



Applying a value chain collaboration perspective to addressing food waste in the United States

PACKAGING-BASED SOLUTIONS TO CONSUMER FOOD WASTE

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Executive Summary

Each year, around 40% of all food in the United States,¹ enough to fill the Empire State Building 91 times,² goes uneaten. This is equivalent to throwing out \$165 billion each year along with substantial amounts of energy, fertilizer, and 25% of all freshwater.³ Although food is wasted at each step in the value chain, consumers are the largest generators of food waste in the US. The average American wastes 209 to 254 pounds of edible food each year,⁴ which amounts to \$2,275 thrown away per year for a family of four⁵ while more than 17 million US households did not have enough food on their table.⁶

Research into consumer behavior, preferences and social psychology help to inform the challenge of tackling consumer food waste. We explore the key reasons why US consumers waste food and find that a comprehensive strategy, making use of both information campaigns and enabling technologies at the product level will be needed.

In reviewing the state of US initiatives to address food waste, we noted that there is a gap in efforts in food-related industries to provide product-based solutions designed to help consumers waste less food. To date, private industry players are addressing their own waste, such as waste generated in the food processing stage, and government is beginning to engage individual consumers with information-based strategies. We see advanced packaging applications, such as ethylene absorption, as well as further application of basic packaging formats, such as resealable bags, as a potentially impactful avenue to explore, but one which is lost in the gaps between existing US initiatives. We explore some of the trade-offs and challenges in bringing these packaging changes to market.

A more comprehensive, structured and goal-oriented collaboration among US food industry stakeholders is necessary to achieve the significant level of action that is needed across the full food value chain. In light of our exploration of the intersection between the reality of food waste as described by the data, consumer behaviors that drive wasteful practices and advances in the food packaging space, we recommend these key areas for action by industry stakeholders:

- Strengthen and broaden collaborative activity within the food industry;
- Deepen knowledge and communication regarding food waste within individual companies;
- Strengthen ties with industry partners through integrated value chain waste management;
- Engage with the consumer to learn more about their preferences and to help them understand the role packaging and proper storage can play in saving food and saving money; and
- Support the development and implementation of new packaging technologies that positively balance the financial and environmental trade-offs inherent in food and packaging combinations.

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Introduction to Food Waste in the US

Food production accounts for 70% of global water use and 6% of energy use,⁷ and contributes significantly to deforestation. Yet, throughout the United States, food is treated as a disposable commodity. Most individuals living in the developed world are disconnected from the environmental, social, and economic impacts of food production. Each year, around 40% of all food in the United States,⁸ enough to fill the Empire State Building 91 times,⁹ goes uneaten. This is equivalent to throwing out \$165 billion each year along with substantial amounts of energy, fertilizer, and 25% of all freshwater.¹⁰

Consumers are the largest source of food waste in the US, responsible for 44% of total food waste.¹¹ Waste is generated at every step in the supply chain, including production, harvest, storage, processing, transportation, distribution and retail. Of the estimated 60.8 million tons of food waste that is generated each year in the US, 21 million tons (35%) is diverted from the landfill, primarily to animal feed. The remaining 39.7 million tons (65%) is sent to landfill or incinerated post-harvest.¹² Food waste is the single largest type (21%) of municipal waste material sent to the landfill, and accounts for more than 20% of all methane emissions in the United States.¹³

While the average American wastes 209 to 254 pounds of edible food each year,¹⁴ which amounts to \$2,275 thrown away per year for a family of four,¹⁵ more than 17 million U.S. households did not have enough food on their table in 2010.¹⁶ The issue is compounded at the global scale. Of the four billion metric tons of food produced, as much as 30-50% never reaches a human stomach.¹⁷ The quantity of food wasted at the consumer level in industrialized nations is almost as high as the total net food production of sub-Saharan Africa.¹⁸ If it were a country, food waste would be the third biggest greenhouse gas emitter in the world, after China and the US.¹⁹ The monumental scale of food waste's impact on natural resources, society and economies is a tragedy that needs to be addressed in order to meet the challenge of providing for future generations.

Current Initiatives Addressing Food Waste

Addressing food waste requires a comprehensive response, such as targets for prevention, policies to support food donation and deter landfill disposal, funding for pilot projects, and active collaboration between public, private, and other organizations. These measures must also engage and gain the support of consumers, such as via communication campaigns.²⁰ Unlike the nations of the Europe Union, which have the Waste Prevention Framework, the US lacks a national goal for food waste reduction. However, there are a few programs in the US that strive to reduce food waste, including:

Food: Too Good to Waste

In late 2012, the US Environmental Protection Agency (EPA) developed a pilot community-based social marketing toolkit, *Food: Too Good to Waste*, with the aim of reducing household food waste by engaging local stakeholders. The approach focuses on social marketing incentives and messages directed at individuals within targeted communities. The toolkit includes a research report,

messaging and implementation guides, behavior change tools and templates, and measurement tools. The kit can be used by any interested local government or community group and is projected to help a four-member household save more than \$1,600 annually.²¹

U.S. Food Waste Challenge

Launched in June 2013, this is a collaborative effort between the US Department of Agriculture (USDA) and the EPA to challenge players across the food chain, including producer groups, processors, manufacturers, retailers, communities, and other government agencies, to reduce, recover, and recycle food waste.²² As part of its efforts towards this challenge, USDA is seeking to reduce waste in schools, educate consumers about food waste and proper food storage, and develop technologies to reduce food waste. The EPA will leverage its Food Recovery Challenge program²³ and provide access to its data management software along with technical assistance to help participants quantify and improve their sustainable food management practices.

Food Waste Reduction Alliance

The Food Waste Reduction Alliance (FWRA) is a joint initiative between the Grocery Manufacturers Association (GMA), the Food Marketing Institute (FMI), and the National Restaurant Association (NRA).²⁴ Representing the food and beverage companies (GMA), food retailers (FMI), and the foodservice industry (NRA), the FWRA is a collaborative effort that engages over thirty leading companies and other partners towards the common goal of reducing the amount of food waste generated within their company boundaries, increasing the scale of food donation, and recycling unavoidable food waste.

Initiatives in the United Kingdom

Programs underway in the United Kingdom are the gold standard when it comes to tackling food waste. UK programs include waste reduction goals, comprehensive ongoing research and campaigns that disseminate information and food waste reduction strategies to consumers. The Waste and Resources Action Programme (WRAP) was established in 2000 as a non-profit organization backed by government funding from the UK and EU²⁵ to promote resource efficiency and sustainable waste management. In 2007, WRAP launched the *Love Food Hate Waste* campaign²⁶ that has since helped raise awareness about food waste and offers practical actions to minimize household waste. In a span of five years (2007-2012), the UK reduced its household food and drink waste by 1.3 million tonnes, the equivalent of saving 2,600 Olympic-size swimming pools full of food.²⁷ This 15% reduction has mitigated 4.4 million tonnes of CO₂e and also saved the local authorities over US\$135 million in avoided landfill tax in 2012 alone.²⁸ These substantial savings are attributed to the rising cost of food, the Love Food Hate Waste campaign, and the Courtauld Commitment, by which food sector stakeholders have committed to reduce food and packaging waste generated at households and across the supply chain.^{29,30}

Focus of This Project

In reviewing the state of US initiatives to address food waste, we noted that there is a gap in efforts in the food industry to provide product-based solutions that will help consumers waste less food. Private industry players are addressing their own waste, such as produce that spoils in transit to the retail store, and the federal government is beginning to engage individual consumers with information-based strategies. However, there does not appear to be a concerted effort at scale to apply the capabilities of the food industry to developing supply chain and product-based strategies that will enable consumers to make smarter and more complete use of the food that they buy. We, thus, have focused our work for this project on how and why companies, namely food manufacturers, retailers and their key supply chain partners, can make changes to their products that will help reduce food waste both within their corporate boundaries and in the consumer's home. We see advanced packaging applications, such as ethylene absorption, as well as further application of basic packaging formats, such as resealable bags, as a potentially impactful avenue to explore, but one which is lost in the gaps between existing US initiatives. A more comprehensive, structured and goal-oriented collaboration among US food industry stakeholders will be needed to achieve the significant level of action that is needed across the full food value chain.

Consumer Contributions to Food Waste

Behavior that Leads to Food Waste

Food is a fundamental human need and is vital for our existence. Today, Americans are consuming 15% more food and calories per person per day than they did in the 1970s.³¹ The food we consume affects not only our health, but also the environment, and society. The average American wastes 209 to 254 pounds of edible food each year.³² Understanding and influencing individuals' behavior has the potential to significantly reduce the amount of food being wasted at the consumer level. Some of the common consumer behaviors that lead to household food waste are:

1. **Low cost of food relative to income:** Americans spend 6% of their household income on food, the lowest in the world compared to 14% in France and as much as 45% in Kenya.³³ This inexpensive and abundant supply of food creates a perception of food waste as being insignificant.
2. **Lack of awareness of amount of waste generated:** Waste is made invisible to consumers by the trash can. Since individuals generally throw out only small amounts of food waste at a time, and it is soon collected and hauled away, it is almost impossible for one to acknowledge and appreciate the aggregate amount of waste that one generates.³⁴ This, coupled with the average American's disconnection from the food production system and the inconspicuousness of waste management infrastructure have resulted in a dominant social convention towards wasteful consumption.

3. **Lack of planning prior to shopping and impulse purchasing:** Shopping without a grocery list or weekly meal plan results in consumers having difficulty in estimating how much food they require. Supermarkets and grocery stores regularly advertise in-store deals and promotions that encourage bulk buying. This, paired with impulse purchases, which make up as much as 20% of total grocery store purchases,³⁵ results in consumers buying more than what they need.
4. **Cooking knowledge and over preparation of food:** Meal portions have significantly increased over the past two decades.³⁶ People prefer to serve more food than required and this contributes to plate waste. Individuals also often have inadequate knowledge of how to properly use and store leftover food and ingredients.³⁷

Reasons Edible Food is Thrown Away

There are a very limited number of studies in the United States that focus on identifying the reasons food is thrown away. The majority of research in this area comes from the UK.³⁸ Understanding and quantifying these reasons in the US can help inform the design of solutions that minimize waste. Some of the commonly identified reasons that households dispose of food are:

1. **Uncertainty over proper method and duration of food storage:** The way food is stored significantly impacts its freshness and shelf life. A survey³⁹ identified that consumers have difficulty discerning the best way to store different food types, citing lack of time and organization. Moreover, a vast majority of consumers do not leave food in its original packaging – which is often the optimal storage method – and lack appropriate storage containers for unpackaged items and leftovers. Compounding this issue is uncertainty about the duration of time for which different types of food can be stored safely.
2. **Confusion and misinterpretation of date labels:** Over 90% of Americans prematurely discard edible food due to misinterpretation of “sell by”, “use by”, and “best before” labels.⁴⁰

What causes food to spoil?

1) *Microbial Activity:*

Microorganisms that occur naturally in the environment cause food to deteriorate. There are three types of microorganisms:

a) *Bacteria: Microscopic organisms that cause food poisoning when consumed. They thrive in warm, moist, and low-acid environments.*

b) *Yeast: Single-celled organisms that cause food to ferment and spoil.*

c) *Molds: A form of fungi that can be seen by the naked eye. They reproduce by forming spores on the surface of foods.*

2) *Enzymatic Changes:*

These natural chemicals help speed up reactions, causing food to age and ripen.

3) *Physical and Chemical Reactions:* Improperly stored food is exposed to conditions (moisture gain, oxidation etc.) that change their physical and chemical properties, causing spoilage.

The problem is exacerbated by the lack of regulations or standards for date labeling.^a This results in high variability in date label implementation by individual manufacturers and retailers, leading to ambiguity in their interpretation as a guide to the freshness or safety of food.

3. **Refrigerator clutter:** Americans have the biggest refrigerators in the world, with an average volume of 17.5 cubic feet.⁴¹ This, coupled with the sense that refrigerators need to be well stocked, leads to crowded shelves resulting in poor visibility and forgetful behavior.⁴² Furthermore, people are unsure about the right temperature at which food should be stored in the refrigerator,⁴³ thereby exacerbating spoilage of edible food.
4. **Poor management of leftovers:** Adding to the refrigerator clutter is the poor management of leftover food and ingredients. Apart from forgetting or not knowing how to store leftovers properly, anecdotal evidence suggests misconceptions exist about health concerns from eating leftover food or using leftover ingredients.⁴⁴
5. **Skepticism over appearance:** Many fruits and vegetables that are perfectly edible are discarded because of their irregular shape, size, and blemished or wilted appearance.

Products that End Up as Food Waste in Significant Amounts

It is critical to have an estimate of the amount, type, and value of food products that get wasted in significant amounts. Such data provides quantitative insight for policy makers, NGOs, and private industry to design initiatives that minimize food waste and conserve vital natural resources. Figure 1 shows the extent of food loss across the supply chain, from initial production down to final household consumption.⁴⁵ It can be observed that most of the losses occur at the consumer level.

^a The only product for which date labeling is federally regulated in the US is infant formula.

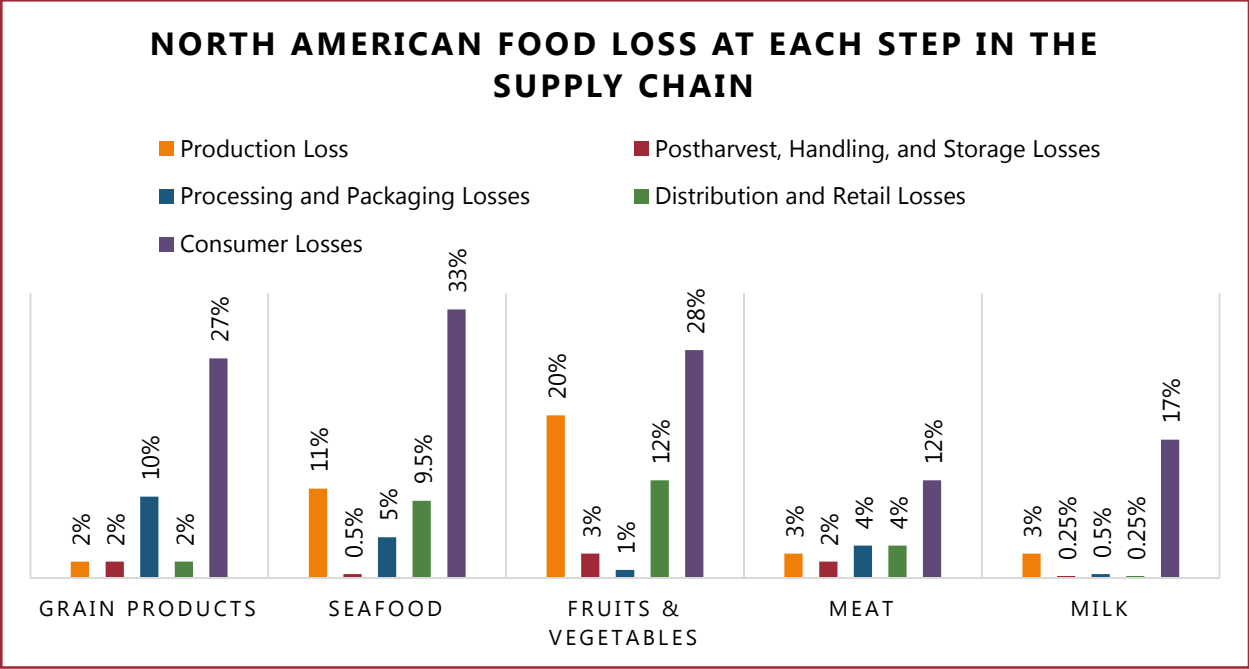


Figure 1: North American (including US, Canada, Australia, and New Zealand) Food Loss at Each Step in the Supply Chain⁴⁶

Research conducted by Buzby and Hyman⁴⁷ provides an assessment of the total and per capita value of food loss at the retail and consumer level in the US. Their estimated total value of food loss at the retail and consumer level in the US during the year 2008 is shown below in Figure 2.

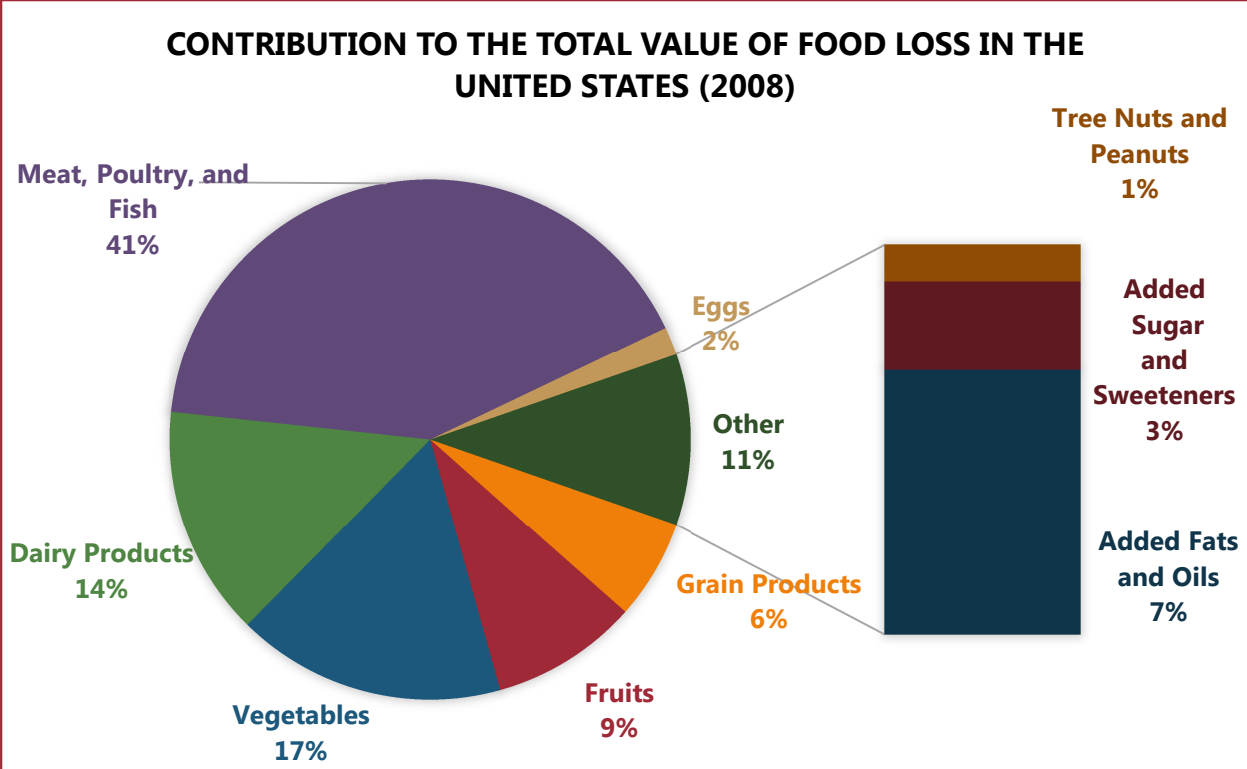


Figure 2: Total Retail and Consumer-Level Food Group's Contribution to the Total Value of Food Loss (US\$ 165,579 million) in the United States in 2008⁴⁸

In 2008, the estimated total value of food loss in the US, at both the retail and consumer level, exceeded US\$ 165 billion.⁴⁹ This is equivalent to 1% of the 2012 GDP of the country. As seen in Figure 2, the top three food groups with the highest stake in the total value of food loss at the retail and consumer level are meat, poultry, and fish (41%), vegetables (17%), and dairy products (14%), with a combined value of US\$ 118.8 billion. If governments, NGOs, industry members, and consumers are able to reduce just 1% of waste in these three categories, they would capture over US\$ 1 billion in avoided food cost.

A study conducted in the UK by INCPEN⁵⁰ identified the top twenty most-wasted food types in the retail food supply chain. The study is based on data from three major retailers whose combined UK FMCG retail market share is 65% by value. The study also quantifies products that are either dumped due to damage or spoilage or sold as reduced-to-clear. Figure 3 shows the food products that experience the most wastage, by value. Such data provide insights needed to prioritize food waste minimization efforts.

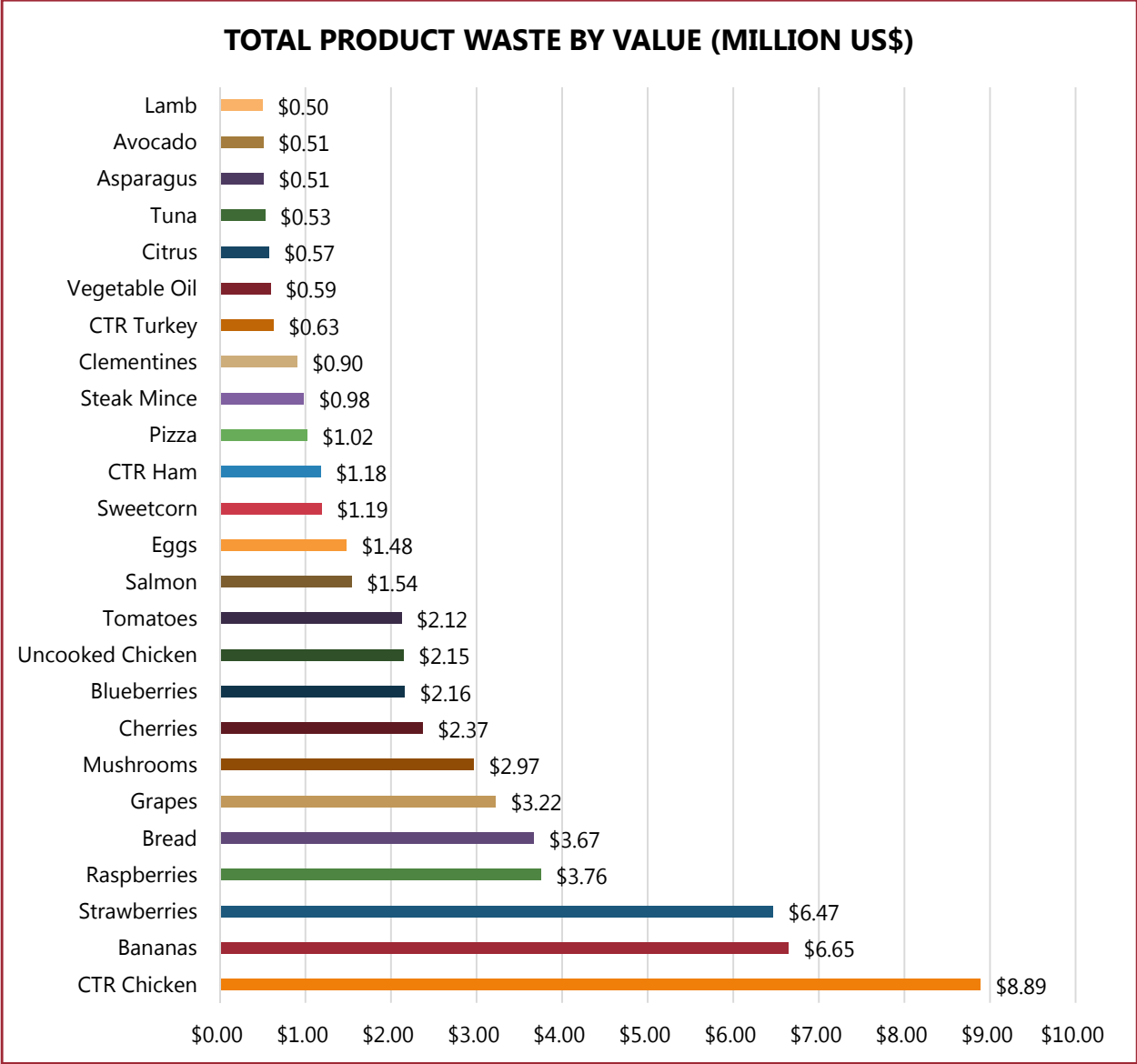


Figure 3: Total Value (in Million US\$) of Food Waste for the Top Twenty Food Products⁵¹

From the studies discussed in this section, it is clear that the largest segment of waste is in the fruits and vegetables, meat and poultry, and baked goods categories. The majority of the top wasted foods listed in Figure 3, including chicken, bananas, berries, bread etc., are typically sold pre-packaged as well as loose over the counter. Since, on average, 44% of all food waste in the US occurs at the consumer level,⁵² it would be worthwhile to invest and focus on consumer-oriented solutions for these high-waste food products as a strong step to reduce the amount of food being wasted. Packaging has significant potential to contribute to reducing food waste at the consumer level. Apart from containing and protecting the food throughout the supply chain, packaging helps increase shelf life and provides better product dispensing. However, the impact of packaging on food waste depends on consumer behavior in relation to the packaging and hence it is crucial to have psychological insight into factors that encourage behaviors that prevent waste.

Brief Insight into the Psychology of Waste

In order to develop packaging strategies that can influence and change the consumer behavior that generates food waste, it is important to understand the psychology of waste. No one *wants* to be wasteful or even to appear to be wasteful. Individuals even tend to make choices that contradict their economic self-interest in order to avoid the appearance of being wasteful.⁵³ However, for the behavioral reasons outlined above, even though consumers do not want to be wasteful, this is exactly what happens when it comes to food. One contributing explanation can be found in the *principle of social proof*,⁵⁴ a phenomenon whereby people assume the behavior and actions of others in an attempt to reflect correct or appropriate behavior for a given situation. Plate waste is an example of a wasteful behavior that may be influenced by social proof, as many consumers do not want to be seen as glutinous by finishing their whole plate of food. Similarly, an aversion to getting restaurant leftovers packed up to-go is influenced by strong social norms around food.

A model commonly applied to explain waste prevention behavior is the *theory of planned behavior*,⁵⁵ which suggests that an individual's intention to act is derived from three factors: their attitude, their perceived ease or difficulty of performing the act, and their perception of social norms. Furthermore, the theory proposes that the individual's intention is expected to translate into action, provided there are no limiting external barriers. Table 1 below summarizes the motivations and barriers for waste prevention behavior.^{56, 57}

Table 1: Summary of Motivations and Barriers for Waste Prevention Behavior⁵⁸

Motivations	Barriers
<ul style="list-style-type: none"> • <i>Universal Value</i>: where collective values are valued more than personal gains. • <i>Personal Responsibility</i>: often cited as a primary requirement for prevention behavior. • <i>Self-Efficacy</i>: skills, knowledge, and personal capabilities to implement a particular behavior. Campaigns like <i>Love Food Hate Waste</i> focus on this aspect. • <i>Saving money</i> through avoided cost. • <i>Social Norms</i>: knowing that someone else is taking action. • <i>Habits</i>: can have a positive or a negative effect. 	<ul style="list-style-type: none"> • <i>Apathy</i>. • Viewing the problem and the solution as <i>someone else's responsibility</i>. An example would be to view food waste as a problem for retailers and manufacturers, expecting them to develop solutions. • <i>Inconvenience</i>. • <i>Cost</i> is a barrier when consumers perceive there will be little to no discount, or they think that an alternative would be more expensive.⁵⁹ • <i>Weak Self-Efficacy</i>: The feeling that an individual's contribution is marginal. • The <i>prevailing social convention</i> of wasteful consumption. • Dominance of the <i>recycling norm</i> that skews an individual's perception of waste reduction.

Using Knowledge of Consumers to Inform Packaging Strategies

Optimal packaging strategies should factor in consumers' attitudes towards food, their reasons for wasting it, and the psychological aspects that encourage waste prevention behavior.⁶⁰ Improving self-efficacy by imparting the skills and knowledge needed to tackle wasteful behavior is a key enabler of other motivators, such as influencing positive habit formation and transforming social norms.⁶¹

In terms of disseminating knowledge that enables waste prevention, beliefs regarding packaging present a key perception barrier that must be overcome.⁶² There is a misconception about the role packaging plays once food is brought home. The prevailing view, which is largely incorrect, is that keeping products in the original packaging leads them to spoil more quickly.⁶³ The industry must help educate consumers about the role packaging can play to help limit food waste. This will necessarily include helping consumers understand the trade-offs inherent in the decision to package foods that could be distributed and sold unpackaged, or to use a specific packaging format or technology. Consumers should be informed about the environmental as well as monetary value that can be gained through packaging that extends shelf life and maintains product safety.⁶⁴

Since one of the reasons consumers throw away food is a lack of appropriate storage containers, packaging solutions should provide convenient storage options, such as resealability, split portions, and better visibility of the product. Packages should also feature on-pack labels that provide easy-to-understand information about the packaging's waste reduction benefits, as well as clear directions about proper product use and storage.

Behavioral change requires awareness, opportunity, and motivation.⁶⁵ As individuals become more cognizant about the convenience as well as the environmental and food expenditure benefits of packaging solutions, one will begin to recognize the opportunity that packaging and behavior change provide to help reduce their household waste. This can motivate the individual to embrace behavioral changes and adopt new packaging technologies.

The Role of Packaging in the Food Industry and the Food Waste Problem

Packaging – and we focus on primary product packaging^b – in the food industry has several different purposes with differing importance across a range of products. An emerging supplemental purpose is that packaging can help reduce food waste at each step in the value chain. The key reasons underlying the use of packaging for food today are:

- Physical protection of the product in transition from farm to manufacturer to distribution center to retail and into the home;
- Protection against spoilage by sealing out contaminants;
- Reducing the respiration rate of the product by limiting oxygen;
- Containment of the product in set quantities;
- Organization of the product for efficient transport and retail stocking;
- Dissemination of information, such as storage instructions or nutritional data; and
- Providing a vehicle for marketing or branding.

To the consumer, the value of packaging can include maintenance of food quality, extension of shelf life, enhanced food safety, delivery of product information, recognition of brand identity, convenience of pre-prepared food or portion sizes, and more. In the supermarket today, consumers will find a wide range of packaging strategies that, although introduced in recent years for other reasons, are also helping to reduce household food waste. These central strategies that are widely available include:

- Resealability and split packs, to maintain product quality and freshness for longer;
- Transparency, to allow visual inspection and monitoring of product; and
- Smaller sizes, for convenience and portion control.

The benefits of packaging require trade-offs, namely added cost, reduced flexibility in purchase quantities, and a new source of waste. Packaging solutions have evolved over time to reduce these monetary and environmental costs. The pursuit of “efficient packaging” has emerged in place of “sustainable packaging,”⁶⁶ as stakeholders look to optimize the trade-offs between packaging’s benefits and its financial and environmental costs.

Contributing to the benefits side of the ledger, efficient packaging has an important role to play in responding to the problem of household food waste. Packaging can help consumers reduce waste by addressing a number of the consumer behavior-driven challenges mentioned above, primarily by

^b Primary packaging refers to unit-level packaging, whereas secondary and tertiary packaging is involved in parceling multiple sales units and aids transportation and distribution of sets of products.

extending the period of product freshness and safety. Basic packaging can be further optimized to enhance its contribution to reducing food waste, such as via:

- Expanding the use of transparent materials to enable consumers to see the quantity and state of food remaining in the package;
- Providing clear guidance for optimal storage conditions to maximize shelf life;
- Explaining the role of packaging in optimal storage to combat misperceptions about keeping food in the original packaging;
- Simplifying and explaining date labels to reduce the “when in doubt, throw it out” mentality; and
- Optimizing packaging formats and attributes, such as enhanced oxygen barriers, modified atmosphere or resealability for individual products.

Active and Intelligent Advanced Packaging

Beyond making tweaks to the messaging, format or size of what is now standard packaging, food industry stakeholders have new opportunities in front of them to use advanced packaging strategies to further reduce food waste in the supply chain and the consumer’s home. These up-and-coming strategies are further along the adoption curve in Europe than in the US, and include:

- Ethylene-absorbers;
- Advanced modified atmospheric packaging;
- TTI labels and color-changing packaging material; and
- RFID-enabled labels, including combined RFID-TTI.

Ethylene-absorbing strips and sachets are designed to increase the shelf life of fruits and vegetables by absorbing the ethylene produced by the food, which normally enhances ripening. The strips are placed inside produce packages and are invisible to the consumer. The technology is being rolled out by at least two major grocery retail chains in the UK, who estimate that their application could potentially save 1.6 million packs of tomatoes, 350,000 packs of avocados and 40,000 packs of strawberries per year.⁶⁷ The ethylene absorbers have been found to increase the shelf life of strawberries by 50%, increasing their longevity from 4 to 6 days.⁶⁸

Modified atmosphere packaging (MAP) swaps out normal air in sealed packages of food for low oxygen gases and gas mixtures. Carbon dioxide and nitrogen are common replacement gases. Using these other gases in proper combinations reduces the rates of decay and potential for spoilage of food products by reducing rates of respiration and inhibiting aerobic bacterial or mold growth.⁶⁹ Using MAP can increase the shelf life of food products prior to their first opening, enabling lower waste in the supply chain and the consumers’ home by keeping the product fresh for longer.

Time-temperature integrative (TTI) technologies track the integrity of the cold chain by indicating accumulated exposure of the product to temperatures conducive to more rapid bacterial growth. Unlike static “sell by” or “best before” dates widely in use today, which *assume* proper temperature

storage of the product, a TTI indicates actual product life remaining based on the true history of its handling through the supply chain, at retail and into the customer's home. TTIs take the form of labels or primary packaging itself. The TTI is calibrated to each specific product to indicate remaining shelf life based on the temperature tolerance of the food. For example, Figure 4 provides the shelf life decay rate curve for cauliflower based on storage temperature.

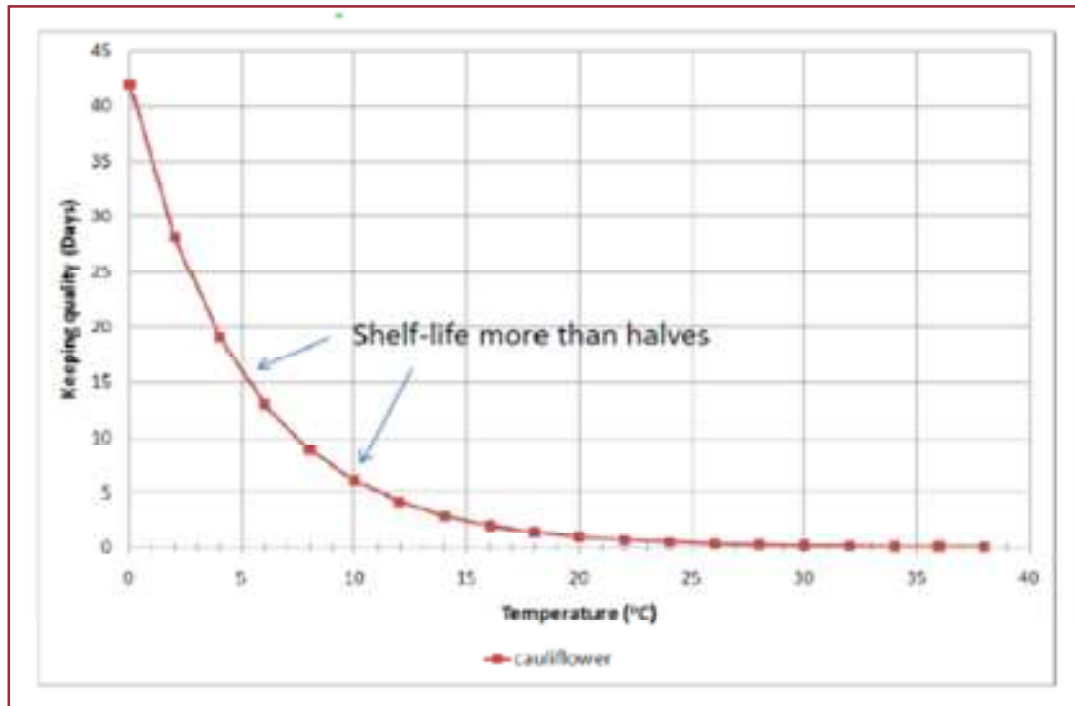


Figure 4: Fresh Cauliflower Longevity as a Function of the Temperature at Which it is Transported and Stored⁷⁰

TTIs can help reduce food waste by increasing the visibility of the importance of proper storage throughout the life of the food product. The label provides a visual cue to distribution and retail employees and the customer to maintain the product at proper storage temperatures. TTIs also allow food retailers to use a more efficient “Least Shelf Life, First Out” (LSFO) distribution and stocking system, rather than the common “First In, First Out” system.⁷¹ This switch can reduce waste by cutting the amount of product that spoils prior to sale from 22% to as low as 5%.⁷² Further, TTIs can replace the static and nearly meaningless date label, obviating the significant confusion date labels cause, although TTIs will have to be introduced in conjunction with clear messaging on how to read the new label. TTIs should also reduce consumer waste caused by the “when in doubt, throw it out” mentality, by providing an objective measurement of the remaining life of the product. However, retailers will have to monitor the potential for customers to sort through products – as some already do with date labels – to find the package with the greatest remaining shelf life according to the TTI. Efficient management, enabled by a switch to LSFO, should help mitigate this potential problem.

TTIs can be combined with radio-frequency identification (RFID) technology to further enhance the supply chain management utility of using TTIs. By combining with RFID, the exact point(s) of

temperature breach or break in the cold chain can be traced, allowing value chain participants to make modifications that address specific transportation, loading/unloading or storage challenges.

To contribute to sustainability, these packaged products must be evaluated from a full life-cycle perspective. This includes assessing trade-offs to achieve lower food waste through packaging, such as the potential to increase packaging cost and materials used, add logistical complexity in distribution or stocking, increase use of materials that are difficult to recycle, increase difficulty of composting food waste at intermediary supply chain steps and without sufficient communication, actually lead to static or increased consumer waste. In general, adding packaging to a product that would otherwise become waste requires one tenth of the resources that it takes to grow, manufacture and transport the food product that was saved from the landfill.⁷³ To illustrate the potential for optimizing packaging solutions to help reduce food waste, simply applying a thin plastic sleeve to cucumbers can increase their shelf life by more than a week.⁷⁴

While progress has been made, centered in Europe, numerous challenges exist to achieving optimal packaging to minimize food waste. These challenges are discussed next.

Considerations and Barriers to Realizing Packaging Solutions to Food Waste

The primary challenges that stand as barriers to adoption of optimal packaging strategies, such as resealability, TTI labels and ethylene absorption strips, which can contribute to reduced food waste in the supply chain and the consumer's home include:

- Lack of industry stakeholder knowledge of newer packaging technologies;
- Insufficient data to identify and prioritize causes and consequences of food waste, and even to recognize food waste as a significant cost to business and society;
- Added cost of some packaging strategies;
- Concern regarding consumer acceptance and understanding of changes to packaging; and
- Difficulty of influencing consumer behavior change.

Our secondary research and conversations with industry stakeholders reveal additional challenges that will require a concerted effort on the part of industry here in the US to overcome, namely insufficient collaboration among food industry players, lack of corporate and societal sustainability emphasis on food waste and the time intensity of developing product-by-product solutions in a very diverse industry.

Learnings from Past Experience in Packaging Change

Examples of successful and unsuccessful modifications to food packaging in the past shed some light on the challenges and possible path forward towards efficient and effective use of packaging to reduce food waste. The growth of resealable packaging is an example of a successful, but not fool-proof, consumer product packaging change. Resealability, as discussed previously, reduces food waste by helping keep a product fresher for longer after the manufacturer seal is broken by the

consumer. Resealability did not arise as a response to food waste, but rather as a means to maintain product freshness and quality longer and to provide additional convenience to the consumer. The application of resealability has grown as manufacturers and retailers discover the value to their customer of this added feature.

While some manufacturers have found that adding resealability to their packages has added to their production costs, this cost can be seen as a marketing investment, as research shows that consumers prefer, and are *often willing to pay more for*, resealable functionality.^{75, 76} This finding indicates that consumers can make the connection between packaging attributes, their satisfaction with the product, and its price, which is critical to making the case for adoption of such technologies as TTIs.

Experience with resealability also provides lessons on enabling the success of a packaging change. Most importantly, manufacturers learned that communication with consumers – that resealability is available, how to do it properly and what its benefits are – is critical to consumer adoption of the packaging change.⁷⁷ Such communication, including clear on-package messaging, will be important in future innovations to educate consumers on proper storage, the utility of the packaging and its advanced features and how to interpret smart labels.

Some packaging changes made in recent years have not been successful. The importance of communicating the benefits of a product and packaging change was made clear when concentrated laundry detergent first hit the market. The new smaller size was perceived as less product, not more concentrated. It was not until the product was reintroduced with better communication that consumers adopted the new format.⁷⁸

Consumer value-add from a packaging change is also an important success factor. Sun Chips, for example, launched a new chip bag in 2010 that was compostable. The change was a flop because the only difference perceived by consumers was that the bag was noisy – compostability did not provide value to the average consumer, particularly since the change was made ahead of most US consumers having access to composting facilities as a waste disposal option. As a result, Frito Lay halted use of the bags until it could make a quieter version, which it launched on a limited basis in 2011.⁷⁹

Discussion

Insights from Research and Conversations with Industry Stakeholders

Evidence across food products and packaging formats indicates that consumers desire product formats that deliver convenience, quality, safety and longer shelf life.^{80, 81} With technologies available to provide these attributes and also reduce food waste, why aren't these advances widely in use yet in the US food industry? In addition to our secondary research, which covered reports, press releases, company websites, conference proceedings, news articles and other resources produced by governments, academics, trade associations, news media, non-profits and private companies, we

spoke with a cross-section of industry stakeholders to gain a better understanding of the nuances of the challenge of bringing waste-reducing packaging changes to market in the US.

A number of critical gaps will need to be addressed in order for active and intelligent packaging to contribute meaningfully to reducing food waste in the US. Progress will be best achieved through a comprehensive industry response to consumer food waste to address these key gaps:

- A need for more knowledge and knowledge dissemination throughout industry about the availability and benefits of active and intelligent packaging advances;
- A need for a more granular understanding of the financial, environmental and social cost of food waste in the US and its key sources in the value chain;
- Insufficient collaboration and information sharing within and between food industry players, limiting dissemination of knowledge and the ability to build integrated value chain-based solutions;
- Although studies indicate the potential for positive acceptance of advanced packaging, such as TTIs,⁸² there is a need for better understanding of consumer preferences and behaviors that will affect uptake of such packaging advances;
- A need to take a supply chain view of the costs of some packaging advances, including the benefits they provide to the manufacturer, distributor and retailer that may (more than) offset the cost of the new packaging feature;
- A need to demonstrate the business case for advanced packaging to help reduce food waste in the supply chain and consumers' homes; and
- Development of clear and consistent messaging to consumers about the role packaging plays and how to make the best use of it to prevent waste and keep food fresh.

Strategies for Getting Started with Packaging Advances

Building from the an understanding of these gaps or barriers to successful implementation, there appear to be a number of channels and strategies to be applied to help get advanced packaging applications off the ground in the US. Based on industry experience with other packaging changes, it is possible for successful changes to be initiated by either the manufacturer or the retailer.

1. **Go for quick wins:** Implement those opportunities first that are less potentially controversial or disruptive due to their invisibility to the customer, such as ethylene absorbent strips. Getting started will help develop the communication and collaboration channels necessary within and between players in the food industry value chain.
2. **Pilot changes in-house:** Retailers with private label brands can pilot test packaging changes in their own product lines, over which they maintain control through a simpler chain of custody. Store brands also tend to yield higher gross margins for the retailer than do sales of branded items, making it more feasible to test out changes that carry small incremental costs.
3. **Start big and simple:** Develop processes and refine implementation of the technologies involved, such as TTI or RFID-TTI, by starting with pallet-level implementation on consumer

products, or by first applying the technologies to the food service industry supply chain, where unit volumes are higher and consumer behavior is not an issue, as opposed to the retail supply chain.

4. **Learn from others:** Reach out to and learn from the application of similar advanced packaging strategies in other industries, such as pharmaceuticals, chemicals and cosmetics.
5. **Create customer value:** Because the costs of retail packaging advances will almost inevitably be passed along to the consumer, the change should provide tangible value to the consumer, such as prolonged freshness of their purchase or enhanced confidence that the consumer knows when a product is safe to eat still.
6. **Timing helps:** Time changes in packaging with other changes in the product, such as a new product launch or a new generation of an existing product. This will allow the potential added cost of the packaging advance to be wrapped into the value-add of the new or improved product.
7. **Communicate:** Use changes to help train consumers to take note of instructions and other messaging on packaging that will help them understand the role of packaging and proper storage in delivering food waste reduction benefits.

The Business Case for Applying Advanced Packaging

There are business risks, upfront costs and technological challenges that reduce the incentive for manufacturers and retailers to “stir the pot” by implementing changes to retail packaging. However, there are potentially significant benefits waiting for those industry players who do decide to collaborate to bring these changes to market. These benefits include:

1. **A tighter, more efficient supply chain.** By identifying sources of food waste and engaging in collaborations with manufacturing and distribution partners, retailers will realize efficiencies in their supply chain. As supply chains grow longer due to globalization and industry concentration, efficiency gains that deliver more high quality, fresher product to the customer will have increasing value. This capability will become even more valuable as food prices rise due to increasing global demand.
2. **Better supplier relationships.** Collaboration initiated by the hunt to reduce food waste can help foster a new culture of symbiotic supplier-buyer relationships in the industry, and broaden those connections from salesman-buyer to all integration-relevant parties within partnering companies, such as supply chain or marketing managers.
3. **Consumer loyalty.** Retailer and brand loyalty may rise due to increased satisfaction with the freshness, quality, safety and longevity of their food purchases. Providing products and services that make the consumer’s budget go further by wasting less, and the rising awareness of corporate social responsibility activities can also contribute to positive loyalty outcomes.^{83, 84}

4. **Reduced waste.** Retailers and distributors, like consumers, will save money by reducing waste. Further, advances that better predict remaining shelf life, such as TTIs, will enable retailers and distributors greater opportunities to salvage unsalables as markdowns, food donations or compost, because they will be better able to identify product with insufficient shelf life remaining to enter the next step of the retail value chain.
5. **Customer expectations.** As awareness of food waste as a problem has grown in the UK, customers have begun to hold the food industry responsible for *consumer* waste.⁸⁵

The Value in Going Beyond the Packaging Basics

With resealability, single serve packaging and transparent materials becoming more of the norm in the grocery store and already providing a means to reduce food waste, why should food industry players go beyond these basic, proven strategies supplemented with a dose of consumer education?

- Some of the most problematic items, by value of food wasted, are not suitable for basic packaging strategies;
- Basic packaging strategies do not improve indication of food safety, which is the root of significant quantities of waste that follow from misinterpretation of date labels and a ‘when in doubt, throw it out’ mindset;
- Basic packaging strategies do not improve traceability of waste hotspots in the supply chain, nor do they incentivize or enable supply chain efficiency improvements among supply chain partners;
- Smaller portion packages reduce food waste at the cost of generating a non-trivial increase in per-serving packaging waste; and
- Resealability relies upon proper usage by the customer, whereas many advanced packaging strategies function properly independent of consumer behavior.

Recommendations to Food Industry Stakeholders

In addition to maximizing the potential of traditional supply chain solutions, such as collaborative forecasting and stock rotation, food industry stakeholders must engage with each other collaboratively to contribute to further reductions in food waste within corporate boundaries and to influence and enable consumers to also reduce their own waste. In light of the challenges, gaps, and potential benefits to business, society and the environment discussed in this paper, we recommend the following next steps to industry stakeholders:

1. **Strengthen industry collaboration.** The Food Waste Reduction Alliance is a great start to the US’s efforts to curb food waste. More in-depth collaboration is needed to make a real dent in the problem:
 - Broaden the collaboration to include more representation from diverse industry stakeholders, including government, NGOs, packaging companies, distribution companies, produce wholesalers and academics.

- Collect data. Good measurement of the problem is a critical gap in creating efficient and effective solutions.⁸⁶
 - Collect and share insights into consumer behavior as it relates to generation of food waste and reactions to information-based strategies and packaging changes.⁸⁷
 - Learn from each other by sharing successes and challenges. Research from the UK finds that different retailers have different waste profiles,⁸⁸ indicating an opportunity to learn from one's peers.
 - Set targets for food waste reduction within corporate boundaries and nationally.
2. ***Get to know your own company better.*** More communication within companies is needed to ensure the relevant parties are aligned in the pursuit of reducing food waste, both within corporate boundaries and outside. For instance, sustainability, supply chain, brand, marketing and packaging managers should be in close communication in order to capitalize on the best cross-functional solutions for the business.
 - Collecting comprehensive waste audit data, particularly by retailers, can help pinpoint the sources of waste and key wasted products from the point of receipt from supplier to the point of sale to the consumer.
 3. ***Get to know your supply chain partners better.*** Moving outside of one's own company, look up and down the supply chain to develop stronger relationships with your suppliers and distributors. Collaborative relationships along the value chain will open doors to integrated solutions that benefit the full supply chain.
 4. ***Don't ignore the consumer.*** With the majority of food waste occurring at the consumer stage in the US, their contribution cannot be ignored. While the focus of this paper is how companies in the food industry can enable consumers to waste less by using advanced packaging, companies should also become active in helping consumers reduce waste by addressing the information gaps and behavioral and psychological underpinnings of consumer waste. Educational and behavioral campaigns have been a key element of waste reduction success in recent years in the UK, led by the model "Love Food, Hate Waste" campaign. Strong lines of communication and a trusting relationship with the customer will be critical to the success of packaging changes that require consumer adoption. Models for influencing consumer behavior, such as Defra's "4 Es" – Enable, Engage, Exemplify and Encourage⁸⁹ – can be useful guides for this process.
 5. ***Keep abreast of new technology and try it out.*** Technology in the food industry is evolving. Stakeholders must keep an ear to these advances *and share this information* with the relevant parties within their organization. When potentially viable technologies are paired with waste hotspots identified through data collection, focus groups, pilot programs and other trial tactics should be used to test the market viability and food waste reduction potential of the technological advance.
 6. ***Be cognizant of trade-offs.*** Trade-offs and hidden consequences abound in integrated systems. Continued vigilance in weighing the benefits and costs – financially, environmentally and socially – of potential responses to food waste is critical. For instance, adding packaging

to a fresh vegetable extends its shelf life at the cost of packaging materials and likely adding a date label, which may cause a new source of food waste due to consumer over-reliance on these misunderstood labels.

Conclusion

The enormous amount of food waste in the US is a financial, social and environmental failure. Thirty three million tons of food waste was generated in the US in 2010,⁹⁰ resulting in one fourth of freshwater consumption and 300 million barrels of oil being wasted⁹¹ while 17.2 million American households were food insecure.⁹² As population and demand for food grow globally, and environmental degradation hampers agricultural productivity, we will simply no longer be able to afford to waste so much food. Before the price signal becomes inescapable, food industry stakeholders in the US have the opportunity to proactively address the problem of food waste. Collaboration, education and taking a full value chain approach are critical to both the viability of an industry-led response to this challenge and to obtaining results at the consumer level.

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