

Commentary

Mitigating Food Waste in the Retail Supply Chain: Marketing Solutions

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Food loss and waste is a global problem with an enormous magnitude. It has substantial economic, social, and environmental consequences. In this article, we focus on the problem of food waste, which is defined as loss of edible foods at the retail and consumption stages. Although not the main source of food waste in relative terms, retailers have a major role to play in food waste mitigation, by incentivizing upstream suppliers to reduce waste of resources and minimizing negative environmental impacts and by encouraging consumers to shift toward sustainable purchase and consumption behaviors. Given the close connection of marketing to retail operations and consumer behaviors, marketing scholars have the opportunity to make significant contributions in addressing the global food waste challenge. Our discussion focuses on how to mitigate food waste in retail outlets and by consumers through leveraging digital technologies and marketing knowledge. We first outline the economic, social, and environmental impacts of food waste, and then synthesize current mitigating practices by retailers. We discuss several technologies that are particularly important for mitigating food waste. Finally, we propose five areas that offer opportunities for future research and actions on food waste mitigation.

KEYWORDS

Sustainability, food security, retail management, digital technologies, consumer behaviors

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1. Introduction

Food loss and waste (FLW) is a global problem with an enormous magnitude. About one third of the food produced globally is wasted: about 45% of fruit and vegetables, 35% of fish and seafood, 30% of cereals, 20% of dairy products and meat (Lyons, 2015). According to the Food and Agriculture Organization of the United Nations (FAO), food loss refers to “the decrease in edible food mass at the production, post-harvest and processing stages of the food chain”, while food waste refers to “the discard of edible foods at the retail and consumer levels” (FAO, 2022).

Fourteen percent of total global food production is lost in the harvest and post-harvest production stages, and 17 percent of food produced globally is wasted at the retail, food service, and consumer stages (FAO et al., 2019; UNEP, 2021; FAO et al., 2022). A recent report by the UN showed that in 2019, 931 million tons of food were wasted, 61% of which came from households, 26% from food services, and 13% from retail, with an approximate value of \$650 million (UNEP, 2021). In the United States, about 40 million tons of food are wasted per year (RTS, 2022). Walmart, which accounts for over 20% of the US food market, alone

generates 3.5 million tons of food waste per day, resulting in an annual loss of \$7.4 billion (Kleinman et al., 2018).

The loss of edible food mass occurs at all stages of the supply chain, from production, harvest, and transportation to retail outlets and post-purchase consumption (Gustavsson et al., 2011). But the significance of these stages for food loss depends on characteristics of the food products in question, local climate, economic factors, infrastructure, and market conditions. In low- and middle-income countries (LMICs), more food waste occurs upstream in the supply chain. In contrast, most of the waste occurs downstream at retail outlets and households in high-income countries. Nonetheless, large differences exist within each income tier of countries, depending on local conditions.

Although not the main source of food waste in relative terms, retailers have a major role to play in food waste mitigation and stand to benefit from it (De Moraes et al., 2020; Huang et al., 2021; Vadakkepatt et al., 2021). In Western economies, retail outlets are the main providers of food to consumers. The retail industry is highly concentrated, which gives large retailers the market power to bring about changes both upstream to farmers, agricultural companies, and food manufacturers, and downstream to consumers. Because retailers hold a central position in the supply chain, they are well-positioned to play an active and crucial role in reducing food waste (De Moraes et al., 2020; Vadakkepatt et al., 2021).

Mitigating food waste is an essential element of sustainability. It has received increasing attention in many academic fields. Most prior research on food waste management has been conducted by scholars in agricultural economics, production engineering, food science, and supply chain management. Retailing lies at the intersection of supply chain management and marketing. Given the important role that retailers can play in addressing food waste problems, we believe marketing scholars have the opportunity to make greater contributions to addressing this global challenge. In this article, we focus on food waste mitigation in retail outlets and by consumers in high-income countries and discuss how such waste can be reduced through leveraging

digital technologies and marketing knowledge. We will first outline the economic, social, and environmental impacts of food waste, followed by synthesizing mitigating practices by retailers. We will then highlight several domains of technologies that are particularly important for mitigating food waste. In the final section, we will offer some conjectures on future opportunities for marketing research and actions on food waste mitigation.

2. Economic, Social, and Environmental Impacts of Food Waste

In the United States, 40% of food is wasted each year, with an estimated value of \$218 billion, amounting to 1.3% of GDP (Chang, 2021). Reducing food waste in line with UN Sustainable Development Goal (target 12.3.1) has the potential to significantly affect economic growth and create job and business opportunities. For example, according to Refed (2021), investing \$140 billion in food waste reduction programs in the U.S. over the next ten years would decrease food waste by 45 million tons each year, result in over \$70 billion in annual net financial benefit, and create more than 50,000 jobs. Low- and middle-income countries have even more to gain from those economic opportunities.

Food waste has not only enormous economic impact but also profound social and environmental consequences. About 35% of the world's land mass is devoted to agriculture. Agriculture is the largest cause of deforestation and biodiversity loss. Seventy percent of the world's freshwater resources are used in agriculture and this sector is responsible for about a quarter of CO₂ emissions causing global warming (Jaglo et al., 2021). In addition, agricultural use of fertilizers is a major source of pollution. Food waste needlessly contributes to pollution and greenhouse gas emissions. Food packaging disposal, especially plastics, is another source of major environmental concern. The reduction of food waste has therefore been seen as an important solution to the climate crisis (Jaglo et al., 2021).

At the same time, food shortage is a persistent problem in many parts of the world. In 2020, almost 10% of the world population was undernourished, and

food production needs to increase by 70% to feed the world population by 2050 (UN, 2022). Malnutrition in children is irreversible at the age of two years, and it can result in poor brain development, obesity, and diabetes later in life. In the United States alone, almost 50 million people are food insecure in 2022, and 19 million people live in so-called food deserts with insufficient access to affordable fresh food (Annie E. Casey Foundation, 2021). Generally, urban planning and zoning laws impact retail store locations, availability, and consumer food shopping and consumption behaviors (Hebinck et al., 2021). Food waste drives up food prices, especially for fresh food, which disproportionately affects lower income consumers. The 690 million hungry people in the world could be theoretically fed from one quarter of the food that is wasted in Western economies, and the water used in producing wasted food could satisfy the needs of 9 billion people.

Consequently, in its Sustainable Development Goals (SDGs), the United Nations has formulated the specific target to reduce global FLW at the retail and consumer level by 50% by 2030, in addition to reducing food losses during the harvest, post-harvest, and production stages (UN, 2015; SDG Target 12.3). In 2021, the UN Food Systems Summit (UNFSS) initiated novel actions that should bring about progress on food waste reduction. There are a variety of policy initiatives in the U.S. and around the world that aim to reduce food waste. For example, Champions 12.3 is an international coalition of executives from governments, businesses, research institutions, and farming groups that works toward achieving UN SDG Target 12.3 by 2030. In the U.S., the Environmental Protection Agency (EPA) has launched initiatives to create awareness of and implemented policies for food waste reduction. In addition, California passed a law in 2022 that requires retailers to donate unsold food and tasks cities and counties to come up with local plans. Reducing food waste has gained priority in policy, social, environmental, economic, and business domains.

Recognizing the urgency of the food waste problem, many retailers have taken concrete actions to mitigate the problem. For example, Kroger has set a goal to achieve zero food waste by 2025 (Kroger, 2022). Large

food retailers like Walmart, Kroger, Albertsons, Ahold Delhaize, and Aldi are among the 45 companies designated by the United States Department of Agriculture as 2030 food waste champions, which have committed to cut their food waste in half by 2030 (U.S. Department of Agriculture, 2022). In the next section, we will synthesize food waste mitigation programs in retail practices.

3. Food Waste Mitigation Program in Retail Practices

Driven by increasing consumer demand and regulatory and competitive pressures, retail companies are increasingly embracing environmentally and socially responsible corporate strategies. Specific strategies are taken to prioritize sustainable and/or local sourcing, employee well-being, consumers' healthy lifestyle, animal welfare, as well as reducing pollution, energy usage, and waste (Vadakkepatt et al., 2021). In these strategies, sustainability is an integral part of growth and profitability goals. The retail industry is a high volume and low margin business. Reducing food waste has the direct benefit of lowering costs for retailers. While part of the cost savings may be passed on to consumers in the form of lower prices, food waste reduction is likely to increase profitability and enhance corporate image (Kor et al., 2017).

Reducing food waste fits into retailers' broader mission of Sustainable Supply Chain Management (SSCM), which focuses on reducing, reusing, and recycling of materials by augmenting the standard supply chain with a reverse supply chain that enables the flow of information, packaging materials, and products back from consumers to producers or resellers (Vadakkepatt et al., 2021). Retailers can play a central role in mitigating food waste at all stages of the supply chain. In terms of upstream suppliers, they can incentivize suppliers to reduce the resources and materials used in food productions (such as water, energy, and packaging materials) and minimize their negative environmental impacts. In terms of downstream consumers, retailers can leverage a variety of marketing actions to enable and encourage sustainable purchase and consumption behaviors (see Vadakkepatt et al., 2021, Table 2, for examples).

Retailers have already made great strides in managing food waste through mitigation programs in their own operations. Generally, European retailers have led the way in this effort. For example, the percentage of overall food waste generated by retailers is estimated to be 5% in the European Union (Stenmarck et al., 2016), 8.9% in North America (Harris, 2021), while it is about 13% worldwide (Putnam, 2021). According to the EU Waste Framework Directive, the most preferred mitigation option is waste prevention and reduction, followed by reuse, recycling, and energy recovery. Many retailers follow this hierarchy when designing and implementing their food waste management programs (Huang et al., 2021).

De Moraes et al. (2020) link the causes for food waste to mitigation practices in retail operations. They identify several major causes for food waste, such as stringent standards for food appearance, poor demand forecasts and inventory management, and improper packaging and handling during transportation. Huang et al. (2021) and De Moraes et al. (2020) chart food waste mitigation practices currently used by food retailers, echoing some of the strategies proposed earlier for that purpose (UN, 2022). The two most important categories of practices are: (1) waste reduction and prevention, and (2) surplus food reuse.

With respect to the first category of *waste reduction*, Huang et al. (2021) organize retailers' food waste reduction programs based on their internal vs. external orientations. *Internal operational changes* include improving merchandising decisions such as assortments (e.g., offering imperfect produce, reducing breadth and depth of assortments), pricing, and promotions (e.g., dynamic pricing based on expiration dates, food waste reduction campaigns via in-store displays, pamphlets, and websites). They also include enhancing product packaging (resealable packs, reduced pack sizes, reusable packages, packs that prevent handling damage and extend shelf life) and improving internal processes (staff training, investing in technology for tracking, recording, and forecasting food sales and waste, and inventory and shelf space management). *External operational changes* involve enhancing the efficiency of planning, ordering,

forecasting and supply chains, purchase guarantees to food producers, and more flexible cosmetic standards. Cooperation with food producers, for example by sharing forecast data and knowledge of productivity-enhancing techniques, helps them optimize food production plans. Cooperation with farmers, food manufacturers, distributors, NGOs, and governments is a critical aspect in developing sustainable retail practices. In the second category of *surplus food* reuse practices, many retailers have routine programs of donating to charity organizations and re-processing food (e.g., rescue-based food). In addition, a small number of retailers have put in place programs of reselling via specialist discounters and secondary market platforms or swapping arrangements with distributors (Huang et al., 2021).

4. The Role of Technologies in Food Supply Chains and Waste Reduction

Technologies have been an integral part of food supply chains and waste reduction programs (ITU, 2021). In this section, we highlight several domains of technologies that are particularly important for mitigating food waste in the retail supply chain.

4.1. RFID and Blockchain

Radio Frequency Identification (RFID) labeling of products enables contactless identification of products via radio signals and automated collection of information on the flow of products through supply chains. RFID technology enhances retailers' abilities to share data with suppliers and to improve production planning, creating hyper-transparent supply chains and contributing to food waste reduction through improved synchronization and coordination between channel members (Nikolicic et al., 2021).

Blockchain technology holds the promise of further increasing efficiency in the supply chain (Reichental, 2019). Blockchain recording platforms provide a digital record of any transactions along the supply chain, and thereby improve transparency, reliability, and efficiency. Blockchains can be used to monitor each shipment of food at every touchpoint in the supply chain and to produce a detailed record accessible to each party in the supply chain, including the conditions under

which it was grown, harvested, processed, and stored. For example, Walmart has partnered with IBM on using blockchain to enhance food safety, by requiring all suppliers of green vegetables to use it. This has reduced the amount of time to track down the source of food from about seven days to a little over two seconds (Miller, 2018). This tremendous gain has improved not only food safety but also sustainability and food waste reduction (Park & Li, 2021).

4.2. Data Analytics and Artificial Intelligence (AI)

Data-driven decision making is critical in improving food waste mitigation programs at all stages of the retail supply chain, including production, transportation, inventory management, and merchandising decisions (see Afresh.com and Neurolabs.ai as examples). Accurate demand forecasting is essential to efficient procurement and inventory management. Shopping basket data and stock-keeping unit (SKU) level sales data collected through point-of-sale (POS) check-out systems have long been used to make demand forecast for food products. Loyalty program data provide individual-level purchase history information and thereby enable more accurate (individual-level) forecasts. With the development of E-commerce operations in food retailing, online browsing and purchase data offer even richer information on shopper behaviors, which can further enhance preference predictions and demand forecast at the individual household or consumer level. Marketing researchers have developed a rich body of data analytics tools for demand forecasting. Recent developments in machine learning and AI provide exciting opportunities to further enhance the predictive power of existing retail decision support systems and to develop new tools and frameworks for food waste mitigations (Frost, 2022; Magnin, 2019).

In addition to recording sales and shopping activity data, tracking expiration date, in-store inventory, spoilage, and waste is critical for designing an effective food waste reduction program. For example, Delhaize tracks food waste using scanner data and waste separation data (CEC, 2022). Such data tracking infrastructure, coupled with machining learning techniques and AI, presents a powerful way to mitigate food waste

in retailing. For example, the systems can be used for improving assortment management, inventory planning, promotion plans, and dynamic pricing of foods close to expiration (Wasteless.com). In addition, AI can be used to predict and optimize the re-purposing of foods for in-store meal bars, delis, smoothie bars, and so on. In addition, it can be used to build product recommendation engines for customized promotions that can reduce food waste. Online recipe-based shopping experiences (single-click add-to-cart recipes) can also be used to reduce overstock inventories. Moreover, retailers can utilize their private label brands in their food waste mitigation efforts, because of the flexibility and speed in implementing markdowns. Finally, data analytics and AI enhance retailers' ability to connect in real-time with partners of food waste mitigation programs, such as food banks, other charity organizations, and second-hand hard discount resellers. As an example, Kroger uses cloud storage and computing to find patterns in their store data and data from food bank partners to optimize opportunities for food donations to meet their goal of 3 billion meal donations by 2025 (Intrakamhang & Ryckman, 2020).

4.3. Digital Platforms

Digital platforms are two-sided markets enabled by mobile or internet applications that support interactions between two (or more) user groups which stand to benefit from the economies of scale that may result (Wikipedia, 2022). A variety of digital platforms promote sustainable food consumption. They can be consumer-to-consumer (C-to-C), business-to business (B-to-B), or business-to-consumer (B-to-C) platforms. For example, B-to-C platforms include those that enable local food markets (e.g., Reko-rings.com), click-and-collect of discounted near-expiration foods (e.g., Flashfood.com), direct to consumer sales of imperfect foods (e.g., hungryharvest.com, imperfectfoods.com), sales of past-sell-by-date products (e.g., TooGoodToGo.com), sales of boxed meals (e.g., hellofresh.com), and discounted after-hours restaurant meals (e.g., Foodforall.com, goMkt.com). C-to-C platforms mostly enable food sharing among consumers (e.g., Olioex.com, FoodRescueHero.org). All these apps aim to help consumers develop new

ways to acquire food. B-to-B platforms often facilitate communications between retailers, restaurants, and caterers on the one hand, and food charities on the other hand (e.g., Foodcowboy.com, Goodr.com).

Furthermore, there are non-platform apps that help consumers with home inventory management (e.g., fridgelyapp.com, nosh.tech), restaurants and kitchens with food waste management (e.g., Winnow.com), and food producers with assessing perishability of their food (e.g., Impactvision). While some of these platforms have seen marked successes, others have not yet been as successful in changing consumers' behaviors (Fuentes et al., 2021). Reasons include the limited functionality and glitches of some apps. In addition, it may not be easy to integrate these apps in consumers' habitual behaviors of food acquisitions (Fuentes et al., 2021). Nonetheless, as technologies continue to improve, digital platforms hold great promise in increasing the efficiency of food distribution and reducing spoilage and waste in the future.

5. Moving Forward: Challenges and Opportunities

Great progress has been made in mitigating food waste around the world. Yet, much still needs to be done to tackle this global problem. We highlight five areas that need more attention and actions (Figure 1). Marketing researchers and practitioners can make significant contributions to addressing problems in these areas.

1. *Standardizing food waste measurement and doing it at a more granular level.* Much research has been done to quantify the extent of food waste, especially by scholars in agricultural economics, production engineering, and supply chain management. Although there has been some progress in establishing standards for measuring food waste, data availability is still limited, especially from low- and middle-income countries (LMICs) (De Moraes et al., 2020; UNEP, 2021). Most prior research has focused on quantifying food wastes by country, stage of the supply chain, or source of food waste (see Parfitt et al., 2010, Eberle and Fels, 2016, Teller et al., 2018 for reviews of each group of studies). Detailed multi-market comparisons both within and across geographic regions can shed light on sources

of inefficiencies in food distribution and retailing. In addition, research is needed at a more granular level, such as by the type of retail outlets and food services, product category, and household income level. Among a variety of data sources used to measure household food waste (see Withanage et al., 2021 for a review), household-level panel data offer opportunities that have to date remained untapped. Moreover, retailers need to put in place tracking systems to monitor and measure food spoilage and waste at the retail-level in real time. Many of them still do not have a good handle on this issue. It would require a change of mindset for retailers to realize the importance of tracking waste as the first step in identifying the sources and designing and testing waste prevention and reduction programs. Marketing research companies and scholars can play an important role in helping retailers develop, implement, and test the effectiveness of technologies, build dashboards, and create and validate standardized tracking systems.

2. *Optimize food utilization close to expiration dates.* While many retailers have implemented food waste prevention programs, only a small number of them have routine programs in place to reuse and repurpose food close to expiration dates (Huang et al., 2021). In fact, even the designation of food expiration dates lacks standards and government regulations (e.g., Frasz, 2013). The common practices of dealing with food close to expiration dates are dynamic pricing and price discounts, production of rescue-based food (such as deli meals), charity donations, and selling to specialist hard discounters or secondary-market platforms. A combination of these practices may be optimal. Yet many retailers simply dispose of food close to expiration dates or end of shelf life. Consumer perceptions of "use by" date labelling and suboptimal food products play an important role in designing effective food waste reduction programs by retailers (Aschemann-Witzel et al., 2017; do Carmo Stangherlin et al., 2019; Wilson et al., 2017). While prior studies have shown consumers' concerns over food close to expiration dates, how to design retail interventions to repurpose, reuse, and promote these seemingly undesirable yet still

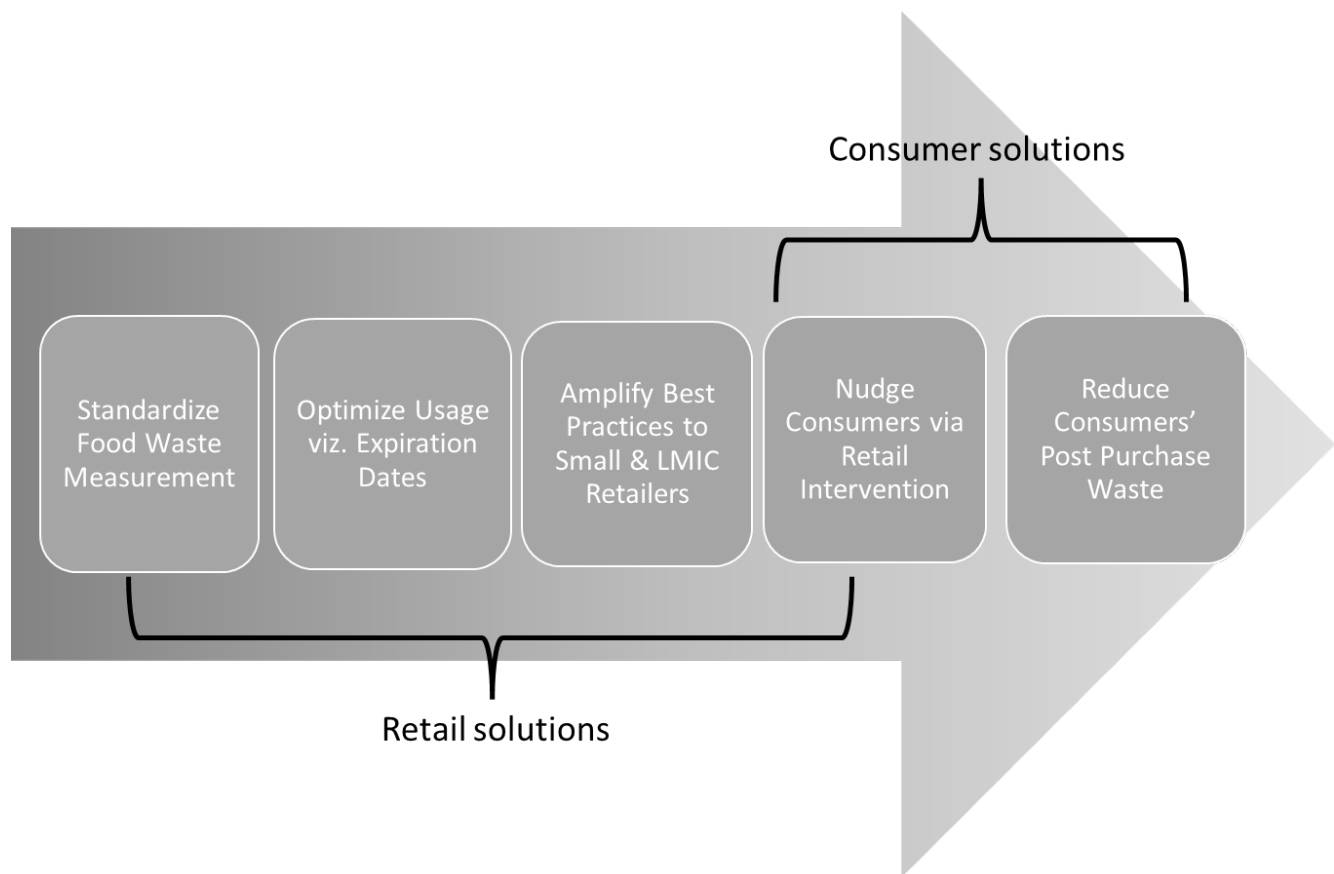


Figure 1. Five Areas for Future Research and Action on Food Waste Mitigation.

perfectly edible food remains a big challenge that deserves more research. In addition, the emerging retail format of stores selling suboptimal foods has only begun to receive attention by academics in recent years (Aschemann-Witzel et al., 2020). More marketing research is needed on consumer purchase behaviors and retail strategies in this new context.

3. *Amplifying good practices to small local retailers and retailers in LMICs.* The retail industry, especially in high-income countries, has made significant progress toward reducing food waste through various mitigation programs. Yet there is a huge discrepancy between large national and multinational retailers and small local retailers, and retailers in emerging markets. It requires significant resources and institutional efforts to achieve SSCM. Technologies such as blockchain and RFID are still beyond the reach of many small

businesses, especially those in LMICs. These small and medium sized businesses often lack internal capabilities to utilize data analytics and AI for accurate demand forecast and inventory management. Small retailers in high-income countries may face constraints of urban planning, infrastructure and zoning laws that influence availability, supply chains, and consumers' shopping and consumption behaviors. The challenges facing retailers in emerging markets vary largely according to the local conditions and the nature of the retailing business. According to a review article by Rolker et al. (2022), the majority of intervention programs in LMICs focused on food loss preventions in the production, storage, transportation, and processing stages, while only a small fraction of programs targeted food waste mitigations at the retail and consumption stages. A big challenge facing the retail industry is how

to amplify good practices of food waste reduction programs by large and sophisticated retailers to resource-and-infrastructure constrained small local retailers and those in LMICs. Addressing this challenge will require creative thinking, agility, and collaboration among retailers, retail federations, suppliers, and academic researchers.

4. *Nudging consumers toward more sustainable purchase and consumption behaviors through retail intervention programs.* Modern retailers have made great strides in reducing food waste in their retail operations. Yet they still have a long way to go in designing and implementing intervention programs to nudge consumers toward more sustainable purchase and consumption behaviors. Prior research has documented a large intention-behavior gap of consumers' stated desire for sustainability and a lack of actions to follow through (see [White et al., 2019](#) for a review on this topic). A big challenge involves identifying ways to create opportunities that incentivize and encourage behavioral changes to reduce this gap. The academic marketing field has generated a wealth of knowledge on consumer psychology and behavioral mechanisms, as well as expertise in quantifying the impacts of intervention programs. [Calvo-Porrall et al. \(2017\)](#) have proposed several marketing actions that can mitigate food waste, such as eliminating buy-one-get-one-free promotions and raising food waste awareness. There is a great opportunity for marketing scholars to conduct more research and work with the retail industry in designing and evaluating retail intervention programs aimed at helping consumers reduce food waste at the purchase and post-purchase stages.

5. *Reducing food waste at the post-purchase stage.* According to the 2021 Food Waste Index Report by the United Nations Environment Program, 61% of global food waste occurs during household consumption, making this stage the single largest source of food waste ([Putnam, 2021](#)). Yet, food waste at the post-purchase stage is also the least studied domain. A variety of socio-cultural and material factors influence household food waste ([Hebrok & Boks, 2017](#)). More research is needed to understand the causes for food waste at this stage, which may vary by country,

lifestyle, income level, local infrastructure, degree of urbanization, residence/dwelling type, etc. In addition, like in retail operations, more accurate measures of food waste in households at more granular levels are needed. It may seem that retailers have little to benefit from helping consumers reduce food waste, but research should investigate whether such behavioral changes may result in more repeat purchases and deeper customer loyalty for retailers. Based on a thorough understanding of the causes for and types of household food waste, researchers, consumer advocates, and public policy makers can utilize technologies to inform, educate, and help consumers with better planning and budgeting. For example, [Woolley et al. \(2022\)](#) developed a data-driven recipe suggestion tool which considers household food inventory and expirations dates. In addition, e-commerce platforms can make just-in-time deliveries of food more convenient and affordable, which can reduce over-purchasing. Moreover, technologies such as expiration checking apps, meal plan apps, and community-based food sharing apps can play a large role in reducing household food waste. The internet-of-things and smart devices have the potential to revolutionize consumer experiences ([Hoffman & Novak, 2018](#)), and thus they could become very relevant to food waste reduction in the foreseeable future. For example, smart refrigerators linked to online shopping apps can track at-home food inventory and expiration dates in real time and make purchases and replenishments automatically, which takes away the need to over-purchase in exchange for fewer shopping trips.

In conclusion, we have sketched the magnitude of the FLW problem and its business, economic, social, and environmental impacts, with an emphasis on food waste at the retail and consumption stages in high-income countries. We have outlined the progress that has been made in the retail industry and highlighted the role of digital technologies in mitigating the food waste problem. We propose five areas that marketing scholars and retail practitioners can work on to make significant contributions to this important topic. We hope that this article will stimulate ideas, research, and actions to help mitigate a major sustainability problem facing the world, not only in high-income countries but

also in LMICs.

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LUMINOUS
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