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ORIGINAL EMPIRICAL RESEARCH

The food production–consumption chain: Fighting food insecurity, loss, and waste with technology

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Abstract

The UN's Sustainable Development Goal (SDG) 12 seeks to achieve sustainable food production and consumption, including reduced food loss and waste; SDG 2 proposes the goal of zero hunger. In pursuit of these goals, technology arguably has a central role, at every level of the food value chain. To establish this role, the authors identify and examine current technologies aimed at increasing food production and suitably redistributing unused food, as tactics to combat food loss and waste, with the shared end goal of reducing food insecurity. A proposed 2×2 typology illustrates how existing technologies can influence food production, distribution, and consumption, as well as influence the stakeholders in the food production–consumption chain. These insights also inform a research and development agenda pertaining to the need for technology applications that can increase food production and/or reduce food waste effectively enough to achieve the goal of zero hunger.

Keywords Sustainability · Food production · Food waste · Technology · Food insecurity

Achieving sustainable food production and consumption and reducing food loss and waste represent central features of the UN's Sustainable Development Goal (SDG) 12; zero hunger is the primary objective for SDG 2. Both priorities reflect relevant concerns about both global food insecurity and staggering estimates of food loss and waste; according to the U.S. Department of Agriculture's Economic Research Service (2010, p. 1), about 30% of the 430 billion pounds of food available goes uneaten, amounting to $162 billion in food lost, or "1.2 pounds of food per person per day." Other estimates similarly approximate that one-third of all food produced gets wasted and that farms lose 20 billion pounds of food annually (FoodPrint 2018), due to overplanted fields, damage to crops from pests and weather, or low market prices that make it unprofitable to harvest and transport products (Azevedo 2021). Yet globally, nearly 200 million people lack "consistent access to enough food for an active, healthy life" (Brown et al. 2019, p. 980; see also Gustafson 2022; UNWFP 2021), and 600 million people suffer from hunger (Bernabe 2022).

Both (i) food loss, i.e. edible food—post harvest—that is available for human consumption, but then is not consumed, and (ii) food waste, which is a subset of food loss, occurs after customers acquire food, but then goes unconsumed (Buzby et al. 2014, p. 5), are pressing issues. For example, end-consumers might buy and cook more than is needed, then discard the excess. Retailers engage in excessive ordering (Buzby et al. 2014; U.S. Department of Agriculture 2023), struggle to store food, and discard unattractive or blemished food (Grewal et al. 2019). At the farm level, food gets destroyed by pests or weather; issues in harvesting, drying, or processing foods also leads to inefficient production (Buzby et al. 2014; U.S. Department of Agriculture 2023).

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Yet oversupply also can have negative downstream effects, if insufficient post-harvest preservation leads to substantial losses of abundant harvests (Azevedo 2021).

In this sense, increasing food production is necessary to combat global food insecurity, but it is not sufficient to eliminate world hunger (Azevedo 2021), which also requires reducing food waste. According to the preceding statistics, retrieving wasted food would provide more than four times what is needed to relieve undernutrition and hunger worldwide (Azevedo 2021). Yet such a complex, persistent, global challenge needs innovative approaches, for which technology might be key. We argue that technological innovations, directed at different parts of the food chain, can establish new means for expanding the metaphorical food pie (i.e., increase production and reduce inefficient production) and effectively distributing that food pie in ways that reduce food waste and loss (SDG 12) and move toward the goal of zero hunger (SDG 2).

Some companies already are testing pertinent new technologies. Consider food production to start. In Kenya, the Seed Trade Association's Mbegu (Seed) Choice program aims to help farmers select appropriate seeds that match their land and weather conditions, as well as their crop preferences. By inputting information pertaining to the country, ecological zone, and crop details, farmers receive personalized, optimal seed recommendations (Senthilingam 2017). In China, ongoing laboratory experiments seek to develop seeds that can yield greater output, using fewer resources (e.g., water), even in extreme weather conditions (Kaizhi 2022; Pultarova 2022). One engineered wheat crop, Lunyan 502, grown from seeds developed in outer space, offers 11% greater yield than traditional Chinese-grown wheat, uses less input, and provides greater resistance to pests. In a partnership, tractor company John Deere and drone-based transportation company Volocopter developed the VoloDrone, which features a tank and sprayer that can dispense appropriate amounts of fertilizers, pesticides, and anti-frost chemicals from the air. Recent efforts aim to expand its capacities, such as sowing seeds (Etherington 2019). In addition to increasing usage efficiency of seeds, frost control, pesticides, and so on, this technology offers new methods to reach croplands with challenging topography (Mohan 2020). VoloDrone also might facilitate sustainable farming practices, such as ecological farming, by spreading natural materials where they are most needed.

Turning to food redistribution, we find technologies by Food for All (United States) and Too Good to Go (United Kingdom) that help restaurants sell or donate food, at substantial discounts, in the hour before they close; Food Rescue (United States) relies on an algorithm to connect sources of food donations with homeless shelters and other organizations that aid populations that are food insecure (Bozhinova 2018). Such technology-enabled food (re)distribution tools can benefit both the supply side (decreasing the amount of wasted food) and the demand side (getting resources to people who need them).

Artificial intelligence (AI) also has turbocharged the impact of such technological solutions, due to its relative advantages over prior methods (e.g., better, more cost-effective predictions; Davenport et al. 2021) and access to higher quality and expanded data. Cocoa growers in Ghana had been struggling with poor efficiency, due to climate change and new diseases and pests, but a newly developed, AI-based predictive crop monitoring platform called CocoaSense helps them manage and monitor crops by providing "weather-based advisory and promote[s] climate-smart agriculture. In addition, farmers benefited from timely and dependable pest and disease alerts" (www.cropin.com). Farmers using the platform reported a threefold increase in efficiency. This tool relies on AI and its predictive capabilities, which in turn depends on the availability of good data gathered from both farm sensors and satellites.

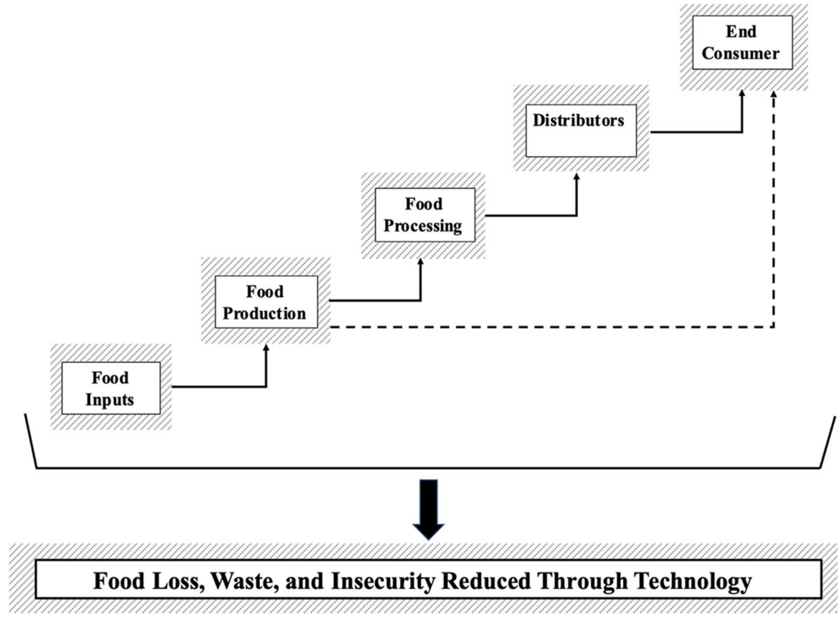
Another example involves Lumitics, which works with hotels like The Four Seasons in Singapore and airlines like Etihad, using AI to track exactly which foods are being wasted. When food gets thrown in garbage cans, a combination of cameras, sensors, and AI technology determine the type of food discarded (e.g., steak, bananas) and the reason (e.g., spoiled, uneaten, scraps). The service providers then can identify avoidable waste, which gives chefs insights into how to order the food for their menus more efficiently. For example, Lumitics technology might show hotels that they do not need so many croissants on their breakfast buffet or reveal to airlines that they can order fewer box lunches—strategic choices that reduce food waste (and costs) without affecting food quality or service standards. The increased food available in the system also might be rerouted to consumers who are food insecure (Gunia 2021).

In line with these real-world, current examples, we examine the entire food production–consumption chain,[1] starting with crop inputs and moving through the chain to end-consumers' waste and disposal choices (Fig. 1). Building on insights from practice and relevant literature, we predict how technology might influence *all* stages of the production–consumption chain, in ways that enhance inputs and increase food production, optimize food (re)distribution, and reduce loss and waste in various stages to combat food insecurity. In turn, we propose a 2×2 typology of how technologies determine the food pie, according to the stakeholders in the food production–consumption chain they target. This typology reflects findings from interviews with eight key informants in the food industry (see Appendix 1), triangulated with extant literature.

In turn, this article offers three contributions. First, we prioritize the role of technology (including – but not

[1] We focus on food production pertaining to agriculture, as opposed to livestock or aquaculture.

Fig. 1 Food production–consumption chain



restricted to—AI) for reducing food insecurity, loss, and waste. Technology can increase the amount of food produced, help distribute existing food more equitably, and thus minimize loss and waste. Second, we propose a typology of how existing technologies affect the metaphorical food pie and which stakeholders they target. With this typology, we identify critical technological gaps pertaining to efforts to reduce food insecurity, loss, and waste. Third, we offer an agenda for further research in this area.

The food production–consumption chain

Overview

The food production–consumption chain consists of five (somewhat overlapping) stages (Fig. 1). First, the food input stage involves decisions about food inputs, whether to plant crops, which types of seeds or fertilizer to use, and so on. Second, the actual growing or food production stage differs by crop. Some take longer to grow, while others grow quickly; some products can be grown across multiple seasons, but others have only a single growing season. After the food is grown, it must be harvested. Third, food processing involves the transformation of agricultural products into food (e.g., rice gets cleaned, husked, polished, and suitably packaged). Processing encompasses any steps needed to make the food suitable for distribution and ultimate consumption. We thus define processing broadly, to encompass many different forms, from grinding grain to make flour, to home cooking, to complex industrial methods that produce convenience foods. Fourth, distributors (midrange entities, intermediaries), including retailers, restaurants, governments, and public entities, acquire food that has been processed for their use. Fifth, the last stage culminates with end-consumers, who engage in consumption, disposal, and waste practices.

Food loss and waste occurs across all stages of this chain, but they become relatively more intense in later stages. In the United States, approximately 43% of total food waste comes from households and 40% from retailers (e.g., grocery stores, food service companies, restaurants). Thus, less than 20% of food waste occurs at farms (food inputs, growing, harvesting stages) or during processing (Recycle Track Systems 2023). These statistics vary somewhat by country and region. Globally, about 14% of food waste occurs during transportation between the harvesting and retail stages, but this percentage is higher in less industrialized countries where technology to keep food fresh during transport is less accessible. For example, only about 5–6% of food is wasted between harvest and retail in Australia and New Zealand, whereas it reaches 20–21% in Central and South Asia (Global Agriculture, 2019). Block et al. (2016) thus suggest that improvements to food distribution systems (food input, growing, production) should have greater impacts in developing countries, but reducing food waste at the retailer and consumer stages is more critical in industrialized countries. That is, technology should have substantive impacts on all stages of the food value chain, but those impacts also may vary by region.

Objectives across the food production–consumption chain

To specify improvement objectives, we turn to buyer–seller literature as it applies to the food production–consumption chain. Distinct buyer–seller relationships appear throughout the entire food production–consumption chain, such that the entities that provide food inputs to food producers represent sellers, while the food producers are buyers. Then food producers function as sellers that interact with food processors as buyers.

Buyer–seller relationships generally seek both pie expansion (Jap, 1999) and pie sharing (Jap, 2001). *Pie expansion* refers "to the collaborative process of creating mutually beneficial strategic outcomes between buyers and suppliers" (Jap, 1999, p. 461), such that the joint benefits (i.e., benefits pie) expands more than could have been achieved if buyers or suppliers were working in isolation. A key driver of pie expansion is enhanced buyer–seller coordination (Anderson & Narus, 1990; Dwyer et al., 1987; Heide & John, 1992; Jap, 1999), such that the parties share information, opportunities, and knowledge that help them generate competitive advantages and the overall value available to them. In line with resource-based theory, greater outcomes (bigger pies) result from the dyadic resources that arise from coordinated, collaborative efforts. To combat food insecurity, pie expansion would imply that more food gets produced throughout the food production–consumption chain. When two entities work jointly to create mutually beneficial strategic outcomes related to food production, the food pie, as well as the profits for both parties, likely expand.

In contrast, *pie sharing* involves the division of the value created in a buyer–seller dyad, often viewed "as a competitive process… [that] emanates from game theoretic research in economics and psychology" (Jap, 2001, p. 86). Equality and equity guide pie sharing, in line with equity theory (Walster et al., 1978), "which states that people judge an outcome as fair when the ratio of their own resources and output equals the ratio of resources and output of comparison others" (Jap, 2001, p. 89). The fight against food insecurity also relates to equity, because it requires that people who endure food insecurity attain suitable relief.

So when is pie expansion the primary objective, relative to pie sharing? Block et al., (2016; e.g., their Fig. 2) outline concerns across the food production–consumption chain, such that in the initial stages, concerns (and objectives) primarily relate to pie expansion, but in the later stages of the chain, concerns (and objectives) pertain primarily to pie sharing. Such reasoning is consistent with research in other marketing domains. In studies of product lifecycles for example, Lumpkin and Dess (2001) find that in earlier lifecycle stages, firms focus on proactiveness, to gain market opportunities, but in later stages, they prioritize aggressiveness, to deal with competition.

Consistent with these insights, we propose that in the initial stages of the chain (i.e., food input, production, and processing), the objective is pie expansion, so beneficial uses of technology would promote buyer–seller coordination. In later stages (i.e., food distribution and end-consumers), the objective is pie sharing, and beneficial uses of technology would entail equity-oriented food sharing. We describe these various stages of the production–consumption chain, together with examples of how technologies might promote coordinated pie expansion efforts or equity-oriented pie sharing endeavors, next.

Additionally, as noted earlier, food-related issues vary in different countries, and, thus technology that helps to expand the pie versus more equitably share the pie will also be more/less effective in different countries. For example, in developing countries such as Mexico and Ethiopia, food insecurity and undernourishment are key issues, and, thus, technology that could expand the food pie in these countries would be highly impactful. On the other hand, in highly developed countries such as the United States and Australia, food waste is a more prevalent issue, so technology aimed at more equitably distributing the pie would be more impactful in these countries. Further, technologies that would allow for more efficient and reliable transportation of food across longer distances could benefit consumers in a broad range of countries, as it could allow the oversupply of food in more developed countries, i.e. food that is currently going to waste in the United States, for example, to be more effectively shared with consumers in underdeveloped countries, thereby increasing the food pie in those countries.

Early stages: Pie expansion

Food inputs

The food production–consumption chain starts with food inputs; as discussed, the central challenge for this stage is finding efficient ways to increase food production. Some optimal combination of inputs will lead to the greatest or highest quality output, thereby increasing the food pie, but knowledge gaps make it difficult to discern, define, and update such optimal combinations. Some technology solutions (Eastwood et al., 2019) require monetization, such that they only benefit farmers who pay (at least partially) for them. Currently, these technology solutions may be out of reach for some farmers, particularly (i) smaller farmers, and (ii) farmers in developing countries. However, we also note that the key benefit of AI is that it lowers the cost of prediction (Agrawal et al., 2018), and so as AI advances, it is likely that the costs associated with some of these technology solutions will decrease, thereby making them more accessible to more farmers. In other cases, third parties—such as government agencies or nongovernmental organizations-intervene to cover the costs of obtaining these technology solutions. We present three examples that differ in both the levels of complexity and involvement of the farmer and technology provider.

First, using AI-enabled technology, Solena analyzes soil and creates customized solutions to help farmers increase their crop outputs and maximize crop quality. Once farmers receive a sampling kit from Solena, they send back a soil sample, then wait to receive customized biofertilizers that promise to increase their soil productivity and crop yield. Solena then maintains relationships with these farmers, offering follow-up analyses to ensure that the soil remains healthy and able to support efficient growth patterns. On average, Solena users – which includes small farmers—report a 30% increase in their profits.

Second, Dimitra Incorporated's blockchain platform integrates a host of technologies (e.g., mobile, satellite and drone imagery, machine learning, AI). Its associated app grants farmers a host of functionalities, ranging from access to crop inputs, to financing, to insurance, to advanced farming education modules.

Third, Krish-e consulting (Farming-as-a-Service, provided by the Mahindra Group, India as an "affordable service") provides advice pertaining to virtually every aspect of farming, from preparing the land prior to sowing seeds to which fertilizers and treatments to use on planted crops. To demonstrate its effectiveness, Krish-e asks farmers to assign some portion of their land to following its advice completely, then compare this land's output with the output from the balance of farmer's land (on which the farmer maintains conventional practices). Discussions with a key respondent[2] at Krish-e indicate that the output from land worked in accordance with its advice is typically significantly greater than the output obtained from conventional methods. Mahindra also has observed an increase in income per acre, from US$63 to US$186, among farmers who embraced Krish-e–assisted farming techniques (Grand View Market Research, 2023).

Solena, Dimitra, and Krish-e all facilitate better coordination, such that food producers are more likely to source suitable inputs (seeds, fertilizers, pesticides) from their sellers. Solena enables food producers to identify and order suitable, customized biofertilizers; Krish-e and Dimitra offer technological solutions that align food producers and their inputs to realize improved crops. In these food input stages, beneficial uses of technology primarily would promote buyer–seller coordination and thus encourage pie expansion, as we theorized. Such services can extend to smaller farmers, either due to extensive use of AI, or due to financial support from a third party.

[2] Appendix 1 provides more details about the discussions with key respondents.

Food production

In the food production stage, efficiency and waste mitigation are relevant concerns. If farmers have determined the inputs to use, they now must manage their growing process (e.g., how much to irrigate, when to harvest) to achieve maximal or the highest quality output. First, they need information about how to manage the growing process, which may come from learning and previous experience but also might be achieved with the help of technology that provides relevant data. Second, farmers must constantly monitor pertinent conditions, such as weather or pestilence threats, that can rapidly, substantially change over the course of a growing season. Farmers then need to respond appropriately, according to the unique conditions they face. Thus, they likely would benefit from AI-based predictions about future conditions (Davenport et al., 2021; Guha et al., 2021, 2023).

Increasing the pie—that is, the amount of food grown—also requires reducing inefficient production. Farmers can avail themselves of technology that relies on cloud computing, AI, and machine learning technologies to gain insight into their crop production and management processes. For example, a company called Arugga (Israel) has developed an AI-supported robot called Polly that uses visual data to determine which tomato plants are ready to be pollinated. Its efforts thus produce better results than solely human involvement (20% yield improvement). Additional technological tools being added to Polly promise to integrate pest and disease detection capabilities too (Kontzer, 2021).

Some technology applications enhance both efficiency and quality. The CropIn ag-ecosystem technology company provides, in addition to its previously mentioned CocoaSense platform, a cloud computing solution for individual farmers and producers, large companies, governments, and nonprofits (Shu, 2022). In partnership with the Alliance for Green Revolution in Africa, it works to help farms achieve efficient resource usage, leading to two key benefits. First, efficiency increases: More crop output gets produced with a given input. Second, crop quality improves, which typically translates into higher prices. In our discussions with a key respondent at CropIn, we learned that these benefits emerge primarily after the farming operations and data are digitized, which enables CropIn to make real-time recommendations at the crop or farm level, in accordance with its prediction capabilities (driven by AI) about weather, pests, and so forth.

As shown in Fig. 1, food producers also might deal directly with end-consumers (i.e., direct-to-consumer [DTC] sales), by shipping produce directly to consumers or participating in local farmers' markets. Farmer Jones Farm (2023) in northern Ohio (United States) ships boxes of vegetables straight from the farm to consumers' front doors and leverages technological platforms to manage this process. The U.S. Department of Agriculture estimates that in 2015, approximately

115,000 U.S. farms engaged in DTC sales, which earned them annual sales of $3 billion (Kaplan, 2018), higher prices per product, and closer consumer relationships (Kaplan, 2018). A key respondent, employed by a large Asian conglomerate, suggested other versions of this model, in which large intermediaries donate pertinent apps to farmers, who use them to estimate crop quality. If crop quality is extremely high, the larger intermediary might transact directly with the farmers, leading to better price realization. Otherwise, farmers can sell to smaller intermediaries, who screen and curate the produce for quality, then bring the acceptable items to the larger intermediary, which does not want the burden of screening many submissions of uneven quality. These efforts feed forward and increase production, through the quantity produced and improved quality.

Another pressing challenge arises when market conditions are such that farmers harvest crops to clear land but do not bring the produce to market, because they will not earn sufficient economic returns to justify such efforts. Predictive technology might help farmers time their harvests appropriately, so that the market is more likely to support sufficient returns; other technology tools might grant them access to alternate markets. For example, a Qualcomm-supported app called FarmPrecise issues constantly updated reports, customized to specific firms, that provide (among other information) five-day weather forecasts and market price trend reports. A key informant at Qualcomm explained that FarmPrecise gives farmers information that enables them to speed up or delay their visits to market, so they can sell their crops on days on which prices are highest.

A third challenge relates directly to waste reduction. For example, Taranis uses technology and AI to analyze high resolution photographs taken by drones, planes, and satellites, which have been uploaded to Google Cloud, and thereby determines the health of crops at the literal leaf level. The results get posted to farmers' individual Taranis dashboards, enabling them to address any unhealthy plants immediately and reduce crop losses (Beyer, 2022). In another example, Agerpoint uses AI to identify and provide insights about any crop photographed through its app, including plant health, disease presence, potential remedial actions, and future inputs needed, all of which can help reduce waste. For example, rather than uniformly applying pesticide to all areas, the Agerpoint app helps farmers identify select areas that need pesticide, thus reducing pesticide usage and costs. Note that Agerpoint works at a relatively affordable price point, affordable due to its use of AI (rather than human experts) ("impact [of our product] is about access and affordability." — CEO Agerpoint; Pixel Scientia, 2023).

Arugga, CropIn, and Agerpoint each facilitates better coordination between food input sellers and food producer buyers, such that food producers buy more suitable inputs (seeds, fertilizers, pesticides) from the sellers. FarmPrecise also enables coordination between food producers and food processors, by helping food producers decide which foods to sell to which market. Through these efforts, parties engaged in the food production stage focus on pie expansion, and beneficial uses of technology should promote buyer–seller coordination. Similar to what was earlier noted, the use of AI improves access and affordability.

Food processing

To depict the food processing stage, we use the example of rice crops. Retailers and restaurants buy rice in bags, so some prior member of the supply chain must have purchased the rice crop, processed it, and packed it into bags. Such efforts are critical to increasing the longevity of farm produce, parceling out and packaging the crop yields, and thus making them accessible to downstream actors such as retailers or restaurants. In this processing stage, both efficiency and waste reduction considerations are prominent.

Regarding efficiency, food processors need to account for various demands, including the need to ensure that the food retains its taste and nutrition, establish an extended shelf life, and still maintain cost effectiveness. Furthermore, most producers separate their crops into products for human consumption and those designated for other purposes, such as feeding livestock. But such sorting processes are cumbersome and challenging; determining whether an apple can sell in the grocery store or instead should be designated for a horse farm requires much skill. The sorting technology provider TOMRA relies on multiple technologies—x-ray, near-infrared spectroscopy, cameras, machine learning/AI, and even lasers—to support its automated sorting tool. The tool gauges various attributes of different crops to ensure that each piece of fruit or vegetable gets sorted efficiently and sent to the appropriate market channel (Sharma, 2019).

Regarding waste, food processors not only need to minimize any food losses due to their processing efforts but also account for and mitigate waste-related issues further downstream in the food chain, related to shelf-life considerations, quality, and appropriate packaging. For crops processed as frozen foods for example, this stage must address the risk that the products might be subject to unsupportable temperatures and humidity levels, in which case they could develop ice crystals. The Xsense monitoring system constantly keeps track of the conditions surrounding frozen packages. If a freezer malfunctions and temperatures rise, the system alerts relevant actors and even can be programmed to initiate corrective actions (e.g., lowering the temperature using emergency controls) to avoid losses of the frozen items (Jackson, 2016).

In some cases, efficiency and waste are closely linked, and so some technological solutions address both elements. For example, One Third leverages AI-enabled cameras, installed in handheld scanners, to gauge the freshness and quality of various foods. Then processors can prioritize those items that are closer to spoiling and must be shipped immediately, while holding on to less mature produce for processing later. Or they might send the nearly expired products to nearby markets, and ship less ripe items to more distant recipients, because the latter are more likely to make the long trip still intact. The scanners are more efficient than human labor in detecting items at risk of spoiling, and the resulting recommendations effectively reduce the risk of waste due to spoilage (Moran, 2023). Thus, in seeking to achieve both increased efficiency and reduced waste, technology solutions can provide relevant, customized, real-time information, as well as identify factors that trigger waste and enable real-time interventions to avoid it. In effect, One Third facilitates better coordination between food producers and downstream entities, so that food processors can make suitable decisions about which foods to send where. As we theorized, in the food processing stage, like the prior stages, the focus is on pie expansion, and beneficial uses of technology involve encouraging buyer–seller coordination.

Later stages: Pie sharing

Food distribution

Food distribution gets conducted by entities like restaurants, retailers, and institutions (e.g., armed forces, universities) that buy food from food processors. Despite their different methods for acquiring and distributing food, they all purchase it from upstream actors in the food supply chain, then sell or provide it to end-consumers. The focus in this stage, from a food insecurity standpoint, is on waste reduction. For example, as expiration dates for food items approach, distributors might seek ways to reduce food waste and bolster their public relations by donating edible food.

Several illustrative articles explore factors that might affect food waste among distribution entities, as we summarize in Table 1. Companies in the food service and grocery industries likely recognize the existence and moral burden of food waste, but they appear to do relatively little to decrease it (Gruber et al., 2016; Martin-Rios et al., 2018; Vizzoto et al., 2021), nor do they seem to realize the potential benefits, such as the cost savings they could obtain (Principato et al., 2018). Frontline workers and managers perceive their own lack of power or capacity to make changes to food waste systems, as well as a lack of time and other resources (Gruber et al., 2016; Sakaguchi et al., 2018). In restaurants, several factors contribute to food waste; establishments with meat-based menus and fewer seats tend to have more waste (Principato et al., 2018). Reducing plate sizes, leveraging social cues, and signage focused on being mindful can be effective at reducing food waste among customers dining in restaurants and university food halls (Kallbekken & Sælen, 2013; Pinto et al., 2018).

Few studies of food waste involving distribution entities identify a role for technology, though various technology applications could be effective. For example, by integrating the Gander technology platform into their in-house processes, Irish retailers can assign steep discounts to food approaching its expiration date. These offerings can be especially appealing to food-insecure populations because the items in question are fully edible but available at very low prices (Belfasttelegraph.com, 2022). Cisco's "AI for good" program supports RePlate (Connor, 2021) by identifying an intermediary to pick up food that otherwise would be thrown away; the intermediary then transports the food to nonprofit groups that serve food-insecure populations (Bernabe, 2022). Food providers, including the San Francisco International Airport and various restaurants, log details about food they have available and initiate the pick-up. The data collected by RePlate also can help these entities identify common types of waste (e.g., if they constantly have bread left over, they might order less from the bakery). Furthermore, RePlate's site tracks the specific needs of charitable organizations, to avoid situations in which it delivers food items that the nonprofit cannot use. By tracking both push (i.e., available food items) and pull (i.e., actual demand) factors, RePlate seeks to find an optimal balance that reduces food waste.

Food Bank Singapore works with distribution entities to reroute edible food to consumers. However, a key respondent whom we interviewed noted that many of these consumers expressed dissatisfaction with the program, for two reasons. First, recipients did not have any say in what food they received. Second, the donated food was left outside of their homes, highlighting their food insecure status, with negative impacts on their self-worth. To address both issues, Food Bank Singapore installed vending machines in prominent locations (which they call Food Pantry 2.0), allowing recipients to make their own selection of food items and to retrieve them at any time that was convenient (and perhaps when others are not around).

Technology applications like Gander and RePlate encourage equity-oriented food sharing, by reducing frictions that may prevent food from being diverted from those who have surpluses, to those who are food insecure. This approach aligns with equity theory and with our prediction that in the food distribution stage, the focus is on pie sharing, and beneficial uses of technology could reduce frictions related to equity-oriented food sharing.

Table 1 Illustrative distribution entity food waste research

Paper	Domain	Region	Type of Paper	Conceptual/ Theoretical Framework	Quadrant Related To (Table 3)	Key Insights
Kallbekken and Sælen (2013)	ECON	Europe	Empirical	Choice Architecture Theory	4	Reducing plate size and providing social cues are two effective ways of reducing food waste in hotel restaurants. Both methods reduced food waste by approx. 20%
Gruber et al. (2016)	MKTG	Europe	Qualitative Methods	Marketing as Exchange Theory	4	According to retail managers, much food waste occurs because food is only observed as a spreadsheet item, rather than considering the benefits of the food to market participants. Store managers often feel a moral burden with wasted food but do not have the autonomy to change it
Martin-Rios et al. (2018)	ENVSC	Europe	Qualitative Methods	Innovation Management, Social Constructionism	4	Companies in the foodservice industry are becoming more aware of the importance of waste management, but very few are actively being innovative with trying to reduce waste. The implementation of food waste innovations at the foodservice level depends on management's beliefs, knowledge, goals, and actions
Pinto et al. (2018)	ENVSC	Europe	Empirical	N/A	4	Making University students aware of food waste through communication campaigns can significantly reduce food waste at University food halls and restaurants. Signage with reminders about only taking food that they knew they would eat lowered food waste among students

Table 1 (continued)

Paper	Domain	Region	Type of Paper	Conceptual/ Theoretical Framework	Quadrant Related To (Table 3)	Key Insights
Sakaguchi et al. (2018)	BUS	North America	Survey	N/A	4	In Berkeley, CA (USA), 65% of restaurants measure food waste, and one of the most common methods for reducing food waste is giving edible leftovers to restaurant employees. Many restauranteurs claim that they do not have the time or resources to change and improve their food waste behaviors and many avoid food donation because of fear of legal liability
Principato et al. (2018)	Hospitality	Asia, Australia, Europe, North America	Empirical	N/A	4	Several factors associated with higher food waste at restaurants are identified, including not recognizing a reduction in food waste as an opportunity to save money, menu type (meat-based menus tend to be higher in food waste), and the number of seats in a restaurant (the more seats in a restaurant, the less food waste)
Kim and Hall (2020)	Hospitality	Asia	Survey	Value Theory	4	Sustainable restaurant practices, including efforts towards waste reduction, positively influence consumer value and loyalty
Vizzoto et al., (2021	Hospitality	Global (review studies across all continents except Latin America)	Literature Review	N/A	4	In the foodservice industry, there is a lack of strategies aimed at reducing leftover and serving waste. Additionally, there is much resistance in the foodservice industry to adopting consumer behavior-based strategies that could reduce food waste. Lastly, there is a knowledge gap between academic literature and foodservice practitioners that has resulted in lower implementation of strategies that would potentially be effective at reducing waste at the foodservice level

End consumers

Various articles explore factors that determine food waste among consumers (Appendix 2). For example, plate size and plate materials both exert significant impacts on consumers' food waste; bigger plates and those made of disposable materials increase waste (Wansink & van Ittersum, 2013; Williamson et al., 2016). Situational factors also have a role; Parker et al. (2018) find that when consumers contribute to and consume collective assortments of food (e.g., potlucks), food waste is substantial. Social norms seemingly lead consumers to feel compelled to bring enough food for the entire group. But if each person brings that much food, the result is likely excessive amounts of food, much of which goes to waste. Psychological factors, such as identity-signaling motivations, also influence food waste (Block et al., 2016; Grewal et al., 2019). Consumers avoid purchasing unattractive, but perfectly edible, produce, whether because thoughts of consuming "ugly" produce undermine self-perceptions (Grewal et al., 2019) or because they anticipate an inferior taste. Anthropomorphism, such as displaying produce with a smiling face, can help overcome these negative perceptions, and in-store signage that refers to it as "ugly" as opposed to "imperfect" may make consumers more willing to purchase (Cooremans & Geuens, 2019; Mookerjee et al., 2021). The negative impacts of food imperfections appear to apply solely to non-processed food, such as produce (Suher et al., 2021), whereas for processed foods, imperfections evoke beliefs that the processing has been performed by a human, which can enhance perceptions (Parker et al., 2018).

Although consumers feel anxiety about wasting food, they also often over-purchase, which leads to food waste (Evans, 2012). At the household level, positive intentions to lower food waste and more knowledge about how to consume leftovers safely can reduce food waste (Visschers et al., 2016), but even if with such positive intentions and knowledge, some consumers feel unable to achieve this goal. For example, busy consumers sense insufficient time available to shop effectively, such that they cannot take an inventory before going to the store, make a shopping list, or plan meals. Others likely are unaware of options for redistributing food to others. Consumers' mistakes related to food, despite their best intentions, can lead to waste at different steps in their consumption journey, including improper preplanning, ineffective shopping in store, improper storage or cooking, inefficient consumption, and not enough focus on suitably disposing of edible or useful food (Block et al., 2016; Principato et al., 2021).

Price promotions arguably nudge consumers to buy relatively more, which could increase food waste, leading one U.K. legislator to suggest that "supermarkets should move away from offers such as 'buy one get one free' to help end the 'morally repugnant' waste of millions of tons of food" (Guardian, 2014). Yet recent research challenges this assumption (van Lin et al., 2023), so more research is needed to determine the actual effects of price promotions.

To date, very little research has considered the potential impact of technology on end-consumers' food waste, despite the emergence of real-world tools, such as apps that maintain inventories of consumers' food purchases, remind them of expiration dates, and suggest recipes to use already purchased food. The Nosh app, enabled by AI, helps consumers scan barcodes and other information, then provides suitable recipe information that reflects the food expiration dates. It also offers summary information about consumers' food buying and wasting habits (Silberling, 2021). Other apps connect consumers with nonprofits or other consumers that would benefit from redistributed food. On the Olio app (United Kingdom), households can register any surplus food they have, then receive prompts on their mobile devices to check their pantries and refrigerators for such items regularly. Also on this app, other users can request any posted excess food, which usually happens quickly, such that sharers get rid of unwanted clutter in their kitchens, and requestors receive ready access to available items. In the United States, Feeding America hosts an app for consumers with extra food, but the recipients in this case are local nonprofit organizations. Volunteers collect posted items and deliver them to the nearby shelter or food pantry. With another approach, the Cooklist app encourages consumers to use up the food items they have purchased by allowing them to scan their grocery receipts, then providing them with notifications of likely spoilage dates, as well as ideas for meals and recipes that feature the purchased items.

These apps focus on local, rather than a regional or global, redistribution. Thus, transportation is a persistent challenge for redistributing surplus food from consumers who likely live in higher income areas to consumers who are food insecure and often live in lower income regions. How could European consumers, for example, redistribute surplus food to African consumers in need? Some previously discussed food processing technologies (e.g., Xsense monitoring, One Third) might help address transportation challenges; partnerships of transportation firms and food redistribution technology could have significant impacts. Technology applications like Olio and Feeding America encourage equity-oriented food sharing, such that the focus is on pie sharing, and similar to the food distribution stage, beneficial uses of technology would reduce friction related to equity-oriented food sharing.

Consumers' actual behaviors: Survey data

As mentioned in the preceding discussion, the majority of food waste occurs at the consumer stage of the food production-consumption chain, particularly in developed countries such as the United States. Therefore, a good understanding of consumer's food waste behaviors is critical to gaining a better grasp on ways though which technology could help to reduce waste at this stage. To understand consumers' actual food waste behaviors, we conducted a survey on Academic Prolific with 353 adult participants (M_{age} = 42.59 years, 47.6% men). Most respondents were in North America (United States or Canada 94.1%), but other global regions also were represented (Asia 2.3%, Europe 2%, Middle or South America 0.8%, Australia 0.3%, and 0.6% elected to not disclose). The average household size 2.66 people (SD = 1.64), and the average number of children under the age of 18 years in the house was 0.5 (SD = 0.981). Thus, the sample includes respondents both with and without younger children in the house. The survey goals were to understand consumers' perceptions of their food waste behaviors, their awareness of and interest in using technologies to redistribute food, and their perceptions of restaurants that actively work to reduce food waste. We also sought to identify any food growing behaviors.

To determine if some factors correlate more strongly with certain food waste behaviors, we measured participants' social consciousness (5 items, Flewelling et al., 1993, α = 0.646), altruism (4 items, adapted from Rushton et al., 1981, α = 0.726), technology readiness (4 items, adapted from Parasuraman & Colby, 2014, α = 0.876), frequency of financial and time donations (1 = "never," 7 = "very frequently"), political ideology (1 = "extremely conservative," 7 = "extremely liberal"), and demographic information (education, income, household size, age, gender).

To start, we asked participants to describe their food disposal behaviors, including what types of food, how much typically is wasted (i.e., not consumed) in their household, and how they disposed of that food. Many participants described produce that spoiled before they had the chance to consume it: "I recently purchased a large amount of fresh fruit from a grocery store that ended up going bad before I had a chance to eat it. I had purchased a variety of apples, oranges, and grapes, but I quickly realized that I had overestimated how much I could consume before it spoilt." Others cited diet changes or purchases of new options that they decided to try but ended up not liking, such as a participant who said, "Lately I have been trying to change my eating habits to make them healthier and I have bought healthy foods that I have not liked and have had to discard them."

In the next section of the survey, we asked participants to rate the amount of food waste they produce (1 = "very little," 7 = "a great deal"), how much edible and non-edible food waste they have (1 = "very little," 7 = "a great deal"), how frequently they think about food waste (1 = "never," 7 = "very frequently"), and how important they perceive food waste issues to be (1 = "not at all important," 7 = "very important"). They described disposal or donation behaviors in more detail. A one-sample T-test relative to the scale midpoint (4) indicated that, overall, participants perceive that they produce a fairly small amount of food waste ($M_{foodwaste}$ = 2.87; SD = 1.32; $t(352) = -16.16$, $p < 0.001$). Regarding edible and non-edible food, a paired sample t-test reveals that they discard significantly more non-edible food ($M_{non\text{-}edible}$ = 3.40; SD = 1.65) than edible food (M_{edible} = 1.95; SD = 1.17; $t(352) = -15.904$, $p < 0.001$). One-sample T-tests compared with scale midpoints (4) showed that participants recognize food waste as an important issue ($M_{important}$ = 5.27, SD = 1.51; $t(352) = 15.864$, $p < 0.001$) but do not think about it frequently ($M_{frequency}$ = 4.11, SD = 1.54; $t(352) = 1.348$, $p = 0.179$). Thus, many consumers view food waste as important, but they perceive little food waste in their personal life. This self-reported measure could be inaccurate of course; their actual food waste may be higher than reported. Our survey results indicate limited opportunities to reroute food from consumers to those who are relatively more food insecure. Still, it may be useful to clarify why consumers choose to reroute edible food that otherwise would go to waste.

Therefore, we consider what consumers do with such food and identify influences on the extent to which consumers would be willing to use technology-enabled apps to reroute edible, otherwise wasted food. Most participants report that, at some point in the last month, they threw away unused food (95.5%); most of the discarded food is inedible, so this high percentage makes sense. Relatively few donated unused food (15%), and none had sold it. Among those who donated food in the past month, most provided it to people in need (directly to the person or through a food bank/charitable organization), and some donated to friends or family members. Donation boxes at their workplaces, houses of worship, or children's schools provided sites for redistributing food; they make it convenient for people to donate, because consumers do not have to go out of their way or put in much effort and can simply drop off excess food at places they already visit regularly. This result indicates that consumers may be more likely to donate excess food if it is convenient to do so. If technology could make food donation more convenient, it might have a significant impact on the overall amount of food donated.

Two apps, Meal Connect and Cooklist, aim to reduce food waste at the consumer level by making it convenient for consumers to redistribute unwanted food. We asked about participants' awareness of and willingness to use these two apps, including their general awareness of apps that allowed for the redistribution of unused food (1 = "not at all aware," 7 = "very aware") and if they had ever used such an app (yes/no). After providing descriptions of Meal Connect and Cooklist, we asked about participants' likelihood of using each app (1 = "very unlikely," 7 = "very likely") and willingness to pay a monthly fee to use it (sliding scale, $0–$20).

Awareness of the apps was low. Specifically, only 2.5% of participants had used an app to redistribute unused food, and awareness was virtually nonexistent ($M_{awareness}$ = 1.47, SD = 1.08, one-sample $t(352) = -44.151$, $p < 0.001$ [scale midpoint of 4]). Once we explained the apps, they expressed low to moderate willingness to use either Meal Connect ($M_{likleymealconnect} = 4.11$, SD = 1.98, one-sample $t(352) = 1.023$, $p = 0.307$ [scale midpoint of 4]) or Cooklist ($M_{likleycooklist} = 3.70$, SD = 2.15, one-sample $t(352) = -2.628$, $p = 0.009$ [scale midpoint of 4]). The amount they were willing to pay for the apps also was low ($M_{WTPmealconnect} = \$1.37$, SD = 2.31; $M_{WTPcooklist} = \$1.36$, SD = 2.52). In essence, few people know about these apps, and once aware of them, consumers appear only somewhat willing to use them and not willing to pay for them. Thus, the greatest barriers to using technology to reduce waste and redistribute food efficiently might not be creating the technologies but rather determining how to increase awareness and usage intentions surrounding them. The value of using the app also needs to be communicated effectively to consumers. According to prior research, establishing trust between a food redistribution app and its users is another important criterion, particularly for consumers who receive the food and may face social stigma (de Almedia Oroski and da Silva 2023). App developers should consider these issues when creating their technology and aim to keep the identity of food recipients anonymous when possible.

We checked for individual differences that might determine the extent to which consumers would use or pay for such technology apps. According to the results of multiple regression analyses (see Table 2), willingness to use these apps is higher among participants who score high on social consciousness, altruism, and technology readiness, as well as people who frequently make financial, but not time, donations. Political ideology has a significant impact on willingness to use Meal Connect (not Cooklist though), such that those who identify as more liberal are significantly more likely to use it. In terms of demographic variables, neither education nor income level exerts much impact on the likelihood of using or willingness to pay for either app. Younger consumers and participants who self-report more food waste seem more likely to use and more willing to pay. These starting points signal some factors that may drive the extent to which people adopt technology-enabled apps and thus topics for further research.

Finally, a notably substantial proportion of participants, 34.6%, grow some of their own food, ranging from small herb gardens to large, dedicated plots for produce. Among those who do not grow their own food, about 71% have considered it. As is reasonable, most participants who report growing their own food live in a single-family home (83.6%). It is unclear the extent to which home-grown food can affect food insecurity, as we discuss in more detail subsequently.

Two points emerge from the preceding discussion. First, as is the case for distribution entities, the key challenge for end-consumers is reducing waste. Technology applications can assist in determining suitable orders and moving food to

Table 2 Consumer willingness to use food-related apps based on individual difference variables

Independent Variable	*Outcome Variable*			
	Likelihood of Using Meal Connect App	*WTP for Meal Connect App*	*Likelihood of Using Cooklist App*	*WTP for Cooklist App*
Constant	-.522 (.916)	-1.292 (1.142)	-.177 (.994)	-.254 (1.198)
Social consciousness	.417 (.111)***	.083 (.139)	.498 (.121)***	.023 (.145)
Altruism	.330 (.155)**	.002 (.193)	.404 (.168)**	.218 (.203)
Frequency of financial donations	.230 (.076)***	.233 (.095)**	.032 (.083)	.134 (.100)
Frequency of time donations	.007 (.074)	.132 (.092)	.044 (.080)	.284 (.097)***
Technology readiness	.241 (.070)***	.152 (.088)*	.265 (.076)***	.202 (.092)**
Political ideology	.130 (.062)**	-.069 (.078)	-.060 (.068)	-.194 (.082)**
Education level	-.145 (.080)*	.170 (.099)*	-.064 (.086)	.025 (.104)
Income level	-.022 (.029)	-.050 (.037)	-.038 (.032)	-.011 (.038)
Age	-.029 (.008)***	-.012 (.010)	-.044 (.009)***	-.031 (.011)***
Amount of food waste (self-reported)	.219 (.079)***	.144 (.099)	.389 (.086)***	.206 (.104)**
Household size	.041 (.063)	.159 (.078)**	-.020 (.068)	.136 (.082)
F-Value (df)	7.821 (336)***	3.280 (336)***	8.060 (336)***	5.756 (336)***
Adjusted R^2	0.178	0.067	0.183	0.131

This table contains the results of multiple regression analyses with unstandardized coefficients (standard error). WTP = willingness to pay

*$p < .10$

**$p < .05$

***$p < .01$

consumers who are food insecure (rather than being disposed of in the trash). Second, relative to end consumers, it may be more beneficial to focus on distribution entities, which deal with substantially more food that could be rerouted to consumers dealing with food insecurity.

Technology configurations that influence the food pie and stakeholders

Building on the preceding examples, we propose a 2 × 2 typology of technology applications, categorized in relation to how they affect the food pie (pie expansion vs. pie sharing) and the stakeholders (producers vs. consumers) toward which the technology is oriented. That is, technologies can be used to increase the food pie, through increased production and/or efficiency (i.e., reduced inefficiencies). They also might encourage more equitable (re)distribution of the food pie, such as by enabling food sharing with nonprofits. The focal stakeholder in the food production–consumption chain that is targeted by the technology in turn can be separated into two clusters that face distinct issues: producers, which include food processors and farmers, versus customers, which include distribution entities and end consumers (Table 3). By assigning technologies to this typology, we shed light on technological gaps in efforts to reduce food insecurity, loss, and waste.

In the upper left corner, Quadrant 1 relates to technologies targeted toward producers in the initial stages of the food production–consumption chain, most of which seek to increase food production by facilitating coordination, such as when Krish-e, CropIn, and One Third link producers and input entities, to increase the size of the pie. Other examples include applications like FarmPrecise, which work with producers to ensure that food is not lost due to weather or rotting, during and after harvesting. Reducing food loss in effect increases the size of the food pie. We note substantial interest in this quadrant; increased food production may increase the amount of food available to those who are food insecure.

Next, Quadrant 2 relates to technologies geared toward producers that work to enhance the equitable distribution of the food pie. As may be expected, and as Table 3 indicates, technologies in this quadrant are relatively sparse (as mentioned previously, we find that producers appear more focused on pie expansion than pie sharing in practice). Some producers sell directly to consumers through farmers' markets or roadside stands, and technology might enable such DTC sales and increase efficiency, which could help to decrease prices for end consumers and make products more accessible. Producers often have food that they are unable to sell to retailers (e.g., "ugly," oversupply). Technology such as apps might allow producers to redistribute these unsellable products to consumers who are food insecure, rather than letting the food go to waste. Some apps represent initiative

Table 3 Typology of technology used in the food production–consumption chain

	Technology Oriented Toward Producers	Technology Oriented Toward Customers
Pie Expansion (increase the food pie)	*Quadrant 1* • Kenya's Mbegu (Seed) Choice Program (Africa) • China's Lunyan 502 (Asia) • VoloDrone (Europe) • Solena (Central America) • Dimitra Incorporated (Africa, Asia, South America) • Krish-e (India) • Taranis (Asia, Australia, Europe, North, Central, and South America) • Arugga (Australia, Israel, and North America) • CropIn (Africa, Asia, Australia, Europe, North, Central, and South America) FarmPrecise (Asia)	*Quadrant 3* End Consumers: • Seed to Spoon app (North America) • Moon & Garden app (Europe and North America) • Gardroid app (North America)
Pie Sharing (more equitable distribution of the food pie)	*Quadrant 2* • Flashfood app (North America) • Misfits Market app (North, Central, and South America) • Imperfect Foods app (North America)	*Quadrant 4* End Consumers: • Olio app (Asia and Europe Asia) • Feeding America app (North America) Distribution Customers: • Food for All app (North America) • Too Good to Go app (Europe and North America) • Food Rescue Hero app (North America) • One Third (Europe) • Gander (North America) • Replate (North America) • Food Bank Singapore (Asia)

along these lines, such as the Flashfood app that gives food producers in the United States and Canada the opportunity to send food that has been rejected by grocery stores directly to consumers in need (Bozhinova, 2018). Similarly, MisFits Market (United States; Central and South America) and Imperfect Foods (United States) apps work directly with producers and sell "ugly" produce (and other food items, such as meat and seafood) to consumers at deeply discounted prices in weekly subscription boxes (Richardson, 2021). In Indonesia, Sayurbox technology allows producers to sell directly to end consumers, which cuts intermediary costs and allows food to be sold at lower prices (Deloitte Southeast Asia Innovation Team, 2022). These examples imply that producers might be more directly involved in the equitable distribution of food, but these technology interventions seem less likely to move the needle, in terms of feeding those who are food insecure.

In the upper right of Table 3, Quadrant 3 includes technologies that enable customers to expand the food pie. This quadrant is sparsely populated; because consumers and distributors focus more on pie sharing, they seem less motivated to increase the size of the global food pie. An exception might pertain to end consumers interested in gardening, as an attempt to produce some food. Apps that help end consumers increase the foods they grow fall into this quadrant (Dove, 2022). The Seed to Spoon app uses GPS locations to help consumers determine which vegetables, fruits, or herbs can grow in their region, then alerts them to regional pests and diseases (to reduce inefficient production). Similarly, Moon & Garden uses phases of the moon, together with weather information, to advise consumers on "next day care" for their gardens that can increase production and harvests. Distributors are typically not involved in the production of food, so technologies in this quadrant focus primarily on end consumers.

Quadrant 4, in the lower right corner of Table 3, relates to technologies that enable customers to support more equitable distributions of the food pie, including the Olio and Feeding America apps, which maintain listings of consumers with food surpluses, then connect them with nonprofits or other consumers to redistribute excess food before it spoils. Distributors also might use technology-enabled apps to make connections with charities, homeless shelters, and other organizations in need of the food, which reduces the amount of food discarded. With the Gander app, Irish retailers assign steep discounts to food approaching its expiration date, making such foods especially appealing to food-insecure populations. All these technology applications help reduce frictions that pose barriers to equity-based food redistribution. We also highlight the substantial interest in this quadrant. Customers are fairly motivated to share edible, to-be-wasted food with those who are food insecure. Our expectation, based on our interviews and survey, is that more benefits would accrue from focusing on distribution entities like retailers and restaurants, which have relatively more food surpluses that can be shared. Because such a large percentage of food waste involves consumers and retailers, the applications listed in this quadrant are especially important for efforts to reduce food insecurity and waste.

The contrast between quadrant 1 versus quadrant 4 is stark. Noting that in developing countries, the focus is more on "expanding the food pie", and so the technology initiatives in quadrant 1 relate substantially to those in developing countries. Over time, as AI advances and the cost of prediction is further reduced, the application and impact of these technology initiatives will only increase. In contrast, noting that in developed countries, there are benefits to better "share the – already large – food pie", the technology initiatives in quadrant 4 relate substantially to those in developed countries.

Research and practice agenda

Many questions related to food expansion and the equitable redistribution of food remain unanswered. We outline some of these questions, organized by quadrants in the 2 × 2 typology from Table 3. The proposed research agenda is summarized in Table 4.

Quadrant 1: Technology oriented toward producers to expand the food pie

The key challenges in Quadrant 1 include how to produce relatively more or higher quality crops, holding the inputs fixed, and then how to reduce waste during the crop production process. This area has received relatively substantial research interest, especially with a practice focus, and various investment and technology firms focus on developing relevant solutions. These (non-trivial) efforts continue, reflecting the challenges related to the underlying technology and also organizational issues (e.g., how to get smaller farms to digitize operations). And then the critical issue is how to further expand application of, and access to, these technology inittaives; the advance of AI may well be key to this point.

Beyond coordination issues, other topics of interest relate to efficiency, equity, and ethics. For example, researchers could address how to achieve better (AI-driven) predictions of crop growth, pestilence, and containment; distinguish the impact of offering some farmers access to extreme productivity, while other farmers lack such access; and consider potential issues with creating disease-resistant crops in outer space, albeit with potentially unforeseen side effects.

Table 4 Research questions

Quadrant 1: Technology Oriented Toward Producers to Increase the Food Pie
• In what ways can technology help smaller farmers digitize their farm operations?
• How might predictions of factors that affect crop production be improved over time?
• What are the equity-related issues related to farms' unequal access to heightened productivity via technology solutions, notably AI solutions?
• Are there unforeseen aspects of technologically modified crops, including ethical concerns?
Quadrant 2: Technology Oriented Toward Producers for More Equitable Distribution of the Food Pie
• Which types of producers may be relatively more open to working with consumers who are relatively food insecure and engaging with technology to optimize these connections?
• What incentives are needed to encourage producers to engage with food-insecure populations?
• How can local, state, and national programs encourage connections between producers and those who are food insecure?
Quadrant 3: Technology Oriented Toward Customers to Increase the Food Pie
• How can technology nudge consumers toward food production? Should it involve more inspiring goals or more information provision?
• What are some ways to inspire goals? Is it inspirational content, and if so, what form should that content take? For which types of consumers might this content be most relevant?
• What types of information might be most beneficial for nudging consumers toward food production? How might gamification and/ or virtual reality help?
• Can other entities, such as retailers, motivate farmers to enhance food production? How might technology help such efforts?
Quadrant 4: Technology Oriented Toward Customers for More Equitable Distribution of the Food Pie
• What are the key drivers of customers' willingness to route food that otherwise would be wasted to food insecure consumers, even if it imposes various costs to them?
• How might technology help reduce the friction associated with sharing unused food with those who are food insecure? What are the various types of friction, beyond search cost friction, and what are some tactics to mitigate them?
• Can technology facilitate food sharing, to ensure that food recipients receive the items they want and maintain their sense of dignity?
• How can technology be deployed to predict usage and demand more accurately? At what stage of the consumer's food journey (e.g., pre-shopping, shopping in-store, storage, cooking, food consumption) is waste most prevalent? More broadly, how can technology be used to nudge customers to reduce food waste?
• How to use such technology apps, and how to set up associated processes, such that efforts are perceived as relatively genuine and not perceived as greenwashing?

Note: Most technology solutions have only local impacts. Further research is needed to find regional or global solutions; technology might be less relevant on these levels

Quadrant 2: Technology oriented toward producers for more equitable distribution of the food pie

This quadrant is sparsely populated; most technology applications relating to producers focus on pie expansion. As indicated by Tables 2 and 3, very little academic literature focuses on such issues. Because food producers typically seek to expand the food pie, continued research might examine which types of producers are relatively more open to working with consumers who are food insecure. To motivate producers, local, state, or national (government) incentives might be needed. Research should identify which aspects of such programs effectively encourage and incentivize producers to engage in alternative distribution for some portions of their crops.

Quadrant 3: Technology oriented toward customers to expand the food pie

This quadrant is also sparsely populated, challenged by the reality that customers typically are not involved in food production or determining the size of the food pie. Even if some consumers grow food, this effort typically constitutes only a small fraction of total food needs. Still, these activities appear to be gaining in popularity. Covington (2022), describing the growing trend of urban farming, notes that "if you live in a city, chances are the topic of urban farming has come up once or twice in conversation or at community meetings. These small, but larger than a home garden sites have become a popular way for communities to bring fresh produce, eggs, and meat to the people living around them." Urban farms tend to appear in shared spaces in apartment complexes, such as rooftop gardens or vertical farming approaches.

We envision two main impacts of technology in this quadrant. First, it might function as an enabler that helps consumers who already have chosen to grow their own food, by providing them with incisive, suitable information. For example, Gardroid targets novice consumers, with little experience growing vegetables, providing them with step-by-step guidance related to various aspects (e.g., how many days before the plant is ready, spacing between plants, which types of plants harmonize). Academic research has started to consider the effects of increased consumer production, but continued research is important to determine how to expand the impact of current technologies and which other technologies are needed. Emerging technologies like virtual reality might help promote urban farming; Parikh et al., (2022, p. 1) argue that virtual reality platforms can "support farmer knowledge transfer and innovation that transcend the physical constraints of traditional agricultural extension based on on-farm demonstrations."

Second, technology might inspire or motivate more consumers to engage in growing food, such as inspirational communications that trigger goals (Grewal et al., 2023) or gamification. The survey revealed that approximately one-third (34.6%) of respondents currently grow food; among those who did not, 71% had considered it, signaling strong interest among consumers. Research is needed to identify the most effective ways to motivate these consumers to engage in growing practices. Further research also might define optimal forms of inspirational content for specific target segments. In addition, gamification studies could define which games best encourage people to grow their own food, in line with Kawazoe et al.'s (2021) description of a gamification platform for urban vegetable gardens.

Such considerations also might extend farther across the production–consumer chain. Retailers like Whole Foods already source local produce from local farms, so tactics that increase overall food production by such local farms could have expanded benefits. Some restaurants grow their own food (e.g., farm-to-table restaurants), so the technology we note previously could facilitate their efforts too. Tender Greens, a fast-food chain in Southern California, grows much of its own produce (strawberries, squash, bell peppers) in on-site vertical gardens (Peters, 2015). Rosemary's, an Italian restaurant in New York City, has a rooftop farm that grows both produce and herbs (Durrani, 2016). Despite the extensive potential benefits of growing their own food, including a larger food pie and potentially diminished costs, few restaurants adopt this practice, perhaps due to anticipated difficulties or resources (i.e., time) needed. Technologies that enhance restaurants' capabilities to increase their own food production in convenient ways thus could be very beneficial.

Quadrant 4: Technology oriented toward customers for more equitable distribution of the food pie

In this quadrant, we note four main challenges, related to (1) motivating customers to share food, (2) reducing frictions related to sharing food (perhaps the most important point), (3) making sharing more acceptable to consumers who are food insecure (i.e., recipients), and (4) evoking behavioral changes by motivating customers to modify their consumption practices to waste less food. As Tables 2 and 3 reveal, much prior research has focused on issues related to this quadrant, but very little has considered the impact of technology. Because most food waste occurs here, it is crucial to find ways to influence food waste at this stage of the chain.

First, we largely have assumed that intermediaries and consumers are motivated to provide access to their unused or surplus food to others who need it. We find evidence in support of this assumption from our survey, at least among end consumers. Their motivations could stem from societal norms or public relations benefits. But we need a better, perhaps more nuanced, understanding of the key drivers of actors' willingness to route food that otherwise would be wasted to consumers struggling with food insecurity. A key question relates to differences in their willingness to pay any costs incurred to share food. Even if consumers appear motivated to share surplus food, they likely do not want to incur costs to do so. Our survey indicates very low willingness to pay for food redistribution apps, which presents a challenge for organizations that are trying to develop such apps. Further research should identify ways to communicate the added value of these apps, in ways that can motivate consumers to be willing to pay more.

Second, we need research to determine how technology might be leveraged to reduce frictions related to sharing food, for both entities like restaurants and individual consumers. A key source of friction relates to matching unused food with consumers who need it. Apps like Olio and MealConnect facilitate such connections for local populations. For end consumers, especially those with relatively little surplus food, the benefits of using technology apps are relatively lower. That is, they incur greater per unit costs to transfer food, as well as lesser costs of having food go waste. As such, trying to increase the benefits of using these apps (relative to the costs of using them) might help nudge both restaurants and individual consumers to use them. A recent study with blood donors offers some potential insights: When blood donors receive messages that thank them for their donations and also indicate that their blood had been delivered to a patient in need that day, it increased their likelihood to donate blood in the future by enhancing their relationship investment and relationship quality perceptions toward the blood donation service (Shehu et al. 2024). Similarly, food donation apps might alert food donors when a recipient receives their donation. The relationship investment and quality perceptions of the app in turn could increase among users, such that the benefits of donating start to outweigh the costs of using the app. We call for research into whether these types of messages can nudge various entities to use food redistribution apps.

Third, consumers may value food access in general, but how people receive food matters. As noted previously, Food Bank 2.0 represents a technology-driven solution for sharing food in ways that help food recipients preserve their sense of dignity (e.g., neighbors do not know that the food has been donated) and retain their choice (e.g., choose which foods they receive and reject, even if all the food is free). Further research could clarify how technology might help expand such applications.

Fourth, we need research insights into potential ways to nudge customers toward behaviors that involve less waste—both for business customers like restaurants and individual consumers. Reduced waste requires accurate predictions of consumption rates, as well as demand among food-insecure populations. Such predictive abilities must be precise with regard to both the quantity and types of food (e.g., demand for protein versus carbs). Food apps like Nosh and Cooklist represent initial attempts to provide suitable information that can change behaviors. Noting the powerful capacities of AI (Davenport et al., 2021; Guha et al., 2021, 2023), we call for research into effective deployments of AI-powered apps to predict usage and demand, which in turn identify behaviors to help reduce food waste. Research into food journeys for consumers and distribution customers also could define the stage of the food journey (e.g., pre-shopping, in-store, storage, cooking, food consumption) in which waste is most prevalent.

As an initial gauge of the impact of efforts to reduce food waste at an entity (i.e. restaurant/retailer) level, we asked survey participants whether knowing that a restaurant or retailer was actively working to reduce food waste would affect their likelihood of visiting it (1 = "less likely to visit," 7 = "more likely to visit") and willingness to pay (1 = "less likely to pay a slightly higher price," 7 = "more likely to pay a slightly higher price"). The one sample t-tests (scale midpoints at 4) revealed that participants were more likely to visit a restaurant/retailer that was working to reduce food waste ($M_{likely} = 5.66$, $SD = 1.17$, $t(352) = 26.62$, $p < 0.001$) and even willing to pay slightly higher prices ($M_{likelyWTP} = 4.90$, $SD = 1.33$, $t(352) = 12.682$, $p < 0.001$). Thus, efforts focused on reducing food waste seemingly can enhance consumer perceptions of the distribution entities. Examining this point and its implications would provide helpful insights.

As noted previously, some apps, such as Too Good to Go, allow restaurants to sell surplus food to consumers at discounted prices at the end of the business day. These apps have been popular (Too Good to Go has 5 million users and nearly 11,000 restaurants on the app) and offer great potential to decrease food waste. Yet consumers also have reported issues with these apps, which could undermine their perceptions and potentially lead consumers to view the technologies as merely "greenwashing" attempts (rather than meaningful efforts to decrease food insecurity). For example, one user reported that after using the app to order from a local smoothie shop, she encountered a rude employee who had no idea what she was talking about when she went to pick up her meal (Martichoux, 2021). The user noted that Too Good to Go immediately issued a refund and seemed prepared to deal with this issue, potentially because it is common. For these apps to be truly effective in reducing food waste, restaurants (and their stakeholders) must understand how to leverage the apps and establish effective processes to serve consumers who are food insecure.

Finally, straddling multiple quadrants is the issue of local versus regional impact. Many of the technology applications we have described offer local impacts, largely due to the very nature of food industries that invariably must deal with perishability concerns and transport cost concerns. On the producer side, technology solutions such as CropIn can be applied globally, and it already operates across farmlands in Asia and Africa, but the benefits are local. That is, it helps increase food production in certain areas but has virtually no impact in regions where CropIn is not being deployed. On the customer side, similarly, technology applications can be deployed globally, but the impact is relatively local. The Olio technology solution is available in the United Kingdom and Singapore, but when deployed in the United Kingdom, it only helps U.K. consumers who are food insecure, without affecting consumers in Singapore. Two implications emerge. First, even if the impacts are local, the technology-related and platform-related learnings one derives may then apply across countries, implying indirect regional impact. Second, we need additional research to find ways to address food insecurity at a regional (and ultimately global) level. As an initial conjecture, we propose that such issues are less about technology, and more about food transfers across regions, which implies political and interorganizational considerations.

Conclusion

With this article, we seek an in-depth understanding of the crucial role of technology, and notably AI, in fighting food loss and waste at every level of the food value chain, while also helping redistribute any unused food to consumers who are relatively food insecure. We introduce a 2 × 2 typology to illustrate how existing technologies influence the food pie (pie expansion vs. pie sharing) and which stakeholders (customers vs. producers) the technology targets. In line with this framework, we outline a research agenda for how technology might affect the full production–consumption value chain, with a view to increasing or redistributing the food pie, and with the goal of better serving people who are relatively food insecure. We hope this article and the ideas put forth stimulate further research into the role of technology as it relates to the UN's SDGs 2 and 12, regarding sustainable food production and consumption patterns and the goal of zero hunger.

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References

Agrawal, A., Gans, J., & Goldfarb, A. (2018). *A simple tool to start making decisions with the help of AI* (pp. 2–7). Harvard Business Review.

Anderson, J. C., & Narus, J. A. (1990). A model of distributor firm and manufacturer firm working partnerships. *Journal of Marketing, 54*(April), 42–58.

Azevedo, C. (2021). *Addressing food waste plays a role in ending hunger*. Rise Against Hunger.

Belfasttelegraph.com (2022). *Gander app helps retailers address food waste at store level*. Belfast Telegraph.

Bernabe, D. (2022). *How A.I. technologies could help resolve food insecurity*. Fortune.

Beyer, L. (2022). *Taranis named Planet Labs PBC's agricultural partner of the year*. PR Newswire.

Block, L. G., Punam, K. A., Vallen, B., Williamson, S., Birau, M. M., Grinstein, A., Haws, K. L., LaBarge, M. C., Lamberton, C., Moore, E. S., Moscato, E. M., Reczek, R. W., & Tangari, A. H. (2016). The squander sequence: Understanding food waste at each stage of the consumer decision-making process. *Journal of Public Policy & Marketing, 35*(2), 292–304.

Bozhinova, K. (2018). *16 apps helping companies and consumers prevent food waste*. GreenBiz.

Brown, A. G., Esposito, L. E., Fisher, R. A., Nicastro, H. L., Tabor, D. C., & Walker, J. R. (2019). Food insecurity and obesity: Research gaps, opportunities, and challenges. *Translational Behavioral Medicine, 9*(5), 980–987.

Buzby, J. C., Wells, H. F., & Hyman, J. (2014). *The estimated amount, value, and calories of postharvest food losses at the retail and consumer levels in the United States*. United States Department of Agriculture.

Connor, E. (2021). *Cisco data scientists work with nonprofit partner Replate to improve food recovery and delivery to communities in need*. Cisco Blogs.

Cooremans, K., & Geuens, M. (2019). Same but different: Using anthropomorphism in the battle against food waste. *Journal of Public Policy & Marketing, 38*(2), 232–245.

Covington, L. (2022). *What is urban farming*? The Spruce Eats.

Davenport, T., Guha, A., & Grewal, D. (2021). How to design an AI marketing strategy: What the technology can do today—and what's next. *Harvard Business Review, 99*(July-August), 42–47.

de Almeida Oroski, F., & da Silva, J. M. (2023). Understanding food waste-reducing platforms: A mini-review. *Waste Management & Research, 41*(4), 816–827.

Deloitte Southeast Asia Innovation Team (2022). *The future of agrifood tech in Southeast Asia: Agriculture in the digital decade*. KrASIA.

Dove, J. (2022). *The best gardening apps for 2022*. Digital Trends.

Durrani, S. (2016). *6 restaurants that pick the food right from their own garden*. Business Insider.

Dwyer, F. R., Schurr, P., & Oh, S. (1987). Developing buyer-seller relationships. *Journal of Marketing, 51*(April), 11–27.

Eastwood, C., Ayre, M., Nettle, R., & Rue, B. D. (2019). Making sense in the cloud: Farm advisory services in a smart farming future. *NJAS–Wageningen Journal of Life Sciences*, 90–91. https://doi.org/10.1016/j.njas.2019.04.004 (December, 10009298. Retrieved September 3, 2023 from).

Etherington, D. (2019). *Volocopter and John Deere team up for a crop-spraying autonomous agricultural drone*. Tech Crunch.

Evans, D. (2012). Beyond the throwaway society: Ordinary domestic practice and a sociological approach to household food waste. *Sociology, 46*(1), 41–56.

Farmer Jones Farm. (2023). *Vegetable Boxes*. Farmer Jones Farm.

Flewelling, R. L., Paschall, M. J., & Ringwalt, C. L. (1993). *SAGE Baseline Survey*. Research Triangle Park, NC: Research Triangle Institute.

FoodPrint. (2018). *The problem of food waste*. Food Print.

Global Agriculture (2019). *FAO: 14% of the world's food is lost between harvest and retail*. Global Agriculture.

Grand View Market Research. (2023). *Farming as a service. Market size, share & trends analysis report by service type (farm management solutions, production assistance, access to markets), by delivery model, by end user, by region, and segment forecasts, 2023–2030*. Market Analysis Report.

Grewal, L., Hmurovic, J., Lamberton, C., & Reczek, R. W. (2019). The self-perception connection: Why consumers devalue unattractive produce. *Journal of Marketing, 83*(1), 89–107.

Grewal, D., Ahlbom, C.-P., Noble, S. M., Shankar, V., Narang, U., & Nordfält, J. (2023). The impact of in-store inspirational (vs. deal-oriented) communication on overall sales: The importance of activating goal-completion mindsets. *Journal of Marketing Research, 60*(6), 1071–1094.

Gruber, V., Holweg, C., & Teller, C. (2016). What a waste! Exploring the human reality of food waste from the store manager's perspective. *Journal of Public Policy & Marketing, 35*(1), 3–25.

Guardian. (2014). *Buy-one-get-one-free offers 'should be scrapped to cut food waste'*. The Guardian.

Guha, A., Grewal, D., Kopalle, P. K., Haenlein, M., Schneider, M., Jung, H., Moustafa, R., Hegde, D. R., & Hawkins, G. (2021). How artificial intelligence will affect the future of retailing. *Journal of Retailing, 97*(1), 28–41.

Guha, A., Bressgott, T., Grewal, D., Mahr, D., Wetzel, M., & Schweiger, E. (2023). How artificiality and intelligence affect voice assistant evaluations. *Journal of the Academy of Marketing Science, 51*(2), 843–866.

Gunia, A. (2021). *This startup founder's AI-powered garbage cans are helping to reduce food waste-and improve bottom lines*. Time.

Gustafson, S. (2022). *Global food insecurity hits all-time high: 2022 Global Report on Food Crises released*. Food Security Portal.

Heide, J. B., & John, G. (1992). Do norms matter in marketing relationships? *Journal of Marketing, 56*(April), 32–44.

Jackson, T. (2016). *Could tech reduce food waste and help feed the world*? BBC.

Jap, S. D. (1999). Pie-expansion efforts: Collaboration processes in buyer–supplier relationships. *Journal of Marketing Research, 36*(4), 461–475.

Jap, S. D. (2001). 'Pie sharing' in complex collaboration contexts. *Journal of Marketing Research, 38*(1), 86–99.

Kaizhi, L. (2022). *Sowing seeds of food security*. China Today.

Kallbekken, S., & Sælen, H. (2013). 'Nudging' hotel guests to reduce food waste as a win-win environmental measure. *Economic Letters, 119*(3), 325–327.

Kaplan, D. A. (2018). *4 direct-to-consumer models shifting the supply chain*. Supply Chain Dive.

Kawazoe, M. T., Lauer, A. G., & Silva, N. B. F. (2021). UrbanVG: A gamification encouraging urban vegetable garden platform. *2021 IEEE Symposium on Computers and Communications (ISCC)*, Athens, Greece, pp. 1–6.

Kim, M. J., & Hall, C. M. (2020). Can sustainable restaurant practices enhance customer loyalty? The roles of value theory and environmental concerns. *Journal of Hospitality and Tourism Management, 43*(June), 127–138.

Kontzer, T. (2021). *Unstung heroes: Startup's AI-powered tomato pollinator gives bees a break*. Nvidia.

Lumpkin, G. T., & Dess, G. G. (2001). Linking two dimensions of entrepreneurial orientation to firm performance: The moderating role of environment and industry life cycle. *Journal of Business Venturing, 16*(5), 429–451.

Martichoux, A. (2021). *App lets you buy leftover restaurant food. Is it worth it*? Newsnation.

Martin-Rios, C., Demen-Meier, C., Gössling, S., & Cornuz, C. (2018). Food waste management innovations in the foodservice industry. *Waste Management, 79*, 196–206.

Mohan, C. (2020). *VoloDrone, the futuristic drone for agricultural use*. Krishi Jagran.

Mookerjee, S., Cornil, Y., & Hoegg, J. (2021). From waste to taste: How 'ugly' labels can increase purchase of unattractive produce. *Journal of Marketing, 85*(3), 62–77.

Moran, C. D. (2023). *6 notable tech updates from the National Retail Federation's 2023 show*. Grocery Dive.

Parasuraman, A., & Colby, C. (2014). An updated and streamlined technology readiness index: TRI 2.0. *Journal of Service Research, 18*(1), 1–16.

Parikh, T., Egendorf, S. P., Murray, I., Jamali, A., Yee, B., Lin, S., Cooper-Smith, K., Parker, B., Smiley, K., & Kao-Kniffin, J. (2022). Greening the virtual smart city: Accelerating peer-to-peer learning in urban agriculture with virtual reality environments. *Frontiers in Sustainable Cities, 3*(February), 1–7.

Parker, J. R., Umashankar, N., & Schleicher, M. (2018). How and why the collaborative consumption of food leads to overpurchasing, overconsumption, and waste. *Journal of Public Policy & Marketing, 38*(2), 154–171.

Peters, A. (2015). *This Hollywood restaurant grows your food next to your table*. Fast Company.

Pinto, R. S., dos Santos Pinto, R. M., Melo, F. F. S., Campos, S. S., & Cordovil, C. M. D. S. (2018). A simple awareness campaign to promote food waste reduction in a university canteen. *Waste Management, 76*, 28–38.

Pixel Scientia (2023). *Measuring the natural world with Kevin Lang from Agerpoint*. Pixel Scientia Labs.

Principato, L., Pratesi, C. A., & Secondi, L. (2018). Towards zero waste: An exploratory study on restaurant managers. *International Journal of Hospitality Management, 74*(August), 130–137.

Principato, L., Mattia, G., Di Leo, A., & Pratesi, C. A. (2021). The household wasteful behavior framework: A systematic review of consumer food waste. *Industrial Marketing Management, 93*, 641–649.

Pultarova, T. (2022). *How China is creating new foods in space*. BBC.

Recycle Track Systems. (2023). *Food waste in America in 2023*. Recycle Track Systems.

Richardson, K. (2021). *These apps aim to reduce the social and environmental impacts of food waste*. Shareable.

Rushton, J. P., Chrisjohn, R. D., & Fekken, G. C. (1981). The altruistic personality and the self-report altruism sale. *Personality and Individual Differences, 1*, 292–302.

Sakaguchi, L., Pak, N., & Potts, M. D. (2018). Tackling the issue of food waste in restaurants: Options for measurement method, reduction, and behavioral change. *Journal of Cleaner Production, 180*(April), 430–436.

Senthilingam, M. (2017). *The tech solutions to end global hunger*. CNN.

Sharma, S. (2019). *How artificial intelligence is revolutionizing food processing business*? Medium.

Shehu, E., Veseli, B., Clement, M. & Winterich, K. (2024). Improving blood donor retention and donor relationships with past donation use appeals. *Journal of Service Research,* 27(3), 346–363.

Shu, C. (2022). *Agritech company CropIn launches its cloud platform to digitize the agricultural industry*. Tech Crunch.

Silberling, A. (2021). *Nosh uses AI to help people and businesses cut down on their food waste*. Tech Crunch.

Suher, J., Szocs, C., & van Ittersum, K. (2021). When imperfect is preferred: The differential effect of aesthetic imperfections on choice of processed and unprocessed foods. *Journal of the Academy of Marketing Science, 49*, 903–924.

U.S. Department of Agriculture. (2023). *Food Waste FAQs*. USDA. https://www.usda.gov/foodwaste/faqs

U.S. Department of Agriculture's Economic Research Service. (2010). *Food Loss*. USDA. https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/food-loss

UNWFP. (2021). *8 facts to know about food waste and hunger*. UNWFP.

van Lin, A., Aydinli, A., Bertini, M., van Herpen, E., & von Schuckmann, J. (2023). Does cash really mean trash? An empirical investigation into the effect of retailer price promotions on household food waste. *Journal of Consumer Research, 50*(3), 1–20.

Visschers, V. H. M., Wickli, N., & Siegrist, M. (2016). Sorting out food waste behaviour: A survey on the motivators and barriers of self-reported amounts of food waste in households. *Journal of Environmental Psychology, 45*(March), 66–78.

Vizzoto, F., Testa, F., & Iraldo, F. (2021). Strategies to reduce food waste in the foodservices sector: A systematic review. *International Journal of Hospitality Management, 95*, 1–10.

Walster, E., Walster, G. W., & Berscheid, E. (1978). *Equity: Theory and Research*. Allyn and Bacon.

Wansink, B., & van Ittersum, K. (2013). Portion size me: Plate-size induced consumption norms and win-win solutions for reducing food intake and waste. *Journal of Experimental Psychology: Applied, 19*(4), 320–332.

Williamson, S., Block, L. G., & Keller, P. A. (2016). Of waste and waists: The effect of plate material on food consumption and waste. *Journal of the Association for Consumer Research, 1*(1), 147–160.