Packaging Strategies That Save Food

A Research Agenda for 2030

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Summary

Thoroughly considering and optimizing packaging systems can avoid food loss and waste. We suggest a number of issues that must be explored and review the associated challenges. Five main issues were recognized through the extensive experience of the authors and engagement of multiple stakeholders. The issues promoted are classified as follows: (1) identify and obtain specific data of packaging functions that influence food waste; (2) understand the total environmental burden of product/package by considering the trade-off between product protection and preservation and environmental footprint; (3) develop understanding of how these functions should be treated in environmental footprint evaluations; (4) improve packaging design processes to also consider reducing food waste; and (5) analyze stakeholder incentives to reduce food loss and waste. Packaging measures that save food will be important to fulfill the United Nations Sustainable Development goal to halve per capita global food waste at the retail and consumer levels and to reduce food losses along production and supply chains.

Introduction

In a world with increasing distance in space and time between the farm and the consumer, packaging systems are a necessity to facilitate the protection, transport, and storage of food products. Packaging saves food from being wasted, but has the potential to further decrease food waste. Reductions in resource use, environmental impact, and undernourishment are urgently needed. The United Nations (UN) has set a goal to reduce by half the (currently) 1.3 gigatonnes (Gt)[1] of edible food wasted annually, as established in Goal 12 (*Ensure sustainable consumption and production patterns*)—SDG Target 12.3—of the UN General Assembly (FAO 2013; UN 2015). This paper proposes a research agenda for how packaging can contribute to the fulfillment of this goal.

Around one third of all food produced in the world is lost or wasted through the supply chain (Lipinski et al. 2013), resulting in direct economic losses of up to US$ 1 trillion per year globally

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(FAO 2014; Lipinski et al. 2017; WRI et al. 2016). Food loss is defined as the crop/food losses occurring during agricultural production and postharvest handling and storage. Food waste is defined as the food discarded by retailers and consumers downstream in the food supply chain (Mandyck and Schultz 2015). We will refer to these together as food loss and waste (FLW), unless otherwise stated. There are many reasons why FLW occurs, including environmental factors during growing and harvesting of crops, such as rigid specifications postharvest; overproduction due to market uncertainties; insufficient temperature control in logistics; inadequate packaging, resulting in poor handling and damage of stock; incorrect batching in processing; overstocking and crushing at retail; and consumer behavior (Baker et al. 2009; Bloom 2010; Buzby and Hyman 2012; Essonanawe Edjabou et al. 2016; Gunders et al. 2017; Gustavsson et al. 2011; Jorgen Hanssen et al. 2016; Lipinski et al. 2013; Parfitt et al. 2010; Qi and Roe 2016; Quested et al. 2013; Silvennoinen et al. 2014; Stuart 2009).

Food production causes about 30% to 35% of the global climate impact, is the major cause of species extinction, and involves about 70% of the global freshwater use (Foley et al. 2011). The agricultural sector and food production especially are the major drivers pushing the environment beyond its planetary boundaries (Rockström et al. 2009). Improving the efficiency of the food system by reducing FLW has the opportunity to create a rapid reduction of the global environmental footprint (ReFED 2016).

Efforts in recent years have focused upon a three-step approach of targeting, measuring, and reducing FLW. A large effort is currently underway by nongovernmental organizations (NGOs), governments, and companies in the food sector to *measure with similar approaches* and share FLW data; one example is the ReFED database in the United States (ReFED 2016). Furthermore, policy actions to reduce FLW around the world have been outlined (Lipinski et al. 2017). Among the goals of this paper is to highlight the potential for packaging to contribute to this process.

Among the great technological improvements to increase the physical-chemical, sensory, and microbiological protection of food products are modern refrigeration technology for fish, meat, and fresh produce and multilayer materials and packaging technologies that extend product shelf life (Murray 2008; Steel 2013; Twede 2002). There have also been many measures to reduce the environmental footprint of the packaging system itself through removal of excessive packaging, smarter product packaging, light-weighting, concentration of liquid products, refill packaging (Van Sluisveld and Worrell 2013), renewable or recyclable materials, and increased recycling (Plumb et al. 2013). However, less attention has been paid to other packaging functions, such as those that help people reduce waste, given their needs, attitudes, and behavior, despite several studies showing that such measures often can be more important than those mentioned above (e.g., see Büsser and Jungbluth 2009; Humbert et al. 2009; Lindh et al. 2016; Silvenius et al. 2013; Verghese et al. 2015; Wikström et al. 2014; Williams and Wikström 2011).

To strengthen the research as well as society awareness about these issues, a group of researchers, whose common interest lies in the role of packaging in saving food from being wasted, established the *Packaging Saves Food Research Group*. We comprise a unique and global team of experts, hailing from the Nordic countries, the United States, and Australia, and bringing together a wide range of academic disciplines, including material science, packaging technology, food quality, supply-chain management, design, consumer psychology, and environmental science.

Organized and hosted by Karlstad University, Sweden, our group first met in April 2016 over 3 days. Through a series of interactive workshops, we discussed the current state of play and future challenges in the role of packaging for sustainability, with a focus on saving food—and an agenda emerged of important working research areas in packaging to reduce FLW. During the workshop, several different stakeholders from large and small companies, institutes, and packaging organizations also participated in the creative work and contributed their thoughts and opinions on the agenda.

In our first co-authored work (Auras et al. 2017), built upon the experience of the authors and engagement and discussions with multiple stakeholders, we presented five issues that need to be further considered and developed by the research community. These five are now slightly reorganized to also include an analysis of stakeholder incentives; see figure 1.

In the following sections, we present and make the case for each of the five identified issues and assemble current knowledge by citing relevant literature and case studies. Finally, we provide some reflection on the policy implications of our research.

Identify and Obtain Specific Data of Packaging Functions That Influence Food Waste

Progress to improve the physical, chemical, sensory, and microbiological protection of food to improve shelf life and to reduce FLW include new technologies, such as nanotechnology and active packaging, which are incorporated in packaging development (Gutierrez et al. 2017; Manfredi et al. 2015; Møller et al. 2016; Yildirim et al. 2017; Zhang et al. 2015). There are economic drivers for such developments if food is saved in the supply chain, and they could be measured to target FLW through expired shelf life.

Many more packaging functions need to be acknowledged and valued in reducing FLW (Lindh et al. 2016). These functions are either related to facilitation of product handling throughout the supply chain or to communication in different parts of the system. To facilitate handling, the package needs to be convenient for different users in several aspects. At retail, the package should be easy to handle and replenish without mechanical damage that otherwise would lead to less product sold and increased waste. For consumers, the package should be easy to open, empty, and reclose in order not to spill

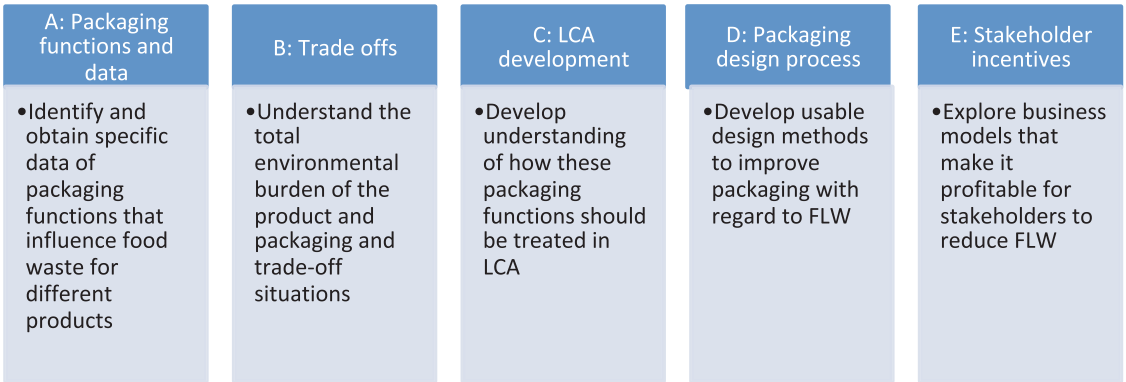

Figure 1 Packaging issues for Research Agenda 2030 to Save Food. FLW = food loss and waste; LCA = life cycle assessment.

or waste product. For example, Duizer and colleagues (2009) found that the elderly often spill product when they open a package. Food items should be apportioned in suitable sizes to not trigger overconsumption or wasted product. For example, a Waste and Resources Action Program (WRAP) study (Quested and Murphy 2014) showed that a large amount of food wasted in households is still in its original packaging, partly emptied, or unopened. Different sizes of packaging for various needs is a major packaging function to consider, in combination with well-designed information about food freshness and safety, and standardized date labeling (ReFED 2016). However, the FLW at retail may increase due to lower turnover rates if there are many packaging sizes for a product. There are some interesting trade-off situations among FLW at retail, in households, and the amount of packaging materials. For some products with high environmental impact, the best alternative is likely to provide only smaller package sizes, despite the increase in packaging materials. The communication function of packaging can also affect waste: For example, use of radiofrequency identification tags or labels during distribution can improve inventory control and monitor shelf life or record the temperature history of the product (Verghese et al. 2015).

Undoubtedly, many packaging functions also play a role in reducing a large amount of food waste. But the magnitude of the potential for packaging to further reduce food waste is rarely investigated. Only a few studies have reported relationships between packaging functions and food waste. A household study in Sweden found that 20% to 25% of the wasted food could be attributed to packaging functions that do not meet consumer needs, such as packages that were too large or difficult to empty (Williams et al. 2012). Other studies, carried out in Norway (Stensgård and Hanssen 2015), revealed that several reasons for consumer food waste relate to the packaging, including the protection and amount of food provided. Reasons included expired product and shelf life, reduced product quality, damaged product, and too much product left in the packaging. Quested and Murphy (2014) carried out one of the most extensive household studies to understand the reasons for food waste due to packaging formats for specific products; however, the quantitative impact of the packaging functions on waste was not examined.

All these examples suggest that packaging functions that influence FLW should be considered and integrated during any product/package design and development that aims to contribute to sustainability. Therefore, it is essential to acquire product-specific data about which packaging functions influence food waste for the package/product under consideration. For example, yogurt, dry pasta, and bread are likely wasted for completely different reasons.

The packaging team (incorporating, e.g., packaging technologists, designers, marketers, food technologists, procurement, and sustainability) needs to know what kinds of functions are most important to develop for a particular product. Furthermore, there is a need to quantify the impact of different functions on food waste for different products, in different markets, and in different kinds of households. Systems to make FLW data publicly available are important for further research and development. With this more comprehensive picture, the packaging team will be more informed and be in a position to design product/packaging with the end user in mind while minimizing waste.

We propose that research should be targeted to collect data on how the vast amount of packaging functions affect FLW along the value chain, in different countries and cultures, for different types of households, and for different food products.

Understand the Total Environmental Burden of Product/Package and Trade-Off Situations

At best, there are packaging design options that simultaneously decrease food waste and the environmental impact of the packaging itself. However, sometimes it may be necessary to increase the environmental impact of the packaging to achieve overall food waste reduction. Can this be motivated by environmental reasons? In some studies, packaging and food data on an aggregated level have been presented. Figure 2 shows the greenhouse gas (GHG) profile of a consolidated number of food items within specific food categories, food waste, and packaging materials over 1 week for a family of 4 people (3 adults and 1 child) in Australia; packaging constituted between 2% and

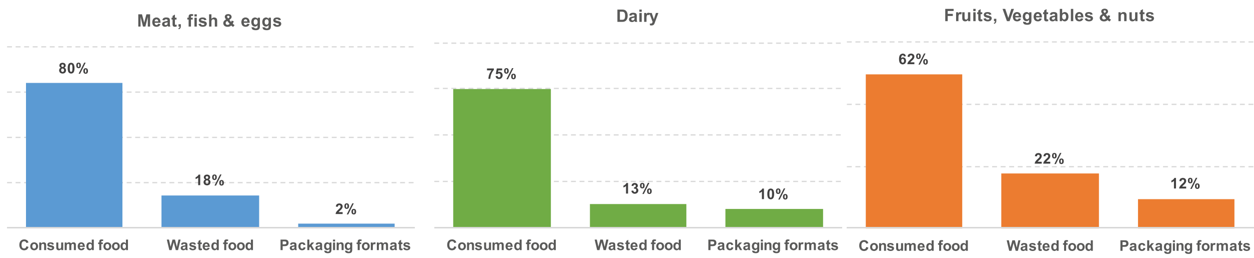

Figure 2 Greenhouse gas distribution between food consumed, food wasted, and packaging materials of meat, fish and eggs, dairy, and fruits and vegetables for a 4-person household over 1 week, adapted from Verghese and colleagues (2014). The climate impact is larger for the food wasted than that of the packaging in all cases.

12% of the GHG impact of all three categories (Verghese et al. 2014). Similar results previously reported indicated that primary and transport packaging represented no more than 10% of the energy associated with the food consumption for 1 person weekly (INCPEN 2009).

However, there are large differences in the environmental impact ratio between packaging and food for different products. Muangmala (2016) found that packaging was responsible for as little as 0.3% of the GHG emissions for resource-intensive food products, such as red meat, but about 20% of the GHG emissions for low resource-intensive food products such as blueberries and raspberries. In an extensive literature review, Heller and colleagues (2018) calculated the food-to-packaging ratio in terms of GHG emissions for a large variety of products; the reported ratios varied between 0.06 and about 700. As the ratios vary so much among different products, it is essential to understand the total environmental burden of the packaging system by considering the trade-offs between product protection, packaging environmental footprint, packaging recycling, and FLW to make informed decisions about packaging for sustainable development. A model to calculate these trade-offs has been proposed (Wikström and Williams 2010). However, simple rules of thumb also can be used. Examples are given below.

Products for which the environmental impact associated with the cultivation, farming, harvesting, and production of food is high relative to its packaging, such as meat and dairy (Clune et al. 2017), the protective role of the packaging is one of the more important functions (Heller et al. 2018; Hellström and Olsson 2017; Licciardello 2017; Verghese et al. 2014; Wikström and Williams 2010). If a red meat package constitutes 0.3% of the GHG emissions of the product, the climate impact of the meat package can be allowed to increase threefold if 1% of the meat is saved from being wasted, and that still results in less climate impact by the entire product-packaging system. For a low resource-intensive product like bread, Williams and Wikström (2011) demonstrated that the global warming potential (GWP) of a package could be doubled if bread wastage was reduced by 1%. Thus, there are many opportunities to explore and understand how to design optimal packaging formats that simultaneously contain and protect food while reducing potential food waste, and efficiently use packaging materials and consider the recyclability of the package at end of life (EoL).

For other food products with low environmental impact, there is a need for more specific data and evaluations of how much packaging material provides the best protection and environmental profile. For some products, such as beer, it could be better to minimize the environmental impact of the packaging even if the level of food waste increases.

A very important factor in the trade-off evaluations between investment in packaging and reduced food waste is the EoL management of FLW and used packaging materials. FLW can end up as animal feed or as methane emissions from anaerobic digestion in a city landfill. Used packaging materials can be recycled into new products, energy recycled, or, in the worst-case scenario, end up in landfills and in the oceans. As shown by Wikström and Williams (2010) and Wikström and colleagues (2016), waste handling scenarios are important to consider in any such trade-off evaluation. It is particularly difficult to model waste treatment of plastic packaging, as their fate often is unknown because of economic and technological difficulties to recycle the materials (Hopewell et al. 2009).

We propose that much more attention be given to acquire data and to model trade-off situations for packaging and FLW and used packaging material recycling for different scenarios, as it will be dependent upon available collection and processing technologies.

Develop Understanding of How These Packaging Functions Should Be Treated in Life Cycle Assessment

The environmental evaluation and concerns about packaging have, to a large extent, been focused on the direct effects—the life cycle of the packaging material itself—without regard to its indirect effects. Although the importance of the indirect effects, including food waste, has been highlighted for many years (Kooijman 1993; Silvenius et al. 2013), they have not been routinely integrated into the LCA practice of food packaging (Wikström et al. 2014). There are several reasons for the slow progress in this area. The most important reason is that there is no unique relation between packaging attributes and human behavior. How the attributes influence human behavior depends on factors such as the content of the package, context for consumption, and attitudes among different people (di Sorrentino et al. 2016). Having such transparent data as a basis for life cycle assessment (LCA) studies can be costly and difficult to obtain. Furthermore, LCA studies tend to simplify steps and boundaries to manage the studies in a reasonable time frame. One way to overcome this shortcoming could be to compare the measured amount of food waste for two different packaging systems for the same product, which would give a quantification of the effect of the packaging attributes. This approach was used in an example for sliced and whole cheese and its packaging (Møller et al. 2012), where consumer food waste was measured in a detailed waste composition analysis. The packaging for sliced cheese had a much higher GWP than the packaging for whole cheese, but the food waste was significantly higher for the whole compared with the sliced product. In many cases, it is difficult to conduct such quantitative studies, so Wikström and colleagues (2014, 2016) have alternatively suggested the use of scenario analysis; see also di Sorrentino and colleagues (2016). The method can be summarized as follows:

- For products of interest, examine waste levels and reasons for waste (e.g., contained too much, spillage, out of date). Obtain data from sources such as literature, experiments, and expert panels (see Daae and Boks [2015] for a more comprehensive summary of experiments). This can be done for the different situations along the value chain.
- Identify packaging attributes that may influence each cause of waste. Literature (see above), expert panels, and consumer tests can assist in the evaluation.
- Develop some reasonable scenarios for how different packaging modifications (e.g., smaller size, additional configurations) can be expected to change food waste levels. This step can be supported by, for example, consumer tests.
- Finally, after obtaining the environmental data for the food item, the packaging (which may include secondary and tertiary packaging if appropriate) and EoL data, estimate whether the reduced food waste levels can motivate the change in packaging measures. It is important to consider factual EoL waste management scenarios in different markets, as the outcome of this exercise can differ substantially, for example, when plastics are recycled or wasted to watersheds.

This exercise can provide valuable insights about the environmental importance of different packaging attributes. The results are considered as if-then characteristics (i.e., reduce the size of the packaged bread by 30% and hence increase the relative impact of the bread packaging by 40%, which in the end will be environmentally favorable if bread waste is reduced by 1%). So far, such analyses are theoretical. To judge if bread waste will be reduced by 1 or more percentage points in reality will be more subjective, but it must be supported by experience and, to some extent, common sense. In the bread example mentioned above, with the vast amount of bread waste in mind, it seems quite clear that smaller bread package sizes should be beneficial for the environment. This procedure is transparent, so the results can be widely discussed. Although precision in the calculations so far is weak, the scenario technique can help to identify products to which resources should be directed to develop packaging that saves food, and serve as an example and inspiration for packaging designers.

We propose that packaging functions that influence FLW should be acknowledged in any environmental assessment of food products that aims to provide advice for packaging development. Standardized scenario analysis is one of many possible tools available to develop transparent assessment.

Improve Packaging Design Processes to Also Consider Reducing Food Waste

Packaging design practices are often separated organizationally and time-wise from food product development (Olander-Roese and Nilson 2009; Olsson and Larsson 2009); therefore, packaging suppliers are subject to cost pressures from purchasing departments in the food industry. Furthermore, the tensions between marketing and sustainability, both on a strategic and an operational level, enhance the tensions that packaging designers must resolve (de Koeijer et al. 2017).

In trying to resolve those tensions, in particular where FLW is concerned, many organizations are uncertain about the consequences of potential design decisions on FLW (Hellström and Olsson 2017). Improved packaging design, which begins from the requirements of the food item and accounts for the whole life cycle of the product-package combination, is often lacking. Simultaneous design of the product and the package could help in finding the best ways to prevent FLW and in minimizing the environmental impacts of the packaging without compromising the product it contains (Grönman et al. 2013). In light of the discussion above, knowledge about product use in the entire product-package life cycle is key for packaging designers and for food developers to integrate knowledge about the packaging functions for food protection (Olsson and Larsson 2009). The first consideration in such a packaging design process would be to choose which aspects in the packaging design (e.g., portion size, empty-ability) to focus on for a specific product, and the second consideration would be to make decisions whereby food protection aspects and an understanding of consumer behavior result in designs that contribute to reduced food waste. The choice with regard to focus may well be the prerogative of marketing or product management. Thus the briefing process, in which the design objective is formulated and communicated to the design team, is a critical step (Petala et al. 2010; Ten Klooster and de Koeijer 2016).

Once a specific focus has been selected, design as a creative discipline has a range of techniques that can respond to this challenge. For example, the desired action can be made the default (e.g., not wasting food through better portion sizing, resealability, or empty-ability) or the package design can be used as a medium to persuade or inform the user of best practice (e.g., innovatively communicating portions or when the product has actually expired). The emerging field of design for behavioral change may offer insights into approaches for packaging redesign (e.g., see Niedderer et al. 2014) that may target the designed environment and an individual's cognition (Simon 1990). To validate the effectiveness of change, streamlined LCA scenarios can then be performed to assess the potential impact of the packaging changes, in line with the procedure described in the previous section. If needed, concepts can be prototyped in limited batches and tested with real users to measure any noticeable differences in food waste.

The above suggestions may still be too extensive for day-to-day practice, where tools will have to work more rapidly, even at a cost, with regard to validity and accuracy. Where the balance lies between costs (time and money) on the one hand and validity and accuracy on the other, and how to select that balance for a given project, must be answered first if we are to succeed in including quantitative tools for food waste reduction (which may vary and be speculative) into the packaging design process. A secondary question would be the design of the tool(s) themselves and how to incorporate them into a variety of existing workflows. Boks (2006) already identified the need for customized tools that fit company-specific design workflows (though not specifically for packaging design), which was confirmed for a food company by Petala and colleagues (2010), who further stressed the need to manage the implementation of such tools, and the continuous training of both marketers and designers who have to work with them.

We propose that research and design be oriented to include FLW generation in the packaging design process. The packaging design process needs to find the tools to evaluate the prospective trade-offs throughout the product-packaging life cycle. From a process perspective, we can distinguish a briefing, an ideation, and an evaluation/decision phase in the design process. Of those, especially, the aspect of effective briefing and the tools for decision support are in need of further research.

Stakeholder Incentives to Reduce Food Loss and Waste

The package is an intermediate between the product and actors (users) along the supply chain, and it has the potential to affect FLW at different stages in the chain (Hellström and Olsson 2017). Looking at FLW from an economic point of view only, some actors (such as the producers) gain by producing more, independently from whether the products are consumed or wasted further down the supply chain. In the same way, transporters gain from driving more goods from production places to retail, and consumers gain from buying large packs at a lower price per kilo or unit even if a portion is wasted (Hellström and Olsson 2017). Therefore, there is a need for new models for risk and gain sharing among supply-chain actors, including consumers and recyclers, that effectively reduce FLW in the entire system.

To create new business models or models for sharing corporate social responsibility, different supply-chain or network actors need to work collectively on solving the common challenge of reducing FLW. Governmental organizations also need to participate with incentives aligned to save resources and create value for packaging systems that save food at the different supply chain stages.

Sharing gains and risks in supply chains is a critical aspect in developing new models for reducing FLW (Lambert and Cooper 2000). If food manufacturing companies select packaging concepts that help to reduce food waste (and everything else is unchanged), their sales will be reduced. To compensate, the companies must find other value-adding features to be able to increase prices and margins on their products. For well-working supply chains "its companies' incentives are aligned – that is if the risks, costs and rewards of doing business are distributed fairly across the network" (Narayanan and Raman 2004, 96). Alignment between supply-chain actors' interests as well as equal incentives among them are key in making new shared business models (Lambert and Cooper 2000; Lee 2004). From a packaging point of view, aligned incentives among stakeholders, organizations, and other involved partners will create beneficial risk and gain sharing, resulting in optimized sustainable solutions that contribute to reducing FLW.

If the supply-chain actors agree to new business models, and manage to create better solutions in terms of reduced FLW, the knowledge and value also must be transferred to consumers. This transfer would occur either by creating better awareness or by creating incentives, so consumers are prepared to pay more for packaging that helps them reduce food waste. However, few consumers are aware of the packaging functions that enable them to save food, and packaging is still generally perceived as something bad for the environment, something that should be minimized (Licciardello 2017; Plumb et al. 2013). It is therefore necessary to educate and involve consumers to change their behaviors and attitudes (Nordin and Selke 2010). With better awareness, we foresee a new type of consumer who chooses value-added packaging for decreased FLW.

We propose to research, explore, and evaluate different business models and governmental mitigations whereby packaging initiatives are evaluated from the perspective of FLW for different stakeholders. And special attention must be paid to determine how businesses can make profits by helping consumers to waste less.

Summary and Recommendations for Further Research and Contribution to UN Target 12.3

Packaging systems can play a critical role in reducing FLW. NGOs, governments, and companies must make sure that optimized packaging systems are part of their new reporting circular economies and sustainability agendas. Consumers also play an important role in making more informed decisions and adjusting their behaviors to food purchasing, preparation, and eating. While the research of the physical-chemical and microbiological protection functions of packaging in relation to shelf life have been relatively well examined, the research on the packaging functions highlighted in this paper, and their importance for FLW, is an emerging area. To make and accelerate progress, we propose that more attention is given to the following:

- Understand and collect data on how the various packaging functions affect food waste along the value chain, in different countries and cultures, for different types of households, and for different food products.
- Acquire data and model the trade-off situations for packaging and FLW for different kind of conditions.
- Develop fair and transparent environmental assessment methods that acknowledge the packaging functions that help to save food, including user behavior. The impact of the food-packaging system, direct and indirect aspects, including food waste should be assessed rather than the packaging system itself.
- Develop usable design methods to improve packaging with regard to FLW.
- Explore business models that make it profitable for stakeholders and consumers to reduce FLW.

Small changes in packaging that save food can have a profound impact on sustainable development. Finding the balance between protection of product and packaging material use can lead to an overall saving in resources, reduce environmental impact, and increase overall system efficiency. There are many challenges ahead as the world grapples with working toward halving the amount of food waste generated by 2030. Packaging will play an important role in realizing UN Goal 12.3, and we must act now to intensify our understanding, research, and business development in this area.

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Note

1. One gigatonne (Gt) = 1 billion metric tonnes = 1 petagram (Pg).

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