Cooking loss and uneaten food, such as plate waste from the edible share.

We used the loss assumptions from the LAFA data series in this manuscript to estimate the amount of food loss at the retail and consumer levels, excluding the nonedible share. Losses between the farm and retailer were not estimated due to data limitations for some of the food groups. One caveat is that the limited ability of researchers to measure food loss accurately at the different levels suggests that actual loss rates may differ from the assumptions used in this data series. Loss estimates at the different levels may be understated or overstated due to limitations in the underlying published studies. Food loss, particularly at the consumer level, is by nature difficult to measure accurately. Participants in household surveys on food waste may be reactive and change their behavior during the survey period (consciously or subconsciously) and/or misstate their true levels of discarded food. 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 U.S. population and thus, the findings of plate waste studies cannot be easily extrapolated to other demographic categories.

Second, following the same methods used in Buzby et al. (2011), we estimated the amount of food loss at both the retail and consumer level in 2008 for each food in the LAFA data.

Third, we estimated national annual average retail prices using Nielsen Homescan data for each food consumed at home in 2008. This method for determining average prices was also used in previous research (Buzby et al., 2011; Reed et al., 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 food consumed away from home was not included in our estimated prices. We used Nielsen's projection factors to estimate what all households across the contiguous United States paid for foods and the quantities they bought. For each covered food, we estimated the average annual retail price per pound (weighted average) by dividing the total dollars spent on that item by the total amount sold. For example, we estimate that Americans spent $4.074 billion at retail market prices in 2008 for 9.191 billion pints (or 9.89 billion lb) of unflavored 2% refrigerated fluid milk providing us with an average retail price of $0.41 per pound.[6] This retail price per pound represents the weighted-average price for all unflavored 2% refrigerated fluid (excluding shelf stable) milk purchased at all types of retail outlets by households of the contiguous United States in 2008 in all sizes of plastic, carton, glass, or pouch type containers (e.g., one gallon and half gallon containers, not cans). For some foods, such as canned fish, we converted the amount to a drained weight using conversion factors for canned solids. We used different sources of conversion factors on yields where appropriate (ARS, 1975, 2010a,b). Estimating the price for each food in the LAFA database was an intricate and time-consuming process, particularly because we had to identify and select products to price that were representative of typical consumption by Americans. We later converted pounds to metric weights for this manuscript.

Fourth, as a validation step, we compared our estimated 2008 prices to 2003–2004 prices in the USDA Center for Nutrition Policy and Promotion's Food Prices database, which used the Homescan data and had a similar range of products (CNPP, 2009). 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. Validation studies confirm the suitability of Homescan data despite that the data contain recording errors by panelists in several dimensions (e.g., households may fail to record a product or a shopping trip or may misreport the store, date, or universal product code information) (Einav et al., 2008, 2009; Zhen et al., 2009). For example, Einav et al. (2008) found that errors in the Homescan data are unlikely to affect estimates of average prices paid by all households. Supplemental tables with estimated prices and value of loss for each food are available from the authors upon request.

Fifth, we multiplied the estimated retail price by the annual amount of food loss for each food at both the retail and consumer levels. Because we used retail level prices for food loss at both of these levels and because foodservice prices would likely be relatively higher per unit for many of the covered commodities than at the retail level, our estimates of food loss are likely to be conservative.[7] We adopted the retail prices for each fruit and vegetable

[6] When, as with fluid milk for example, quantities of items in Nielsen are given in units of volume (fluid ounces) rather than in units of mass (dry ounces) the quantity needed to be converted to pounds according to the density of the substance. In this case, the density of 2% fluid cow's milk is 244 g per cup (FNDDS 4.1). The average retail price per pound of 2% fluid milk is determined by the following calculation: $0.41 per pound = ($4.074 billion)/[(9.191 billion pints)(2 cups/pint)(244 grams/cup)/(453.6 g/Lb)]. We then converted prices to dollars per kilogram.

[7] For each food at the consumer level, we do not know the share of loss arising from home or away-from-home (e.g., foodservice) sources. Therefore at the consumer level, we took the conservative route and applied retail level prices to both kinds of consumer-level loss instead of obtaining and using relatively higher foodservice prices.

Table 2
Estimated total value of food loss at the retail and consumer levels in the United States, 2008.

Commodity	Food supply[a]	Losses from food supply[b]					
		Retail level		Consumer level		Total retail and consumer level	
	Million dollars	Million dollars	Percent	Million dollars	Percent	Million dollars	Percent
Grain products	34,791	4175	12	6123	18	10,298	30
Fruit	62,146	5795	9	9340	15	15,135	24
Fresh	38,120	4353	11	7082	19	11,435	30
Processed	24,026	1442	6	2258	9	3700	15
Vegetables	103,417	9174	9	18,493	18	27,667	27
Fresh	61,039	6631	11	12,316	20	18,947	31
Processed	42,378	2543	6	6177	15	8720	21
Dairy products	97,622	9023	9	14,679	15	23,703	24
Fluid milk	23,665	2844	12	4164	18	7008	30
Other dairy products	73,957	6180	8	10,515	14	16,695	23
Meat, poultry, and fish	176,284	8453	5	59,844	34	68,297	39
Meat	83,127	3747	5	27,911	34	31,658	38
Poultry	69,100	2694	4	25,810	37	28,504	41
Fish and seafood	24,058	2012	8	6124	25	8135	34
Eggs	12,826	1154	9	1751	14	2905	23
Tree nuts and peanuts	10,876	653	6	1022	9	1675	15
Added sugar and sweeteners	13,767	1514	11	2450	18	3965	29
Added fats and oils	37,326	7068	19	4867	13	11,935	32
Total	549,054	47,009	9	118,570	22	165,579	30

Source: This table was computed by authors using loss assumptions used in the ERS Loss-Adjusted Food Availability data for 2008 as of September 26, 2011 (ERS, 2011a) and the US population on July 1, 2008 (304.06 million). Per capita losses at the retail and consumer levels 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.

[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.

estimated by Buzby et al. (2011) and used the retail prices we estimated for all other foods. The value of loss for each food was 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 estimated the total value of each food group by summing individual valuations for the individual foods in each food group.

Results

Table 2 presents our estimates of the total value of food loss in the United States as estimated using food purchased at retail prices. The estimates are presented in the same table format published in Buzby et al. (2011) and Kantor et al. (1997) for the amount of food loss. The table also provides estimates by food group. In 2008, the estimated total value of food loss at the retail and consumer levels in the United States was $165.6 billion. Simplistically, this suggests that a mere 1% reduction in food loss would result in reducing the value of food loss by a substantial $1.66 billion. Fig. 1 presents the total value of food loss at the retail and consumer levels in the United States in 2008 by food group. The top three food groups in terms of the share of the total value of food loss at the retail and consumer levels are meat, poultry and fish (41%), vegetables (17%), and dairy products (14%). These estimates may be helpful for US consumers, industry members, and governments to put total food loss and food loss by food group into perspective and when initiatives are being developed to efficiently reduce food loss.

We estimated the per capita amount (Table 3) and value (Table 4) of food loss in 2008. The per capita estimates may be helpful to consumers to make them more mindful of their daily and yearly food loss. Looking more closely at the estimates for the consumer level only, we calculate that in 2008, 123.9 kg of edible food, per capita, were lost from the US food supply, both at home and away from home (e.g., by restaurants). This translates into 297.4 kg for a household of 2.4 persons/year. This amount is the highest per

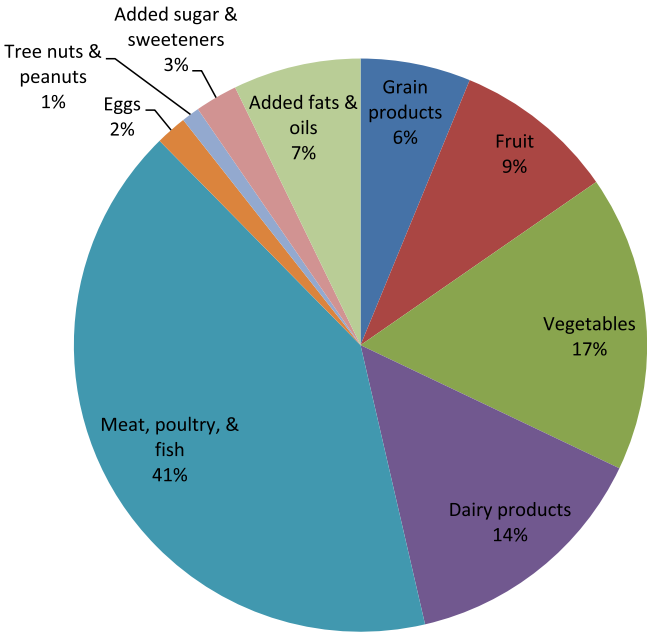

Fig. 1. This figure highlights each food group's contribution to the total value of food loss ($165,579 million) in the United States in 2008.

capita amount from the studies mentioned earlier in this article though differences in data and definitions preclude us from placing too much emphasis on the estimates comparing waste across countries.

This per capita loss at the consumer level translates into each American purchasing but not consuming $390 of food per year at retail prices. This yearly total is almost 10% of the average amount spent on food per consumer in 2008 ($3,961) (ERS, 2011a) and over 1% of the average disposable income ($34,902) (BLS, 2010). The yearly total translates into over 0.3 kg of food per capita per day

Table 3
Estimated per capita amount of food loss at the retail and consumer levels in the United States, 2008.

Commodity	Food supply[a]	Losses from food supply[b]					
		Retail level		Consumer level		Total retail and consumer level	
	Kilograms	Kilograms	Percent	Kilograms	Percent	Kilograms	Percent
Grain products	89.1	10.7	12	15.7	18	26.4	30
Fruit	92.2	8.6	9	13.5	15	22.1	24
Fresh	54.6	6.3	12	9.9	18	16.3	30
Processed	37.6	2.3	6	3.5	9	5.8	15
Vegetables	123.0	10.3	8	24.6	20	34.9	28
Fresh	78.7	7.6	10	17.5	22	25.1	32
Processed	44.3	2.7	6	7.1	16	9.8	22
Dairy products	124.5	14.0	11	20.9	17	34.9	28
Fluid milk	81.2	9.8	12	14.3	>18	24.1	30
Other dairy products	43.2	4.2	10	6.6	15	10.8	25
Meat, poultry, and fish	89.3	4.1	5	30.4	34	34.5	39
Meat	49.1	2.2	4	16.4	33	18.6	38
Poultry	32.9	1.3	4	12.2	37	13.5	41
Fish and seafood	7.2	0.6	8	1.8	25	2.4	33
Eggs	14.5	1.3	9	2.0	14	3.3	23
Tree nuts and peanuts	4.7	0.3	6	0.4	9	0.7	15
Added sweeteners	61.8	6.8	11	11.0	18	17.8	29
Added fats and oils	39.5	8.1	21	5.4	14	13.5	34
Total	638.7	64.0	10	123.9	19	188.0	29

Source: This table updates Kantor et al. (1997) and was computed by authors using loss assumptions used in the ERS Loss-Adjusted Food Availability data for 2008 as of September 26, 2011 (ERS, 2011a) 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.

[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.

Table 4
Estimated per capita value of food loss at the retail and consumer levels in the United States, 2008.

Commodity	Food supply[a]	Losses from food supply[b]					
		Retail level		Consumer level		Total retail and consumer level	
	Dollars	Dollars	Percent	Dollars	Percent	Dollars	Percent
Grain products	114	13.7	12	20.1	18	33.9	30
Fruit	204	19.1	9	30.7	15	49.8	24
Fresh	125	14.3	11	23.3	19	37.6	30
Processed	79	4.7	6	7.4	9	12.2	15
Vegetables	340	30.2	9	60.8	18	91.0	27
Fresh	201	21.8	11	40.5	20	62.3	31
Processed	139	8.4	6	20.3	15	28.7	21
Dairy products	321	29.7	9	48.3	15	78.0	24
Fluid milk	78	9.4	12	13.7	18	23.0	30
Other dairy products	243	20.3	8	34.6	14	54.9	23
Meat, poultry, and fish	580	27.8	5	196.8	34	224.6	39
Meat	273	12.3	5	91.8	34	104.1	38
Poultry	227	8.9	4	84.9	37	93.7	41
Fish and seafood	79	6.6	8	20.1	25	26.8	34
Eggs	42	3.8	9	5.8	14	9.6	23
Tree nuts and peanuts	36	2.1	6	3.4	9	5.5	15
Added sweeteners	45	5.0	11	8.1	18	13.0	29
Added fats and oils	123	23.2	19	16.0	13	39.3	32
Total	1806	154.6	9	390.0	22	544.6	30

Source: This table updates Kantor et al. (1997) and was computed by authors using loss assumptions used in the ERS Loss-Adjusted Food Availability data for 2008 as of September 26, 2011 (ERS, 2011a) 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.

[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.

at an estimated retail price of $1.07/day or .8 kg per day valued at $2.56/day for a household of 2.4 persons. On average, each household purchased but did not eat an estimated $936 of food per year. In terms of the annual value of food loss at the consumer level, per capita, the top three food groups made up 78% of the total: meat, poultry and fish tallied $197/year, vegetables were $61/year, and dairy products were $48/year.

Discussion

Studies suggest that food production could be increased to feed the burgeoning world population in 2050 but not without difficulties, such as sapping already constrained and finite resources like clean water, accelerating the overexploitation of fisheries, or impinging on land needed for urbanization, forests, and protected

areas to the extent that compromises biodiversity and damages ecosystems (Godfray et al., 2010; Spencer and Butler, 2010; The Royal Society, 2010). Therefore, ensuring that a greater share of food that has already been produced fulfills its intended purpose of feeding people will become increasingly important.

In this study, we calculated the amount and value of food loss in the United States. We estimated that on average, for each of the over 304 million people in the United States in 2008, $0.42 of food was lost from the food supply at the retail level per day and $1.07 of food was lost from the food supply at the consumer level per day for a total of $1.49/capita/day at both levels combined. The per capita value would be even higher had we been able to value and include farm-level losses.

Nevertheless, if we input $1.49/day into PovcalNet, which is an on-line tool for poverty measurement by the Development Research Group of the World Bank, there were an estimated 1.8 billion people who lived on less than $1.49/day in 2005 (World Bank, 2011). This is not to say that this food estimated to be lost from the food supply could be magically transported to feed people in need without cost because of the perishability of most foods, high transportation and distribution costs, and the other challenges that exist. Rather these estimates serve to illustrate that there is a significant amount of food lost from the food supply in the United States, the resources from which could have been used to feed food-insecure people. And when considering all of the countries worldwide, each of which also wastes substantial amounts of food, food that is prevented from being wasted or lost from the food supply could make significant inroads to reduce food insecurity. In global food markets, wasted food means that less is available for others to buy and if less food is wasted, the agricultural land and other resources used to grow that food could be liberated to grow food to feed the world's hungry (Stuart, 2009).

At first glance, reducing food loss may be seen as relatively low-hanging fruit out of the broad strategies to feed people in 2050 until one considers that in a developed country, much of the total amount of food loss could be dispersed among millions of food stores, restaurants, households, and other sites and by millions of food industry members and consumers. Data limitations in both developed countries and developing countries mean that it will be difficult to gauge any progress in reducing food waste and to precisely estimate the potential of food waste reductions to feed people in 2050 and beyond. In particular, countries that are rapidly growing and evolving, such as Brazil, Russia, India, and China (BRIC), do not have data on food waste (Parfitt et al., 2010).

In the future, we might even see a backwards slide towards greater levels of per capita food loss for several reasons. For example, countries like Brazil and China are experiencing major changes in their food supply systems (e.g., considerable expansion of supermarkets). As a result, some factors that contribute to food waste in developed countries are beginning to emerge in developing countries, such as overproduction, over-ordering, inaccurate systems to forecast retailer demand, and contracts that permit unsold food to be returned to suppliers instead of having the cost absorbed by the waste producer (Foresight Project on Global Food and Farming Futures, 2010). And, as countries' populations become more affluent, there is evidence that the patterns of food demand change and these changes could increase food waste. These changes include more diversified diets with a higher proportion of relatively high-value and more perishable fresh foods and animal products (Lundqvist et al., 2008) as well as greater demand for food safety and quality (e.g., higher expectations for cosmetic attributes like color, size, shape, and whether the food is blemish-free). Some of these changes may promote trends counter to societal goals, such as reducing food waste, protecting the environment, and feeding the world population in 2050. For example, as consumer demand for fresh produce of high quality increases, this inevitably leads to more edible food wasted before it is even sold (Lundqvist et al., 2008).

Land and other resources that may be liberated from reductions in food loss may be offset by the need for additional resources to feed the growing world population and meet these new demands for food. All of these demands pose social, financial, and environmental challenges. Meeting the changing demands for food will add new challenges to controlling food waste and will place even greater demands on the environment (Foresight Project on Global Food and Farming Futures, 2010).

Given these challenges, reducing food loss within a nation will require a wide range of initiatives to target different sub-populations simultaneously, ranging in scale from small, grassroots initiatives or technological improvements, such as innovative packaging to prolong shelf life, to nationally-mandated or globally-linked policies. The food waste report prepared for the European Commission inventoried over 100 such initiatives (Bio Intelligence Service, 2010).

Because of the difficulty of changing consumer behavior of individuals dispersed in so many households across a given country and because of the economies of scale, we believe that it is the large, industry-led initiatives or government-led policies which have the greatest potential to reduce food loss in the next decade and so are discussed further below. However, even a modest yet economically feasible decrease in food loss from small loss-reducing initiatives or newly-adopted processing, packaging, and storage technologies could lessen the environmental impacts of food waste generation and disposal.[8] And, if more food is recovered for human consumption in this process, it could reduce food insecurity by supplementing existing food assistance efforts and potentially provide tax savings to farms, food retailers, and foodservice establishments that donate food.

Strategies to reduce food loss in developed countries

The food waste study for the European Commission identified several policy options for the EU27 to reduce food waste (Bio Intelligence Service, 2010) and provided a rough estimate of potential implementation costs. Some of these options have relevance to other developed countries and include:

(1) Requiring food waste reporting,
(2) Clarifying and standardizing food date labeling (e.g., "sell-by" or "best-by"),
(3) Setting targets for food waste prevention, and
(4) Aiming targeted awareness campaigns at households and the general public.

Other food-loss reducing strategies in the developed world could include carefully targeted taxation of foods with the highest waste and private and public sector partnerships sharing the responsibility for reducing food loss (Hodges et al., 2010).

Reducing food loss can help improve the efficiency and productivity of the food system by increasing food availability for any given level of land, energy, fertilizer, and other inputs (Comptroller General of the United States, 1977). When implemented, we believe the strategies most likely to be successful are those that make economic sense. They are the strategies where the benefits of reducing food loss outweigh the costs and where the monetary and non-monetary incentives to reduce food loss for food industry members, governments, and consumers are apparent and deemed

[8] It should be emphasized that there really are two separate challenges, how to not generate as much food loss or waste in the first place (*waste prevention*) and what to do with the food waste once it is generated (*waste disposal*). As the first challenge is met more fully, the second becomes less of an issue.

worthwhile. For example, because of diminishing returns, after most strawberries in a field have been harvested, harvesting each additional unit of strawberries will become increasingly expensive so it makes economic sense to leave some un-harvested.

It is in society's best interest to have and accept some level of food loss so that there is enough surplus food to prevent shortages (Stuart, 2009) and to minimize food costs. Therefore, it is unrealistic to think that nations will ever entirely eliminate or have zero food waste. In the end, economic incentives and consumer behavior will be paramount and there will be a compromise between meeting the diverse and often competing goals of a society that include reducing food loss, obtaining an acceptable return on investment by food industry members, protecting the environment and worker safety, and fulfilling consumer demand for food safety, product quality, and a diverse variety of nutritious, flavorful, and acceptably-priced food.

Our estimates of the total value of food loss in the United States are useful in that they can generate awareness of the issue among the food industry members, governments, and consumers. However, any raised awareness alone will not be sufficient to make major inroads in reducing food loss and waste. Instead, such awareness will need to be coupled with a greater understanding of the extent to which food losses are preventable or avoidable, where food waste reductions can be made in the food lifecycle (e.g., during food processing), and how any remaining food waste can either be efficiently prevented or diverted away from disposal and put to more optimal uses (e.g., animal feed). And this increased awareness will need to be followed by actions by governments, industry, and consumers to reduce food loss and waste.

More detailed and specific estimates are needed for use in benefit-cost analyses of specific loss-reducing initiatives. For example, additional types of economic costs could be included, such as the costs of disposing of unused food, the cost of food going to a lower value use (e.g., animal feed), and lost opportunity of resources wasted. The EU study recognized that obtaining reliable data on food waste was a recurring obstacle and that it was difficult to attain quantitative results on the effectiveness of the different initiatives and strategies (Bio Intelligence Service, 2010). The study was able to show, however, that a concerted approach was useful (e.g., approach under development in Austria, current approach used in the UK) and the study concluded that "an EU approach to food waste, particularly regarding data, was considered essential" (Bio Intelligence Service, 2010). In short, more data is needed on where, why, and how food losses and waste occur and the economic incentives to reduce these losses.

Conclusions

In conclusion, we estimate that in 2008, total food loss at the retail and consumer levels in the United States was $165.6 billion. In the most general sense, this means that a 1% reduction in food loss would result in reducing the value of food loss by a substantial $1.66 billion.

On a per capita basis in 2008, the food lost from the food supply at the consumer level is equivalent to 124 kg of food per year at an estimated retail price of $390/year at retail prices or .03 kg of food per day valued at $1.07/day. This is roughly 10% of the average amount spent on food per capita in 2008. In 2008, three food groups were responsible for 78% of the total value of food loss at the consumer level, per capita. These groups are meat, poultry and fish ($197/year), vegetables ($61/year), and dairy products ($48/year). Therefore, these food groups might be potential areas to target when educating consumers about food loss.

Each household (2.4 persons) in 2008 purchased but did not consume 297 kg of food at an estimated retail price of $936. This translates into almost 0.8 kg of food per household per day valued at $2.56/day. This information would likely be of interest to consumers, particularly during the current economic climate.

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