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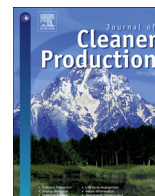
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# Avoiding food becoming waste in households – The role of packaging in consumers' practices across different food categories

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## ABSTRACT

Food waste in households remains a sustainability challenge that poses both environmental and social problems. Among the many factors contributing to this problem, the packaging, including its design and functions, can either leverage or reduce food waste. Yet packaging is often considered an environmental villain, which can lead to missed opportunities for reducing food waste. Against this background, this study explored and quantified the packaging–food waste relationship in households. To explore this relationship, a multi-step method was applied to grasp the role of packaging in consumers' everyday practices and routines. The method incorporated a questionnaire, food waste diary and in-depth interview to measure food waste across different food categories and explore the underlying reasons for food wastage. According to an analysis of 37 households, packaging played a significant role especially in bread, dairy, meat and staple food wastage. For countering this problem, the most important factors related to packaging are its size and display of detailed information about product safety and storage. This study's theoretical contribution lies in offering a service lens and an 'outside-in' approach for exploring the consumer's value creation process and providing a context for better understanding why food wastage occurs in households. For policymakers and packaging designers, this study provides new insights into the relationship between consumer food practices and packaging, thus informing future food waste reduction initiatives.

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## 1. Introduction

Recent review studies and policy documents highlight the significance and impact of household-generated food waste on both the environment and society (e.g. Block et al., 2016; European Commission, 2017; Hebrok and Boks, 2017; Schanes et al., 2018). The Agenda 2030 Sustainable Development Goal (SDG) 12.3 underlines the importance of this issue and calls for action – specifically, 'to halve per capita global food waste at the retail and consumer levels' by 2030 (United Nations, 2015). Households continue to be a major contributor to food waste in the industrialised world (Stenmarck, 2016; FAO et al., 2014), which has necessitated an exploration of new approaches to tackle this

challenge. For example, recent studies have used insights from design theory (Hebrok and Boks, 2017), consumer behaviour (Block et al., 2016), practice theory (Schanes et al., 2018) and innovation (Baron et al., 2018) to explore the reasons for this problem and develop new solution pathways for reducing consumer-generated food waste. So far, the reasons for food waste in households have been reported with general conclusions, but little is known about why specific food items are wasted. The present paper contributes to these discussions by adopting a service lens to investigate the role of packaging and its potential for reducing food waste in different product categories in households.

Packaging is often seen as a double-edged sword. On one hand, it can be questioned due to its direct environmental impact, especially when fossil-based materials and a linear rather than circular model underpin the packaging design process. Most consumers believe that packaging-related waste has a greater environmental impact than food waste, since food is natural and biodegradable

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(Principato et al., 2015; Williams et al., 2012). On the other hand, packaging plays an important role in protecting food, facilitating its handling and informing about the food contents. These functions can play an especially important role in reducing food waste during the consumption phase. For example, from an environmental perspective, there is a strong justification for adding more packaging material to meat and dairy products even when this only slightly reduces food waste (Heller et al., 2019; Wikström et al., 2019). Thus, properly developed packaging has the potential to reduce the environmental impact along the food supply chain.

Yet the relationship between packaging and food waste remains poorly understood. As reported in two recent literature reviews (Wikström et al., 2019; Wohner et al., 2019), only a few studies have investigated packaging-related food waste in households, and only Williams et al. (2012) have attempted to quantify how much of the total food waste can be attributed to packaging (AMERIPEN, 2018). This knowledge gap is significant because it inhibits making an informed decision, including a fair environmental assessment, about packaging design aimed at reducing food waste. Against this background, the aim of this study was to investigate the link between packaging and food waste. Accordingly, the research question was defined as follows:

**Research Question:** Across different product categories, how much food waste can be attributed to packaging functions?

To address the research question, the study applied a service lens alongside a multi-step method. This approach was adopted for two reasons. First, adopting a service lens would result in an alternative theoretical perspective on food packaging and design activities in this domain. The service lens allowed the unit of analysis to shift from packaging as an artefact to the use of packaging and the value it creates during the consumption process (Edvardsson et al., 2005). Accordingly, the design process can begin with an exploration of the consumer's value creation process and how packaging can become a supporting element during this process. In other words, we propose that designing food packaging that truly aims to reduce food waste within households requires an 'outside-in' approach from the consumer rather than an 'inside-out' approach from the designer. The 'outside-in' approach starts with an understanding of how consumers purchase, store, handle and reuse food in their daily lives. Otherwise, even if it is highly innovative in its functionality and protection, the packaging design simply may not support the consumer during the use process or the food that the packaging contains (Lindh, 2016). We propose that the service lens provides a suitable theoretical departure for conceptualising the packaging design process.

Second, the research question addresses the lack of understanding of how packaging design influences food waste across different product categories (Aschemann-Witzel et al., 2015; Hebrok and Boks, 2017; Molina-Besch, 2019; Pauer, 2019). Investigating this relationship in the context of households is challenging because the reasons underpinning food waste are deeply entangled in consumers' everyday lives and practices (Block et al., 2016; Quested et al., 2013; Schanes et al., 2018). Consequently, consumers might not even be aware of the food waste they generate or how different packaging functions affect the quantity of food being wasted. For example, if a consumer finds mouldy, half-eaten salsa in the refrigerator, they might not necessarily identify packaging size as the cause. Yet the purchase of a smaller size of the product might have avoided this waste. Therefore, fully understanding the relationship between packaging and food waste requires an in-depth understanding of consumers' shopping and food consumption practices alongside the packaging solutions that are actually available to them. To meet this requirement, the present study deployed a multi-step method combining a questionnaire, food waste diary for obtaining original quantitative data and an in-

depth interview to investigate the complex relationship between why the food waste occurred and the role of packaging. Generating such an understanding will not only provide a suitable basis for packaging design but also guide future investigations for capturing the multifaceted nature of household food waste.

## 2. Literature

### 2.1. Packaging as a service

In this study, packaging was conceptualised as a service. The adopted service lens drew on service-dominant logic (SDL), which has applications across disciplines to explain the systemic and multi-actor nature of value creation (e.g. Baron et al., 2018; Matthies et al., 2016; Trischler and Charles, 2019). Important for the present study was the premise that value is not embedded in goods or services but is created during use (Vargo and Lusch, 2008a). SDL uses the singular term 'service' to reflect the process of doing something beneficial for, and in conjunction with, some entity rather than the units of output implied in the plural 'services' (Vargo and Lusch, 2008b). During this process, goods simply act as a type of resource that the beneficiary (e.g. the consumer) integrates alongside other resources (e.g. knowledge, infrastructure, etc.) to co-create value (Kleinaltenkamp et al., 2012; Skälén and Edvardsson, 2016).

SDL's premise of value being created during use rather than exchanged through goods and services is significant because it implies that value cannot be predefined or delivered but is 'always uniquely and phenomenologically determined by the beneficiary' based on the specificity of her or his context (Vargo and Lusch, 2016, p.8). This means that even the most advanced packaging solution does not create any value if it does not support the use process. To illustrate, from an SDL standpoint, a completely biodegradable packaging design can be considered a service failure if it frustrates the user during the food handling process (e.g. difficult to open, reseal or empty) or if it is too big for the specific use context (e.g. single households).

### 2.2. Towards an 'outside-in' approach to packaging design

Many organisations follow a manufacturing logic or so-called 'inside-out' approach, which starts with the production and ends with the point of sale, where products and services are exchanged for money. This approach is informed by the popular exchange paradigm of marketing (Hill and Martin, 2014) and the tradition of product design (Kimbell, 2011). For example, common food retailing practices, such as 'buy two – pay less' or the display of price/kilogram ratios, focus on exchange and often lead to consumers buying more or a larger package than they actually need.

Adopting a service lens reveals that the 'inside-out' approach is far too narrow because it overlooks what consumers actually do with the purchased products to serve their specific needs. This argument is in line with recent studies calling for the consideration of consumer practices and routines (Schanes et al., 2018), including socio-cultural and material factors (Hebrok and Boks, 2017) as well as psychological drivers and biases (Block et al., 2016), when designing solutions to food waste. When contrasting these studies with the narrow 'inside-out' design approach, there is little surprise that an increased amount of food is wasted in households while food production, supply and distribution systems become increasingly effective.

We propose that the service lens can provide a starting point for transforming an industry that has traditionally focused on production and exchange while paying little attention to how value is created during use. The service lens shifts the innovation process to

an 'outside-in' approach, allowing new solutions to be based on explorations of possible future use situations and user needs (Gustafsson et al., 2012; Holmlid et al., 2015; Trischler et al., 2018b). This approach is also deeply embedded in service design (Holmlid, 2007; Holmlid and Evenson, 2008), which, like service innovation, is less concerned about designing new products or services as output but about how a new solution changes the way that value is created during use.

The adoption of an 'outside-in' approach requires the application of research methods that enable an in-depth exploration of the specific circumstances surrounding the consumer's value creation process (Helkkula et al., 2012). This requirement applies to the present study because household food waste is deeply entangled in everyday consumer practices and routines (Evans, 2014; Hebrok and Boks, 2017; Quedsted et al., 2013; Schanes et al., 2018). For example, Schanes et al. (2018) conclude that 'multiple methods of data collection (e.g. combining interviews with observations) is important to capture lived experiences and provide a nuanced account of how and why food gets wasted' (p.989). Moreover, and with a direct link to the research question that directed this study, Hebrok and Boks (2017) highlight that 'it is not sufficient to understand why people waste food, what they waste and how much is also important to know in order to generate ideas on how to intervene' (p.382). Thus, the present study responded to these calls by applying a multi-step method that considers individual consumer practices and sheds light on the packaging–food waste relationship across different food categories. Next, we describe the method and data collection process.

### 3. Method

How can food waste attributed to packaging functions be assessed in households? The service lens introduced in the previous section clarifies that such an assessment must consider the relationship between the consumer's value creation process and packaging as one of the many resources integrated during this process. Likewise, from a practice theory perspective, packaging can be seen as one material element within consumer practices. To successfully account for the many contextual factors surrounding the packaging–food waste relationship in households, this study adopted a multi-step method. This method consisted of three data collection tools: a questionnaire, food waste diary and in-depth interview. These tools inherit the traditions of empathic design (Kaario et al., 2009; Kouprie and Visser, 2009) and marketing research (Creswell, 2009; Gummesson, 2005), and in their specific combination, aim to complement and triangulate findings through both qualitative and quantitative methods (Maxwell, 1992). The procedure and design underpinning the applied analysis was additionally informed by previous household studies reviews (Hebrok and Boks, 2017; Schanes et al., 2018), including a study on the role of packaging (Williams et al., 2012). The multi-step method is described in detail below.

#### 3.1. Questionnaire

The first step of data collection involved a face-to-face introductory meeting and distribution of the questionnaire. The questionnaire was designed to serve two purposes. First, it was intended to collect relevant background information from the participating households, including participants' demographics, living arrangement, motivations for participating and food-related practices, such as planning, shopping, cooking and routines after meals. The questions in this part of the questionnaire were derived from the findings of two systematic literature reviews on household food waste (Hebrok and Boks, 2017; Schanes et al., 2018).

Second, the questionnaire was intended to raise awareness about specific packaging functions and their possible effects on food waste. The related questions drew on an expert study which examined six important functions of effective packaging (Wikström et al., 2019): (1) reclosing, (2) correct amount of food for the consumer's needs, (3) easy to empty, (4) past best before date, (5) easy to open without spillage and (6) uncertainty about whether the food is safe for consumption. The products used were the same as in Wikström et al. (2019) because they have a relatively high environmental impact and/or are wasted to a great extent. Asking these questions was deemed important because consumers often do not recognise the role of packaging in their food-related practices, which complicates investigating the link between food waste and packaging functions (Williams et al., 2012). Therefore, the questionnaire administered at the introductory meeting informed participants about the role of packaging. This approach can be compared with sensitising – referring to a process of reflection initiated by the investigator to create awareness around a specific topic or problem (Visser et al., 2005). The motivation for highlighting this focus at the outset was to remove possible feelings of guilt that consumers may have when reporting food waste (Quedsted et al., 2013). This meeting lasted between 45 and 60 min. The questionnaire was reviewed by experts in qualitative research and tested with two representatives – one in each of the two cities of application. The feedback obtained during this review process was then incorporated into the final questionnaire. The full questionnaire is available in Appendix A.

#### 3.2. Food waste diary

After the first meeting, participants were asked to complete a food waste diary over a seven-day period. The diary was used to evaluate the amount of food waste and identify specific reasons for the occurrence of waste. Accordingly, the diary consisted of four parts: (1) instructions and examples of how to measure food waste, (2) record of food waste not connected to meals, (3) record of food waste connected to meals and (4) final questions with observations on food storage areas. All parts were explained to participants during the introductory meeting.

Participants were asked to report the avoidable amount of food waste – that is, food that had been edible at some point before disposal, including leftovers given to pets but excluding bones, peels or any other inevitable wastage. To measure food waste reliably, a scale was provided to each participant. Liquids, for example, were reported in volume; in those cases, we used the density of the product to translate the reported volume into weight. For some products, such as yoghurt, crème fraîche, certain vegetables and some ready-made meals, participants reported wastage within the original packaging. In those cases, we measured the weight of the packaging to subtract that from the reported amount. To enable this, participants were asked to also document the product brand and size of the packaging.

In addition, participants were asked to report on the underlying reason why food waste had occurred. This included three key areas:

- First, participants could choose between nine different pre-defined reasons and one open-ended option to report on *food waste not in direct connection to meals*: (1) bought too much, (2) package too large, (3) difficult to empty package completely, (4) bought the wrong item, (5) accident, (6) past best before date, (7) uncertain if product is fit for consumption, (8) food has gone bad (rotten, sour, mouldy, etc.) and (9) bad/broken package.
- Second, participants were asked to report on *food waste that occurred in direct relation to meal preparation and consumption*: (1) prepared too much, package too large; (2) too little left to

save; (3) do not have the energy to save for later; (4) the food did not taste good; (5) we were not that hungry; (6) saved leftovers not used in time; and (7) children did not want to finish it.

The predefined reasons listed here were identified in previous studies and used by Williams et al. (2012) as reasons.

- Third, participants were asked to observe and document their *food-related practices with packaging functions in mind*. Thereby, they were asked to describe specific examples, such as packages that were difficult to empty, packages that could not be reclosed, packages that led to food spillage during usage or packages that required extra material to sufficiently protect the food.

The food waste diary as such provided insights not only into how much food was wasted but also what food was wasted and why it was wasted.

### 3.3. In-depth interview

Finally, to discuss the reported food waste results in the diary as well as to extend the analysis beyond the one-week period, in-depth interviews were conducted with every participating household as the concluding step. In-depth interviews allow participants to describe experiences in their own words (Creswell, 2009). In the present study, this meant that participants could elaborate on their reported results concerning food wastage by including specific peculiarities that might have occurred during the reporting week. For example, the amount of food waste may have been abnormally high or low due to specific situational factors. Alternatively, commonly observed packaging-related issues might not have occurred during that particular week. During the interviews, participants could point out such aspects to the research team. The interviews lasted between an hour and an hour and 45 min. The opportunity for free association meant that even if the topic at the moment was fruit, participants could start talking about yoghurt. This forced the interviewer to follow the participants' reflections and be flexible while making the field notes.

The use of interviews also enabled the triangulation of data through the application of two methods to the same topic (Patton, 1999). An interview guide was developed to guide the in-depth interviews and it was pre-tested twice and modified before final usage. Appendix B provides an example of an interview guide. All interviews were audio-recorded and complementary field notes were taken by the interviewer.

### 3.4. Participant recruitment and description of the sample

A self-selection procedure was used to recruit participants. Self-

selection is commonly used in innovation projects owing to the assumption that within a large population (e.g. customers, end-users, households), a small number of people are highly intrinsically motivated to contribute their unique knowledge (Lüthje, 2004; Poetz and Schreier, 2012; Trischler et al., 2018a). These people are typically recruited by issuing an open call for participation where the underlying topic and problem are clearly described and compensation for participation is kept to a minimum. Interestingly, self-selected samples that follow this procedure are not only highly motivated but also highly knowledgeable on the underlying topic and possess innovative characteristics (Poetz and Schreier, 2012; Trischler et al., 2018a). Since the current study demanded a significant investment in time from participants (i.e. questionnaire, one-week comprehensive self-reporting, in-depth interview), self-selection of a small number of households was deemed the most suitable procedure. Otherwise, there would have been a considerable risk of early drop-out or wrong reporting of food waste owing to a lack of engagement, participant fatigue or insufficient knowledge of the topic.

The call for participation was issued in two Swedish cities: Stockholm and Karlstad. One major university in these cities agreed to post the call on its website. Information about the call was also posted on a digital meeting place where researchers and potential respondents could make contact. In addition, five members of the research group used their professional and social networks to advertise the project. Households interested in participating were asked to call or send an email to either of the two contact persons.

In total, 37 households (16 in Stockholm, 21 in Karlstad) signed up for the study. Twenty-two households had at least one adult with children under the age of 21 years; 15 households had no children and, of these, five were single-person households. Families with children were slightly overrepresented, while single-person households were underrepresented. The participants ranged in

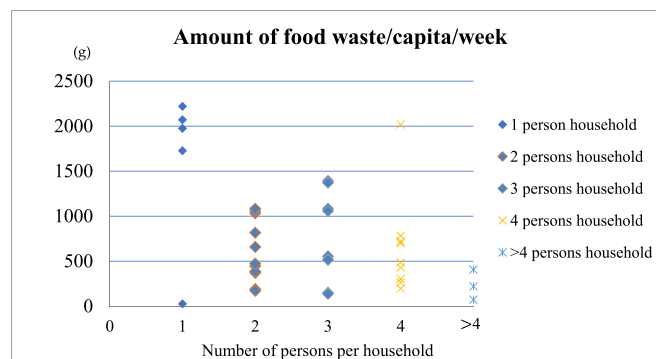


Fig. 1. Amounts of food waste per person per week.

**Table 1**  
Food waste linked to packaging as reported in the diary study.

Reason for food waste	A: Packaging functions	B: Possible packaging functions
Package too large	Contains the right amount	Contains the right amount
Difficult to empty packaging completely	Easy to empty	Information about food safety
Past best before date	Information about food safety	Physical-chemical protection
Uncertain if product is fit for consumption (only packaged products)	Contains the right amount	Information about food safety
Bad/broken package	Information about food safety	Physical-chemical protection
Food has gone bad (in opened packaging)	Physical-chemical protection	Easy to reclose

**Table 2**  
Amount of food waste and reasons for food waste per category and product.

Category	Product	Amount of waste (kg)	Reasons for food waste																	
			Bought too much	Package too large	Difficult to empty packaging completely	Bought the wrong thing	Accident	Past best before date	Uncertain if product is fit for consumption	Food has gone bad (rotten, sour, mouldy, etc.)	Bad/ broken package	Other reason	This dish is not good to eat later	Prepared too much, package too large	Too little left to save	Do not have the energy to save for later	The food did not taste good	We were not that hungry	Saved leftovers not used in time	Children did not want to finish
			a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
<b>Bread</b>	Whole wheat bread	0.6		1				1	1	3		1								
	White bread	3.5	1	7		1	2	3	1	16	1				1			1	3	
	Sandwich*	1.4					1	1	2	1	1		1		4			1		17
	Sweet bread	1.4								3	1	2			1	1	1	2		4
	<b>Total</b>	<b>6.9</b>	<b>1</b>	<b>8</b>		<b>1</b>	<b>3</b>	<b>5</b>	<b>4</b>	<b>23</b>	<b>3</b>	<b>3</b>	<b>1</b>		<b>6</b>	<b>1</b>	<b>1</b>	<b>4</b>	<b>4</b>	<b>21</b>
<b>Fruit and vegetables</b>	Banana*	0.7								4										2
	Apples and pears*	1.1							1	4					1					1
	Citrus*	2.8				1			1	13		2								
	Berries and mango	1.4							1	7	2				1			1		
	Brassica	3.8		2			1	1	1	7		1		1				1	2	2
	Roots	2.6	1						2	16			1		6	3				3
	Tomato	0.7		1						6		1			3	1			1	
	Cucumber, etc.	1.5		1			1		2	9		2	1		4	3	2	1	1	1
	Green leaves/ lettuce	1.8	2	4					2	16	1	1		1					1	
	Mixed salads*	1.2		1	1				1	1		1	1		4	5		1	3	1
	Other vegetables	3.5	1	3		1		1	1	7		1		1	2				4	2
	<b>Total</b>	<b>21.1</b>	<b>4</b>	<b>12</b>	<b>1</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>12</b>	<b>90</b>	<b>3</b>	<b>9</b>	<b>3</b>	<b>3</b>	<b>21</b>	<b>12</b>	<b>2</b>	<b>4</b>	<b>12</b>	<b>12</b>
<b>Dairy</b>	Yoghurt	3.9			22		3	5		1					3		1			3
	Milk	2.8		3	3			6		5				1						1
	Cream	0.6	2		4			1	1	3	1	1				1			1	
	Cheese	1.5		1	1			2	3	11	1			1	2	2	1			
	Egg, fat, ice cream	2.8	1	1				3	4	3					3					
	<b>Total</b>	<b>11.6</b>	<b>3</b>	<b>5</b>	<b>30</b>		<b>3</b>	<b>17</b>	<b>8</b>	<b>23</b>	<b>2</b>	<b>1</b>		<b>2</b>	<b>8</b>	<b>3</b>	<b>2</b>		<b>1</b>	<b>4</b>
<b>Meat, fish</b>	Beef, minced meat	1.0		1			1		2	1		1	1	1	2	1		1	2	1
	Chicken	2.4						1	2	1				1	1	1				
	Charcuteries	0.6			1			1	1			2	2	3	1			1		2
	Fish	0.4		1				1	1	1				1	1					
	<b>Total</b>	<b>4.4</b>		<b>2</b>	<b>1</b>		<b>1</b>	<b>3</b>	<b>6</b>	<b>3</b>		<b>3</b>	<b>3</b>	<b>6</b>	<b>5</b>	<b>2</b>		<b>2</b>	<b>2</b>	<b>3</b>
<b>Staples, condiments and other food</b>	Staple food	3.9						3	2	2		5					1			1
	Olives, etc.	1.5		6	1				5	2		1			1					
	Tomatoes/beans, etc.	1.4		6	1				5	2		1			3					
	Sauces and oil	1.5		3	2		1	4		6		1								
	Sweet, snacks	1.5	2	1			1	1		1		1								

(continued on next page)



Table 2 (continued)

Reasons for food waste																				
Category	Product	Amount of waste (kg)	Bought too much	Package too large	Difficult to empty packaging completely	Bought the wrong thing	Accident before date	Past best before date	Uncertain if product is fit for consumption	Food has gone bad (rotten, sour, mouldy, etc.)	Other reason	This dish is not good to eat later	Prepared too much, package too large	Too little left to save	Do not have the energy to save for later	The food did not taste good	We were not that hungry in time	Saved leftovers not used	Children did not want to finish	
			a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
	Total	9.8	2	13	6		2	16	6	16		8		4		1				1
Cooked food (often mixed)	Cooked pasta	2.3	1				1	1	2			2	2	5	2	1	3	2		4
	Cooked rice	0.9								1			3	5	3	1	2	0	1	
	Pasta/rice - veg	1.2					1					1	3	2		1		1	4	
	Meat/chicken/Fish	3.1						1	1	1		3	2	7	3	3	2	4	10	
	Oat, grits, wheat	1.4			1		1					1	1	2	3	1	1	1	11	
	Mixed vegetarian	3.2			2		2		3	1	1	2	2	9	1	1	1	4	3	4
	Total	11.7	1		3		5	1	7	3	1	3	9	12	31	10	7	12	10	34
Drinks	Coffee, tea	1.3								1		1	3	11						
	Sweet drink, etc.	1.8	1							4	2		1	1	2			1	1	1
	Total	3.1	1							5	2	1	3	12	2			1	1	1
All products and reasons		68.6	11	33	41	2	13	39	39	137	8	25	19	35	78	28	13	22	30	76

Notes: Participants could choose more than one reason for their food waste. Products marked with an \* were considered to not be in packaging.

Notes: Participants could choose more than one reason for their food waste. Products marked with an \* were considered to not be in packaging.

age from 20 to more than 70 years old. Fourteen participants were between 40 and 50 years, nine were in the 20–30 age group, nine were between 30 and 40 years, three were between 50 and 60 years, one participant was in the 60–70 age group and one participant was over 70 years old.

Nine participants had completed upper secondary school and 28 had studied at university (76%), which is well above the national average (42% of the Swedish population obtain a university degree) (Statistics Sweden, 2018). This high number might have been related to the platforms used for advertising the study or a correlation between level of education and environmental concerns about food waste (e.g. Qi and Roe, 2016). The main motivation for participation was environmental concerns including an interest in evaluating one's own level of food waste. All participating households completed the diary and attended the concluding interview, indicating that the self-selection procedure was effective.

### 3.5. Project procedure

The household study (introductory meeting with questionnaire, food waste diary and second meeting including the in-depth interview) was conducted during the two-month period between April and May 2018. A researcher from the project team made initial contact and met with at least one member of each household to explain the study procedure. Most of these meetings occurred at the interviewers' workplace, while others were conducted in the participants' homes. During this meeting, participants received a kitchen scale and detailed instructions on how they should complete the diary and measure food waste at home. They were instructed to handle food as they would normally do, as the focus was on investigating the relationship between packaging and food waste and when and why waste occurred. Participants were also asked to choose a week without any special occasions. The meeting concluded with participants filling in the questionnaire.

After they had completed the diary, participants were asked to contact the researcher to arrange the concluding interview at a location of their choice, which most often was the interviewer's workplace. This meeting included a discussion on the results of the diary study and the in-depth interview. The interviewer started by addressing the food categories reported in the diary, and the interview guide facilitated keeping track of the categories and questions, as many participants moved across categories and associated freely regarding why they had wasted food and the role of packaging or practices. As compensation for their contribution, participants received a €50 gift card and were invited to keep the food waste scale. They did not receive any compensation for travelling to attend the interview.

### 3.6. Data analysis

The results of the diary study were clustered into seven categories within which they were assigned to specific products or product groups. This categorisation established the starting point for exploring the relationship between food waste and packaging (see Table 2 and sections 4.1–4.5). Products within the categories of bread, dairy, meat and fish, staples and drinks are mostly sold in primary packaging, while fruits and vegetables are often sold as loose items. In this study, packaged fruits and vegetables included berries, mangoes, brassica, roots, tomatoes, cucumbers, green leaves, herbs, mushrooms, peas and maize. In the 'cooked food' category, the role of packaging is more uncertain, but ready-made food typically comes in primary packaging.

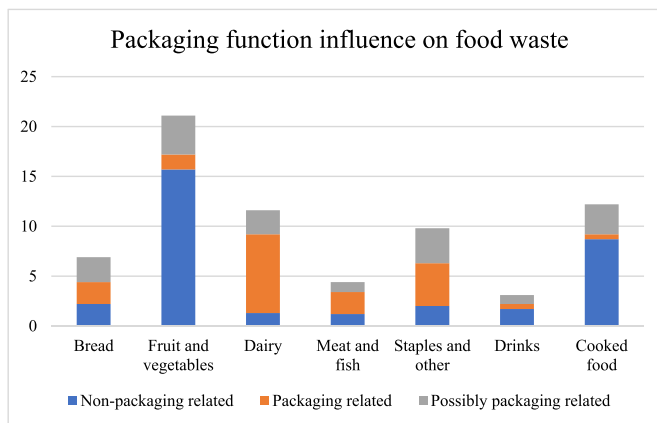
Using findings of previous studies (e.g. Wikström et al., 2014;

**Table 3**

Total amount of wasted food related to packaging functions.

Reason for food waste	A: Packaging functions	B: Possible packaging functions	Amount (kg)
Package too large	Contains the right amount		5.5
Difficult to empty packaging completely	Easy to empty		3.5
Past best before date	Information about food safety		8.2
Uncertain if product is fit for consumption (only packaged products)	Information about food safety		2.7
Bad/broken package	Physical-chemical protection	Contains the right amount	1.0
Food has gone bad (in opened packaging)		Information about food safety	14.6
		Physical-chemical protection	
		Easy to re-close	
<b>Total wastage</b>			<b>33.6</b>

Notes: In column A, the reasons for food waste are directly connected to one packaging function. In column B, the possible packaging functions are described as 'Food has gone bad' for packaged products.

**Fig. 2.** Total amounts of food waste per food category linked to packaging.

Wikström et al., 2019; Williams et al., 2012), Table 1 provides an overview of how food waste may be linked to packaging functions (column A) or possible packaging functions (column B). The identification of these links allowed for calculating how much of the total amount of food waste was due to specific packaging functions per food category and, more specifically, per product group. In cases where two or more reasons for food waste were indicated (e.g. 'package too large' and 'food has gone bad'), the packaging-related food waste was only calculated once. In turn, when there was a direct link to packaging functions, it was calculated as such and not within the possible packaging functions. Since several reasons were reported for some of the wasted food, in some cases, amounts in the specific food categories (Tables 4–8) are higher than those

presented in Table 3 for the specific packaging-related food waste.

In addition, the in-depth interviews were analysed by transferring the data into Microsoft Excel spreadsheets and conducting a thematic analysis (Hahn, 2008). The data were disassembled and reassembled in an iterative process with a thematic focus on links between different product categories and packaging functions. This iterative process allowed for summarising the data in tabular form. To increase the rigour of the qualitative analysis, the data were analysed and then cross-checked by two researchers. The insights derived from the interviews were used to support or discuss more deeply the results of the food waste diary study. The detailed results across product categories are reported in the next section.

#### 4. Results

Both the total amount of food waste per household and the waste that occurred due to packaging are reported. On average, a household discarded 1.9 kg of food during their reported week. The one- or two-person households wasted an average of 920 g per person during the week (+/– 720 g) and households with three-to-eight persons wasted an average of 640 g per person (+/– 500 g). The average food waste per person was 780 g per week, which would translate to approximately 40 kg per person per year. The distribution of food waste with regard to the number of persons per household is presented in Fig. 1.

Fig. 1 shows that the amounts per person per week were the largest for the single household and reduced with the increasing number of people living in the household. Notably, one single household reported almost no food waste (26 g). This participant showed very well-planned routines and thought several steps ahead about what to eat and how to make use of everything. Other

**Table 4**

Total number of reports and amounts of bread waste linked to packaging.

Products and waste	Reasons for wasting	No. of reports <sup>a</sup>	Amount (kg) <sup>b</sup>
<b>Whole wheat bread</b>	Food has gone bad (rotten, sour, mouldy, etc.)	3	0.5
	Past best before date	1	0.1
	Too large package	1	0.1
<b>White bread, unspecified bread, tortilla</b>	Food has gone bad (rotten, sour, mouldy, etc.)	16	2.5
	Package too large	7	1.6
	Past best before date	3	0.4
	Uncertain if product is fit for consumption	1	0.2
	Other reasons unrelated to packaging	1	0.1
	Uncertain if product is fit for consumption	2	0.2
<b>Sandwich</b>	Bad/broken package	1	0.1
	Other reasons unrelated to packaging	22	1.2
<b>Sweet bread, cake, cookie</b>	Food has gone bad (rotten, sour, mouldy, etc.)	3	0.8
	Other reasons unrelated to packaging	8	0.7

<sup>a</sup> Reports of over 100 g are presented.

<sup>b</sup> Several reasons for waste were possible to report.



**Table 5**

Total number of reports and amounts of fruit and vegetable waste linked to packaging.

Products and waste	Reasons for wasting	No. of reports <sup>a</sup>	Amount (kg) <sup>b</sup>
<b>Banana</b>	Other reasons unrelated to packaging	6	0.7
<b>Apples and pears</b>	Other reasons unrelated to packaging	6	1.1
<b>Citrus</b>	Other reasons unrelated to packaging	17	2.8
<b>Berries and mango</b>	Food has gone bad (rotten, sour, mouldy, etc.)	8	1.2
Fresh berries; plastic clamshells	Other reasons unrelated to packaging	5	0.2
Fresh mangoes: sold loose, 2 and 2 in plastic packaging			
Frozen mango; cardboard boxes			
<b>Brassica</b>	Food has gone bad (rotten, sour, mouldy, etc.)	3	0.5
Broccoli, cauliflower, kale: plastic wrapping	Package too large	2	0.3
	Past best before date	1	0.2
	Prepared too much, package too large	1	0.1
	Other reasons unrelated to packaging	9	3.1
<b>Roots</b>	Food has gone bad (rotten, sour, mouldy, etc.)	4	0.5
Carrots: plastic bag	Other reasons unrelated to packaging	28	2.4
<b>Tomato</b>	Food has gone bad (rotten, sour, mouldy, etc.)	5	0.4
Plastic clamshells or cardboard with plastic wrapping	Package too large	1	0.3
	Other reasons unrelated to packaging	6	0.2
<b>Cucumber, aubergine, avocado, pepper</b>	Food has gone bad (rotten, sour, mouldy, etc.)	6	0.6
Cucumber, aubergine and pepper in plastic wrapping	Other reasons unrelated to packaging	15	0.7
<b>Green leaves and lettuce</b>	Food has gone bad (rotten, sour, mouldy, etc.)	16	1.4
Plastic bags or cardboard with plastic wrapping (often 65 g or 150 g)	Package too large	4	0.4
	Uncertain if product is fit for consumption	2	0.2
	Other reasons unrelated to packaging	2	0.1
<b>Mixed salads</b>	Other reasons unrelated to packaging	20	1.2
<b>Other vegetables (herbs, mushroom, peas, maize, melon)</b>	Food has gone bad (rotten, sour, mouldy, etc.)	7	3.0
Herbs: Plastic wrapping/bag	Past best before date	1	0.2
Mushroom: Plastic tray	Package too large	3	0.1
Maize and peas: metal jar or cardboard box	Other reasons unrelated to packaging	6	2.9

<sup>a</sup> Reports over 100 g are presented.<sup>b</sup> Several reasons for waste were possible to report.

households also reported very little food waste per person. Nonetheless, the households' reported food waste was similar to the Swedish average of 37 kg/capita (Swedish Waste Management, 2018). Table 2 provides a comprehensive overview of the amount of food waste across food categories and product groups and associated reasons for the food waste.

As shown in Table 2, fruit and vegetables was the category with the largest amount of waste (30%), followed by dairy (17%), staples, condiments, etc. (14%), bread (10%) and fish and meat (6%). Specific products/product groups that were wasted the most included

yoghurt, followed by staple foods (rice, muesli, bulgur), brassicas (cabbage, broccoli, kale), white bread and the group containing other fruit and vegetables (melon, dates, asparagus, maize, peas, mushroom). Food having gone bad was mentioned 137 times, making it the most prevalent reason for food waste. Other commonly reported reasons included the following:

- difficult to empty the packaging (mentioned 41 times mainly for dairy products)

**Table 6**

Total number of reports and amounts of dairy waste linked to packaging.

Products and their packaging	Reasons for wasting	No. of reports <sup>a</sup>	Amount (kg) <sup>b</sup>
<b>Yoghurt, sour milk, quark</b>	Past best before date	5	2.3
Yoghurt and sour milk; 1 L liquid cardboard 1 L, plastic cups	Difficult to empty packaging completely	22	2.0
Quark; plastic cups, 150 g to 1 kg	Food has gone bad (rotten, sour, mouldy, etc.)	1	0.3
	Other reasons unrelated to packaging	10	0.8
<b>Milk</b>	Past best before date	6	1.6
Liquid cardboard in 1 L or 1.5 L	Package too large	3	1.2
	Food has gone bad (rotten, sour, mouldy, etc.)	5	0.6
	Other reasons unrelated to packaging	6	0.2
<b>Cream, sour cream, crème fraîche</b>	Food has gone bad (rotten, sour, mouldy, etc.)	3	0.3
Cream; liquid cardboard 3 dL or 5 dL	Past best before date	1	0.1
Sour cream; liquid cardboard 3 dL	Uncertain if product is fit for consumption	1	0.1
Crème fraîche; plastic cups, metal sealing, plastic lid 2.5 dL or 5 dL	Bad/broken package	1	0.1
	Other reasons unrelated to packaging	3	0.5
<b>Cheese</b>	Food has gone bad (rotten, sour, mouldy, etc.)	11	1.0
Plastic packaging,	Past best before date	2	0.5
Soft cheeses are sold in both plastic and paper-based wrappings	Uncertain if product is fit for consumption	3	0.3
<b>Ice cream, butter, soymilk, egg,</b>	Past best before date	3	1.1
Ice cream; plastic boxes,	Uncertain if product is fit for consumption	3	0.8
Butter; plastic or combination of plastic and cardboard.	Food has gone bad (rotten, sour, mouldy, etc.)	3	0.2
Eggs; carton boxes in sizes from 6 eggs to 12 or 15 eggs	Other reasons unrelated to packaging	5	2.0

<sup>a</sup> Reports over 100 g are presented.<sup>b</sup> Several reasons for waste were possible to report.

- uncertainty about product safety and date labelling (mentioned 39 times mostly in connection with fruit and vegetables and dairy)
- package too large (mentioned 33 times across all categories).

The cooked food that was wasted accounted for 17% with mixed vegetarian food being the largest product group. The most common reasons for wasting cooked food were 'children did not finish' (34 mentions) and 'too little left to save' (31 mentions).

Table 3 depicts the amount of wasted food linked to packaging functions or possible packaging functions. Notably, there was a direct relationship between 19 kg of food waste and packaging functions, which is 28% of the total food waste, and another 14.6 kg (21%) of food waste and possible packaging functions. Package labelling and provided information regarding food safety seemed to have particularly strong effects on food waste, as they each accounted for about 10 kg of food waste.

As additionally shown in Fig. 2, the role of direct packaging functions for food waste and possible packaging functions varied across categories.

Fig. 2 shows that packaging played a particularly large role in food waste in the categories of bread, dairy, meat and fish and staples/other. This finding suggests the large potential for waste reduction through better packaging design within these food categories. Therefore, the subsequent section focuses on these four product categories and analyses the roles of packaging closely. Moreover, the fruit and vegetables category is included because the packaging can play a significant role in some products. In contrast, drinks and cooked food are excluded from the analysis below because drinks only represented 4% of the participants' food waste and had a relatively weak connection to packaging design (the highest amount of food waste came from preparing too much coffee and tea). In turn, while cooked food represented 18% of the participants' food waste, it is excluded because packaging functions played a small role. However, pasta and rice were mentioned several times (by a total of 24 participants) and the reason given was that participants found it difficult to portion these products. It is possible that better packaging design or advice may influence consumers to cook and waste less. In fact, 15 participants mentioned that better information, devices or portioned packs could reduce their wastage of cooked rice and pasta.

#### 4.1. Bread

Bread products represented 10% of the participants' food waste. In this category, food waste reported in relation to packaging functions was 32% and possible packaging functions was 36%. Thus, up to 68% of bread waste was related to packaging functions. The amounts and number of reports of bread waste are reported in Table 4.

Sixty-nine per cent of all bread waste (excluding sandwiches) was due to 'Food has gone bad' (Table 4), although 43% of participants always froze the bread when they came home from the store. Sixteen per cent specifically mentioned lack of proper resealing of bread packaging. Notably, only a few participants wasted bread because it had passed its best before date. For example, during the interviews, participants said that they look at the best before date when they buy bread but not when they throw it away. In addition, 25% mentioned that they would like more variation in bread packaging sizes; in particular, they would like smaller sizes. 'Package too large' was reported as one of the major reasons for wastage of white bread, and toast was mentioned as a product that often dries out. For example, one participant reflected, 'I noticed that I often buy large packaging and often waste because I look at the price a lot. I figured out that I should buy smaller packages instead'.

In turn, sandwiches were often wasted because 'Children did not finish' their meal (reported 17 times). These insights suggest that too much bread per package, especially for white bread, leads to food waste. Apart from improved packaging sizing, better information on how to store bread or better reclosing functions may help consumers keep bread fresh for longer and, thus, reduce waste.

#### 4.2. Fruit and vegetables

Fruit and vegetables represented around 30% of the participants' food waste. In this category, food waste linked to packaging functions accounted for 7% and possible packaging functions accounted for 19%. Thus, up to 36% of the fruit and vegetable waste was related to packaging functions. The amounts and number of reports of fruit and vegetables are reported in Table 5.

The reasons for waste were similar across most examples of fruit and vegetables. Seventy-six per cent of the waste occurred because the 'food has gone bad'. Twenty-three participants admitted to continuously buying more fruit and vegetables than they need. The following excerpt from an interview represents several participants' purchasing practices: 'I sometimes buy more because I want the family to eat more fruits; I hope that we will eat more than we do'. Only 14 participants mentioned that they planned their purchase of fruit and vegetables before going to the store. Many participants put vegetables in the refrigerator and placed fruit in a fruit basket to remind themselves to eat the fruit. However, fruit stored at room temperature goes bad faster than when refrigerated; thus, this practice contributes to higher waste levels.

As most fruit and vegetables are sold as loose items, there were few packaging-related reasons for waste reported in this category. In fact, there seems to be an expectation that fruit and vegetables do not need to be or should not be packed. A commonly stated reason for buying pre-packed fruit and vegetables was 'it only comes that way'; most of the time, this applied to organic and Fairtrade products. Yet lettuce sold in plastic bags was reported to be often too large or difficult to reseal, which affects the product's freshness. A substantial amount of the food waste in this category, thus, seems to originate from participants buying more than they need. Better planning and storage strategies may reduce food waste, particularly for the purchase of fruit and vegetables that are not pre-packed.

#### 4.3. Dairy

Dairy products represented 17% of the participants' total food waste. Food waste in this category reported in relation to packaging functions was 68% and 21% for possible packaging functions. Therefore, up to 89% of the dairy waste can be related to packaging functions, making this the largest packaging-related food waste category. The amounts and number of reports for dairy are displayed in Table 6.

As shown in Table 6, for dairy products, food having passed its best before date was the main reason for wastage. Yet the majority of participants mentioned that they used date labelling as only one of several indicators to determine whether they should discard a product. In addition, smell was commonly used as an indicator of freshness; accordingly, 25 participants mentioned that they used dairy products for at least one week, or in some cases even several weeks, beyond the best before date. Those participants who used the best before date as an indicator did so primarily for yoghurt and stated concerns about getting sick.

Several participants bought different yoghurt flavours for their children, meaning that several different kinds of yoghurt were open at the same time. Thus, 13% of participants mentioned that they

**Table 7**

Total number of reports and amounts of meat and fish waste linked to packaging.

Products and waste	Reasons for wasting	No. of reports <sup>a</sup>	Amount (kg) <sup>b</sup>
<b>Beef and minced meat</b> Plastic trays	Uncertain if product is fit for consumption	2	0.3
	Other reasons unrelated to packaging	5	0.6
<b>Chicken</b> Fresh chicken in plastic trays; Frozen chicken in plastic bags	Past best before date	1	1.8
	Uncertain if product is fit for consumption	2	0.6
	Food has gone bad (rotten, sour, mouldy, etc.)	1	0.2
<b>Charcuteries</b> Charcuteries plastic packaging	Prepared too much, package too large	3	0.2
	Past best before date	1	0.1
	Other reasons unrelated to packaging	2	0.3
<b>Fish</b> Fresh fish in paper wrapping; Frozen fish in plastic or cardboard	Prepared too much, package too large	2	0.2
	Past best before date	1	0.1

<sup>a</sup> Reports over 100 g are presented.<sup>b</sup> Several reasons for waste were possible to report.**Table 8**

Total number of reports and amounts of staples, condiments, etc. waste linked to packaging.

Products and waste	Reasons for wasting	No. of reports <sup>a</sup>	Amount (kg) <sup>b</sup>
<b>Staple food</b> Flour and muesli, paper bags Pasta, couscous rice in plastic bags or cardboard boxes	Past best before date	3	1.3
	Uncertain if product is fit for consumption	3	1.2
	Food has gone bad (rotten, sour, mouldy, etc.)	2	0.3
	Other reasons unrelated to packaging	5	1.1
	Past best before date	5	1.1
<b>Olives and vegetables in glass jars</b> Glass jar with metal lid	Package too large	6	1.0
	Uncertain if product is fit for consumption	2	0.4
	Other reasons unrelated to packaging	1	0.2
	Package too large	3	0.6
	Food has gone bad (rotten, sour, mouldy, etc.)	2	0.2
<b>Tomato products, beans and lentils</b> Dry products, plastic bags or cardboard boxes With water in cardboard boxes	Uncertain if product is fit for consumption	1	0.1
	Other reasons unrelated to packaging	4	0.2
	Food has gone bad (rotten, sour, mouldy, etc.)	6	0.8
	Past best before date	4	0.3
	Package too large	3	0.2
<b>Sauces and oils</b> Glass or plastic bottles or plastic boxes	Other reasons unrelated to packaging	1	0.3
	Food has gone bad (rotten, sour, mouldy, etc.)	4	0.9
	Past best before date	2	0.3
	Package too large	1	0.1
	Other reasons unrelated to packaging	3	0.3

<sup>a</sup> Reports over 100 g are presented.<sup>b</sup> Several reasons for waste were possible to report.

would prefer smaller yoghurt packages (1 L yoghurt containers dominate the Swedish food market). In addition, two participants stated that they do not buy the smaller plastic yoghurt containers because they are difficult to reclose and generate a large amount of packaging material waste. Some participants reflected on the poor packaging design including how yoghurt can be poured, the package resealed or the container emptied. In fact, much of the yoghurt waste was reported in relation to difficulty with fully emptying the packaging. A participant described this as follows: 'It becomes difficult to get it all out and nobody has the energy to do that'. Difficulty in judging the freshness of yoghurt was also a cause of food waste and, for this, improved information may help to reduce food waste.

Food having passed its best before date was the reason for almost half the milk wastage. Overly large packaging and the product turning bad were the two other main reasons for waste. Some participants occasionally froze surplus milk. Others said that they oriented themselves towards the date labelled on the package to avoid running the risk of getting sick. In relation to these concerns, one participant said the following: 'If the children have left the milk at room temperature, I do not want to risk anything but will waste it even if it doesn't smell bad.' Too much milk per package and lack of information about food safety accounted for most of the milk waste.

Although the wasted amounts of cream and crème fraîche were small, nine participants nonetheless pointed out that the package size of those products is often too large for their needs. Illustrative comments include 'the packaging never matches the food recipe'; 'the smallest one of 2.5 dL is too large'; and 'I always get at least 50% too much crème fraîche. Why can't a tube be used?' Consequently, 'Product has gone bad' and 'Bought too much' were listed as the two major reasons for waste (Table 6). Both crème fraîche and cream were primarily used for preparing special dishes, and several participants said that the food content was more than for one dish and that the remainder was left in the refrigerator and forgotten.

The main reason for wastage of hard and soft cheeses was that they turned bad or dried out, which in most cases occurred because the package was not resealable. Regarding this issue, 12 participants described using extra packaging to keep the cheese fresh, while 29 participants mentioned that they sometimes wasted cheese and others said that they deploy waste avoidance strategies, such as grinding and freezing leftovers. Apart from cheese, other dairy products (1.2 kg in total including ice cream, butter, etc.) were wasted due to uncertainty about the product's quality and whether it was still fit for consumption. Thus, design changes focused on packaging content, reclosing functions and food safety information can all contribute to a reduction in dairy food waste.

**Table 9**

Packaging functions related to food waste when participants observed products in their storage facilities at home.

	Package too large	Difficult to empty	Inability to reclose	Sometimes spills	Needs extra packaging
<b>Bread</b>	Bread		Tortilla Nacho chips		
<b>Fruit and vegetables</b>	Lettuce Maize (metal can) Spinach Beetroot Dates Fruit		Lettuce Maize	Lettuce Maize	Lettuce
<b>Dairy</b>	Yoghurt Cheese Sour cream Eggs Milk	Yoghurt  Cream  Liquid margarine	Yoghurt Cheese Cream	Yoghurt  Cream	Cheese  Butter
<b>Meat and fish</b>	Charcuteries	Caviar (tube)	Charcuteries		Charcuteries
<b>Staples, condiments and other food</b>	Ketchup Sauces Mustard Vinegar Chocolate sauce Dressings Pesto Beans	Ketchup Sauces Mustard (tube)		Ketchup        Oats Grated coconut	

#### 4.4. Meat and fish

Meat and fish products represented 6% of all wasted food. However, 50% of the food waste in this category was related to packaging functions and a further 23% to possible packaging functions. The specific amounts and number of reports for the categories of beef, chicken, charcuteries and fish are depicted in Table 7.

As shown in Table 7, chicken was the most wasted product in this category. A substantial part of this waste was frozen chicken parts which had passed the best before date, in addition to uncertainty about product safety, which accounted for 0.9 kg of wasted chicken. In the interviews, all but four participants indicated that they were more afraid of meat products making them sick than food in the other product categories. The products mentioned most often in relation to best before dates were chicken, beef and minced meat. Twenty-two participants mentioned that they would buy extra meat when the price was reduced; however, the majority of them (19) did not think that this would influence the amount of waste. Either they would freeze meat products for later use or cook large amounts and then freeze those prepared meals. Nonetheless, 13 participants mentioned overly large packaging as an issue, and 22 participants admitted that they waste charcuteries. For example, liver pate was mentioned six times; the reason for wasting it was that the packaging was too large. In contrast, single frozen items, such as chicken breasts or salmon pieces, were highlighted as convenient because they enabled the consumer to select and defrost the number of pieces required for a particular meal.

#### 4.5. Staples, condiments and others

Staples, condiments and others represented 14% of the participants' food waste. Nonetheless, up to 80% of this amount was linked to packaging functions (i.e. 44% to packaging functions and 36% to possible packaging functions). The amounts and number of reports for staples, condiments and other foods are shown in Table 8.

Participants reported having wasted rice, olives, quinoa, cashews and ketchup mainly due to 'Uncertainty about food safety'. In turn, they mentioned 'Package too large' as the main reason for wasting crushed tomatoes, olives, sweet chili sauce and salad dressing. For example, nine of the participating households wasted packaged tomato products because the packaging was 'too large'. In addition, sauces and olives were often mentioned as products that were easily forgotten in the refrigerator. In contrast, sweets and snacks were seldom wasted.

#### 4.6. Observation of storage facilities

Beyond the specific food categories, participants were asked to document food waste that occurred or may occur depending on their specific storage practices. In this regard, participants reported a large variety of products (e.g. lettuce, maize, yoghurt, cheese, cream, charcuteries, ketchup, sauces, mustard) alongside several different packaging functions that may lead to food waste. The insights from Table 9 are significant because they indicate repeated instances of food waste that can be linked to packaging functions. In other words, a packaging design that addresses the below listed malfunctions for the respective food products would not only better support consumers' use process but also help in reducing food waste.

### 5. Discussion

This study is among the first to explore the complex relationship between packaging and food waste across different food categories. To achieve this, a multi-step method combining a questionnaire, food waste diary and in-depth interview was applied to 37 Swedish households. Theoretically, the study employed a service lens that placed the focus of packaging design on the use process and the context in which different packaging functions interact with food-related consumer practices. In combination, this approach provides new insights into the food waste–packaging relationship, which

several recent studies have called for (Hebrok and Boks, 2017; Schanes et al., 2018; Wikström et al., 2019). These insights, as we discuss here, have important implications for policymaking, food packaging design and future research on household food waste practices.

Often, packaging is not considered or is poorly understood in policies aimed at reducing food waste in households (e.g. European Commission, 2019). This is problematic; as the results of the present study show, a substantial portion of the food waste was linked to packaging. The participating households attributed 28% of the generated food waste directly, and another 21% possibly, to packaging functions. Here, it should be noted that the participating households were predominantly environmentally conscious and had been made aware up front of the role of packaging in food waste. Thus, the sample may be seen as 'advanced consumers' who were aware of the role of packaging in their food-related practices. Some participants reported very small amounts of total food waste; however, across the sample, the reported food waste levels were higher or the same as in larger-scale composition studies (e.g. Stensgård et al., 2018). In addition, participants gave important insights into why food got wasted during their everyday practices and routines. It was surprising that they could relate so much of their food waste to the design of packaging and that they found it difficult to buy the right amount or to keep food waste at a minimum during the use process.

The main contribution of this study lies in its evaluation of packaging functions across different food categories. The results show that some packaging functions were particularly important for reducing food waste for some product categories but not for others. For example, a package that is *easy to empty* is important for reducing the waste of dairy products, especially yoghurt. In turn, a package that is *easy to reclose* is important for cheese and charcuteries, while the function *easy to dose* can help in reducing pasta and rice wastage.

However, two packaging functions stood out as relevant for reducing food waste across all food categories. First, packaging should be designed to meet the consumer's needs by *containing the right amount*. With demographic changes resulting in smaller households, this function may become even more important in the future. This study found that a lack of versatility in packaging size led to waste of bread, milk, charcuteries, olives, tomato products and sauces. The simple availability of different packaging sizes combined with better reclosing functions could address this problem. While the food packaging–environmental impact ratio varies widely among different products, adding packaging material or reducing the packaging size is often justified, but this is particularly true for meat and milk products, even if the ultimate reduction in food waste is small, because of the high environmental impact of those food products (Heller et al., 2019; Wikström et al., 2019).

The second packaging function for reducing food waste is *information about food safety*. This function includes date labelling with explanations of what this labelling means, storage information and help with assessing food safety after the package has been opened. The importance of providing information that helps consumers accurately judge the safety of food is particularly important for bread, dairy, meat and fish. The confusion created by different kinds of labels and associated food waste has been documented extensively in the literature (Hebrok and Boks, 2017; Principato et al., 2015; Schanes et al., 2018), yet the problem seems to persist. Therefore, we restate here the requirement for policymakers to review the way in which information related to food safety is provided to consumers in order to meet SDG 12.3. Food packaging should be seen as a *touchpoint* that informs the consumer about the food that it contains. This might also include

information about the environmental impact of the underlying food production and supply chain or information on why this food is packed in its particular way. Such information can create more awareness among consumers about the role of packaging and the consequences of food waste, which is still often perceived as less problematic than packaging (Østergaard and Hanssen, 2018; Williams et al., 2012).

For policymaking and design efforts aimed at reducing household food waste, we contribute a multi-step method that takes an 'outside-in' approach. Adopting a service lens, this approach starts with an exploration of specific circumstances surrounding the consumer's value creation process and how packaging can become a supporting element in this process. We propose that shifting from an 'inside-out' to an 'outside-in' approach is significant because it focuses on the actual use process and thereby considers the context and consumer practices underpinning food waste (Evans, 2014; Hebrok and Boks, 2017; Quedsted et al., 2013; Schanes et al., 2018). In addition, the service lens acknowledges that a product (e.g. the package) is only one of many resources within the consumer's value creation process. As such, the insights derived from the multi-step method can guide the design of interventions to help 'unlock' unsustainable patterns within the consumer's existing practice arrangement (Scheurenbrand et al., 2018). We propose that this unlocking through packaging design can constitute an important prerequisite for reducing food waste across different food categories.

## 6. Conclusion, Limitations, and Future Research

This study has shown that packaging plays an important role in whether food in households is wasted. While the significance of the food waste–packaging relationship and the role of packaging differ from one food category to the next, it is particularly important for food that has a high environmental impact, such as dairy and meat products. Here, the packaging design must ensure that the package contains the right amount of food, provides relevant information about the respective food product and is supportive of consumer practices through functionalities, such as being easy to use, resealable and empty. The results of this study provide insights into which packaging functions are most important for reducing waste across the main food products used in households. We hope that these insights guide policymakers, packaging providers and the broader food industry in their efforts to reduce food waste in households.

One main contribution of this research is its multi-step method applying three different data collection methods to holistically investigate food waste in households. In combination, these methods provide insights not only into how much food is wasted but also how and why food gets wasted, which are important aspects for developing effective policy and design interventions (Hebrok and Boks, 2017; Schanes et al., 2018). However, as is the case with every method, the proposed multi-step method is not without limitations. First, the method is resource intensive for the researcher but also in terms of the time and commitment required of consumers to evaluate food waste in their homes. Consequently, the method is limited to a small, selected consumer group, which leads to concerns about generalisability (Maxwell, 1992). To apply this method to larger samples, future research is required to refine and, where possible, reduce the resource requirement for data collection and analysis. This could be done, for example, through the digitalisation of the diary study, including the automated monitoring of shopping and storing practices through digital solutions. Nonetheless, the self-selection procedure used in the present study seems suitable because it attracts consumers who are willing to contribute their unique insights and experiences of food-



related practices in relation to packaging. In addition, self-selected consumers, as found in innovation studies (Poetz and Schreier, 2012; Trischler et al., 2018a), seem knowledgeable about the underlying topic and ahead of trends. Thus, these consumers might not only be valuable for knowledge generation but might become direct contributors during the innovation process, especially in regard to incorporating their needs into new packaging designs (see e.g. Kim et al., 2020). Thus, we call for future research to investigate what roles consumers can play during our proposed 'outside-in' process for packaging design aimed at reducing food waste.

Second, consumers were sensitised before participating in this study; therefore, at the outset, they were made aware of the role of packaging in household food waste. Sensitisation is typically used to raise awareness around a topic about which participants were not previously aware (Visser et al., 2005). This applies to packaging: consumers often do not recognise the role of packaging in food waste, which makes it difficult to investigate the link between food waste and packaging functions (Williams et al., 2012). In addition, making participants aware that the research focus is not their behaviour but on packaging functions might reduce the common problem of underreporting food waste (Banjo and Val, 2011; Schanes et al., 2018). In fact, the food waste amounts reported in this study were higher than Sweden's national per capita statistics, indicating that participants took specific care in reporting all their waste. Nonetheless, an important avenue for future research is to investigate how the sensitisation step affects self-reported results. This might include a comparative field study where one portion of the sample is sensitised and the other is not and a subsequent investigation into how awareness about packaging affects consumer food waste behaviour and self-reporting.

Finally, and related to the participants' high involvement, the one-week diary study in particular might have led to a process of reflection and subsequent behaviour change in food-related practices. In fact, participants mentioned in the final interviews that they had started to reflect upon their behaviour and the role of packaging when they started the diary. Thus, there is a potential risk that consumers began modifying their shopping, food handling and storing behaviours during the reporting week, either to not have to fill in the diary or to avoid potential feelings of guilt. Supporting this argument, across the sample, the reported wastage was higher on the first two days than on the last two days. On one hand, this observation indicates that it may not be fruitful to use a longer test period than one week because this might result in participant fatigue or misrepresented results. On the other hand, it indicates that a self-report study where participants are required to monitor and measure their own food waste can be a trigger for changing deeply entrenched practices. Behavioural economics theory supports this argument by showing that nudging interventions can be an effective policy instrument for indirectly altering behaviour and decision-making processes (Thaler and Sunstein, 2008). An interesting area of future investigation, therefore, could be to investigate how self-reporting initiatives, such as asking households to document their food waste over a longer period, can lead to short- and long-term changes in consumer practices.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### CRediT authorship contribution statement

**Helén Williams:** Conceptualization, Methodology,

Investigation, Data curation, Formal analysis, Visualization, Writing - original draft. **Annika Lindström:** Methodology, Investigation, Data curation, Formal analysis, Writing - review & editing, Methodology, Writing - review & editing. **Jakob Trischler:** Funding acquisition, Conceptualization, Writing - review & editing. **Fredrik Wikström:** Investigation, Data curation.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jclepro.2020.121775>.

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