



Drivers, barriers and interventions for food waste behaviour change: a food system approach

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Summary

About a third of all food that is produced for human consumption is never eaten. It is widely acknowledged that food loss and food waste have a detrimental impact on the economy, the climate and the society, which has led to an increasing societal and academic interest in food loss and food waste reduction. Reducing food loss and food waste (henceforth FLW) is easier said than done, as it FLW is a complex and multifaceted problem, to which no straightforward solution exists. The objective of this project is to identify the drivers and barriers of FLW reduction behaviour from an actor perspective, and to explore possible solutions to the FLW problem across the food supply chain. The literature research specifically targets *human behaviour* within the food system. Insights from this report are intended to form a starting point for the development of successful intervention strategies to bring about behavioural changes that lead to FLW reduction throughout the food supply chain.

An extensive literature search was performed in Scopus, Web of Science, ABI/Inform, CAB Abstracts and PsychInfo in November 2018. The exact same search was performed in October 2019, to add new publications in Q4 2018 and 2019 to the results. This search resulted in 489 papers. Based on title, abstract and our purpose of covering all actor domains, 63 papers were selected and summarized, highlighting the theoretical basis, actor in the chain, drivers for waste reduction, drivers for food waste, intervention description (if there was one) and the main results and conclusion.

This literature study showed that most studies focus on drivers and barriers of FLW behaviour, and less on behavioural interventions to reduce FLW. Furthermore, the overview of drivers and barriers along the food value chain shows that most of them relate to the consumer level, followed by the retail and hospitality sector. It seems that the current literature provides fewer insights into behavioural drivers and barriers at the agricultural and manufacturing level. Most identified interventions focused at FLW of the consumers as end-user: interventions at the retail level focus on providing consumers with options (or *opportunities*) to reduce FLW, whereas household-level interventions focus on enhancing consumers' *motivations* and *abilities* to reduce FLW. Because a large part of FLW occurs at the consumer level, this focus is understandable. This being said, action is also required at other actor levels to achieve the UN Sustainable Development Goal of reducing FLW with 50% in 2030.

The overview shows that there is room for improvement, concerning the effectiveness of interventions as well as the assessment of actual behavioural FLW effects at multiple actor levels, including potentially unexpected positive and negative effects. Although the picture is scattered and various challenges were identified regarding FLW interventions, the current intervention overview indicates that promoting and tracking attention towards suboptimal foods or products made of ingredients that otherwise would be wasted is an effective strategy to reduce FLW at the retail level. Price reductions of suboptimal foods, discounting products which are close to expiration, as well as Dynamic Shelf Life seem effective to reduce FLW at the retail level, but subsequent effects of these interventions at the consumer household level are currently unclear. Reducing portion sizes via smaller plates or smaller portions seem effective interventions to reduce FLW at the hospitality and catering level. Positive taste experiences with visually suboptimal foods seems to enhance preferences and buying intention, whereas the effect of information-based interventions seems mixed.

Due to the complex interaction of multiple behaviours that lead to FLW, it is recommended to use multi-component & holistic interventions with different conscious and unconscious behavioural change techniques. In addition, it is recommended to use a theoretical framework in the development of interventions. It would be interesting to explore whether consumer models for (FLW) behaviour change can be applied to other actors in the chain.

1 Introduction

The current report presents the results of a literature review on food loss and food waste behaviour among actors along the food supply chain. This research has been executed by Wageningen Food & Biobased Research commissioned by the Dutch Ministry of Agriculture, Nature and Food Quality in the context of the KB project 'Towards a Circular and Climate Positive Society' under Case study 1 behavioural drivers to reduce FLW.

The aim of this report is to identify the drivers and barriers to reducing food loss and food waste behaviour from an actor perspective, and to explore possible behavioural interventions for diminishing food waste and food losses at multiple stages of the food supply chain. The report is written for any reader who is interested in the topic of food waste and food waste reduction.

1.1 Background

About a third of all food that is produced for human consumption is never eaten (Gustavsson, Cederberg et al. 2011); this phenomenon is known as *food loss* or *food waste*. The Food and Agriculture Organization of the United Nations (FAO) defines *food loss* as "the decrease in quantity or quality of food", which encompasses all products intended for human consumption that are ultimately not eaten by people, or that have lost quality in terms of their nutritional value, economic value or food safety. *Food waste* is defined as part of food loss, referring to the discarding or non-food use of food fit for human consumption – either by choice, or after the food has been left to spoil or expire due to negligence (FAO 2015).

It is widely acknowledged that food loss and food waste have a detrimental impact on the economy, the climate and the society, which has led to an increasing societal and academic interest in food loss and food waste reduction. This is for instance evidenced by the recently presented Global Action Agenda by the World Resources Institute (WRI 2019), which proposes actions to achieve the UN Sustainable Development Goal of halving the world's food loss and waste by 2030.

Notwithstanding this ambitious plan, reducing food loss and food waste (henceforth FLW) is easier said than done: FLW is a complex and multifaceted problem, to which no straightforward solution exists. FLW is associated with a variety of both avoidable and unavoidable causes, and it involves multiple stakeholders along the entire food supply chain (Figure 1). In high-income countries, end users are major contributors to FLW (over 40% of FLW in Europe and almost 60% in North America is generated at the retail and consumer stage; but a large part of food is lost before it even reaches the end users, e.g. during agricultural production (21-33%), or during product manufacturing, storage, distribution and/or processing (21-25%; (WRI 2019), based on: (Gustavsson, Cederberg et al. 2011).

Figure 1: Actors involved in FLW along the food supply chain.



In order to tackle the complex problem of FLW and to effectively and substantially change FLW behaviour, a full understanding is needed of when, where, why and how FLW occurs. The current project contributes to this knowledge by taking an integrative approach to FLW: it brings together literature on FLW behaviour from all actors along the food supply chain.

1.2 Project aim

The objective of this project is to identify the drivers and barriers of FLW reduction behaviour from an actor perspective, and to explore possible solutions to the FLW problem across the food supply chain. The literature research specifically targets *human behaviour* within the food system. Technological developments that improve the efficiency of the food supply chain and as such reduce FLW will not be taken into consideration; however, any FLW or FLW reduction behaviour related to such technological innovations will be discussed.

Insights from this report are intended to form a starting point for the development of successful intervention strategies to bring about behavioural changes that lead to FLW reduction throughout the food supply chain.

2 Methods

An extensive literature search was performed in Scopus, Web of Science, ABI/Inform, CAB Abstracts and PsychInfo in November 2018. The exact same search was performed in October 2019, to add new publications in Q4 2018 and 2019 to the results.

The following search terms were used:

Behavio(u)r:

(behaviour OR behaviour OR attitud OR habit) AND (modif* OR chang* OR revers* OR shift OR transform* OR transist*)*

Food Waste:

(Food OR Foods OR Kitchen OR Plate OR Postharvest) AND (Waste OR Wastage OR Wasting OR Leftover OR Loss OR Losses)*

Food System Approach:

Food system OR integrated value chain OR food chain OR food supply chain OR Farm to Fork OR Field to fork OR primary production

In addition, in CAB Abstracts and ABI/Inform the following terms were used:

Driver OR Cause* OR Reason* OR Explanation* OR Factor* OR Effect* OR Barrier* OR Solution* Consumer* OR Household* OR Retail* OR farmer* OR Supermarket* OR Food company OR Stakeholder* OR Players*

This search resulted in 489 papers. Based on title, abstract and our purpose of covering all actor domains, 63 papers were selected and summarized in an Excel-sheet, highlighting the theoretical basis, actor in the chain, drivers for waste reduction, drivers for food waste, intervention description (if there was one) and the main results and conclusion. The papers were categorized – on the basis of the main aim - in the following groups:

- Agricultural production (1 paper)
- Food manufacturing (1 paper)
- Retail (5 papers)
- Hospitality and catering (2 papers)
- Consumer and household (41 papers)
- Multiple actors / whole supply chain (13 papers)

3 Overview of drivers and barriers for FLW along the food value chain

Food is lost or wasted at all stages in the food value chain, from initial agricultural production up to the consumer and household level (Göbel, Langen et al. 2015). The reasons for FLW generation are numerous, and vary for each actor in the chain. In industrialized countries, food is mainly wasted at the end of the supply chain; more than 40% occurs at the retail and consumer level. In these stages of the chain, discarded foods are mostly still suitable for human consumption. In developing countries, FLW occurs mainly at early stages of the food value chain. The reasons are financial, managerial and technical constraints in harvesting techniques or storage and cooling facilities (FAO 2019). In this chapter, we focus on drivers and barriers for FLW in industrialized countries. Over the last decades, the food supply chain has become longer and increasingly complex. Consumers have higher expectations regarding the variety of choices and freshness of products (Priefer, Jörissen et al. 2016). Furthermore, the increased distance between food production and consumption, due to urbanization and globalization, increases the risk of food losses during transportation, storage and distribution (Facchini, Iacovidou et al. 2018).

In order to better understand the complex problem of FLW at every stage of the food value chain, detailed knowledge on drivers (to prevent food waste) and barriers (leading to food waste) is needed. This chapter provides an overview of the main drivers and barriers for each actor in the chain, as found in current literature.

3.1 Agricultural production

At the initial level of agricultural production, there are several reasons for FLW to occur. In industrialized countries, food generally gets wasted or lost when the production exceeds demand. Farmers have to make production plans for agreed quantities of a certain crop. In their planning, unpredictable weather conditions have to be taken into account. Production plans are therefore often on the safe side, resulting in the production of larger quantities than actually needed (Gustavsson, Cederberg et al. 2011). In the case of having produced more than required, some surplus crops can be redistributed to other processors or as animal feed (Beausang, Hall et al. 2017). However, this is often not financially profitable considering low prices in these sectors compared to those from retailers (Gustavsson, Cederberg et al. 2011). Another cause for FLW is careless handling by farmers of produce (CFS 2014). Also, there is in general a lack of communication and cooperation between farmers, making it impossible to redistribute crops from one farm to solve a shortage of crops from another (Stuart 2009). A recent study amongst farmers in Scotland showed that farmers do not consider food waste to be an issue of primary concern and perceive food waste to be an intrinsic part of farming. They do not routinely record waste and have difficulty in providing estimates for FLW when requested (Beausang, Hall et al. 2017).

Another important driver for FLW to occur at the agricultural stage, is the problematic agreements between farmers and retailers on contractual penalties, products take-back clauses and demand forecasting (Parfitt, Barthel et al. 2010, Priefer, Jörissen et al. 2016). Farmers usually sell their produce through 'contract farming', where products are sold to specific retailers or other food manufacturers. Retailers often change or cancel their order at the last minute, leaving farmers with large quantities of unsold foods that is likely to go to waste (Stuart 2009). Furthermore, there are strict quality standards from retailers for perishable products like fruits and vegetables. Irregular sized or shaped products are rejected and therefore large portions of crops never leave the farms (Priefer, Jörissen et al. 2016). Attempts to reduce food waste at the agricultural production level, therefore automatically requires the involvement of actors further along the chain.

3.2 Manufacturing

Food manufacturing is a complex process that at present is mainly based on linear, rather than circular thinking (Rahimifard, Woolley et al. 2017). One of the main reasons for FLW generation in food manufacturing is the absence of detailed data on the amount, timing and reasons for created FLW (Jagtap and Rahimifard 2019). Contamination, accidental spillage, technical limits on production and operation and process losses can all cause FLW at this stage (Parfitt, Barthel et al. 2010). Just like farmers, manufacturers are frequently tied to only one or two retailers. Retailers often reject irregular sized products, so they are either trimmed to fit (e.g. cutting of ends and skins) or rejected entirely (Priefer, Jörissen et al. 2016, Dou, Cochran et al. 2018). It is usually cheaper to discard foods that do not meet the standards for retailers or supermarkets, than redistributing it elsewhere (Devin and Richards 2018). Furthermore, food packages are often too large. In this case, FLW occurs at the consumer level since the packages are difficult to empty before the food turns bad (Aschemann-Witzel, de Hooge et al. 2015), however the manufacturers are responsible for the packaging process. Other reasons for FLW at this stage are the surplus production of supermarket's own brands, that cannot be sold elsewhere and excess stock due to cancellation of orders from supermarkets (Priefer, Jörissen et al. 2016).

3.3 Retail

It has been pointed in several papers that in particular food retailers play an important role in causing food waste. As described in the agricultural production section above, retailers often set high aesthetic standards for fruits and vegetables, resulting in large-scale rejection of edible food on cosmetic grounds at the agricultural production stage (Priefer, Jörissen et al. 2016, Devin and Richards 2018). In a paper of Devin on food waste in the Australian food supply chain, it is even argued that by these practices, retailers ultimately contribute to higher levels of food waste elsewhere in the supply chain (Devin and Richards 2018). Fruits and vegetables are perishable fresh organic products, with relatively short shelf-life. Therefore they require a proper way of cooling, handling, planning and ordering. The main cause of losses are related to inadequate cold storage and overstocking because of inaccurate ordering and forecast demand (Porat, Lichter et al. 2018). Not only for fruit and vegetables, but also for other products, overstocking, improper storage, improper quality control and improper product handling can lead to FLW in supermarkets (Thyberg and Tonjes 2016, Buisman, Haijema et al. 2017). Other causes for food waste are the fact that supermarkets often request products with a too high proportion of shelf-life remaining (Canali, Amani et al. 2017). Supermarkets also buy their stockings according to marketing strategies, like 'buy one get one for free' (Priefer, Jörissen et al. 2016). These market-based strategies can lead to FLW if not everything is sold in time. In addition, supermarkets have obligations to order a wide range of products and brands from the same producer, to get beneficial prices and they often fail to comply with minimum food safety standards (Priefer, Jörissen et al. 2016).

A possible driver to reduce food waste at retail level is willingness to reduce prices of suboptimal foods (Stangherlin and De Barcellos 2018). Another way is to better predict product quality and accordingly adjust the shelf-life (or use-by date) dynamically (Buisman, Haijema et al. 2017). In this way, the shelf-life is adjusted to the actual quality of the product and it might lead to discarding it later than with a fixed expiry date. If supermarkets can still sell their foods to consumers instead of discarding them, this also has a financial benefit for them. These financial motives can act as a driver to reduce food waste.

At present, (un)sustainability that involves companies is often discussed as CSR issues (corporate social responsibility) by the EU. It means that companies should take 'responsibility' for issues of societal interest beyond the business's own profit goals and beyond legal requirements. Moral and strategic motives are both triggers for retailers to initiate actions that reduce FLW (Aschemann-Witzel, Hooge et al. 2016). Acting according to this social responsibility, retailers can encourage consumers by awareness campaigns, for example to encourage them to buy the right amount (Stangherlin and De Barcellos 2018).

3.4 Hospitality and catering sector

In the hospitality and catering sector, food waste is mainly caused by spoilage, food preparations and the food that is left on consumer's plates. Too often food is prepared but not served, or served but not eaten. The main amount of food waste generation occurs in the preparation phase (45%), and a part is due to food deterioration (21%) and to food leftover on plates (34%) (WRAP 2013).

Unfortunately, often the lack of visibility on food waste makes canteen and restaurant managers underestimate its relevance, therefore not focussing on its reduction (Derqui, Fernandez et al. 2018).

Food waste in restaurants occurs at two levels: during preparation and service (or consumption) stage (Principato, Pratesi et al. 2018). In the preparation stage, there is often kitchen waste due to the way food is prepared. The restaurant or caterer is responsible for this FLW. Examples are peeling, cutting, expiration, spoilage and overcooking. Another reason is the way the restaurant handles their product storage and labelling. Knowledge and skills on how to use fridge colour coding and product labelling could help to reduce food waste (Reynolds, Goucher et al. 2019). The same holds for general knowledge on the (amount of food waste) amongst employees. Also, poor management of reserves the restaurant is storing, can lead to a deterioration of those products (Facchini, Iacovidou et al. 2018).

In the service, or consumption stage, food waste is caused by the customer, who leaves the food on their plate. However, restaurants and caterers can also play a part in the generation of this waste, since they often serve too large portion sizes, or offer their food buffet-style (Kallbekken and Sælen 2013, Priefer, Jørisen et al. 2016, Lorenz, Hartmann et al. 2017). Offering buffet-style dinners, encourages customers to take more than they can eat, leading to more leftovers on their plates. In addition, there is a higher change on food turning bad on buffets. Restaurants have to comply to food-safety requirements and hygiene rules and have to throw this food out after a certain amount of time, contributing to more waste. Not only buffet-style dinners contribute to more waste, but also the use of too large individual portion packs (for example jams, cereals, milks at breakfast buffets) (Priefer, Jørisen et al. 2016)

Another factor contributing to waste in this sector is that restaurants can have difficulties in assessing the demand (number of customers) for a certain day, leaving them with too much food in the end. Day-to-day purchasing management can help restaurants to make sure they do not overstock (Principato, Pratesi et al. 2018). If a restaurant or caterer would be willing to provide 'doggy-bags' and allow customers to take home leftovers, this can also be a driver for restaurant managers to prevent food waste. (Principato, Pratesi et al. 2018).

A study of Lorenz et al looked specifically into causes of food left-overs in a university canteen. Their study provided evidence for a general significant impact of behavioural intention and related personal and social determinants as well as for the relevance of environmental/situational determinants such as portion sizes and palatability of food for plate leftovers (Lorenz, Hartmann et al. 2017). Scheduling or time constraints during lunch also play a part in plate waste (Derqui, Fernandez et al. 2018).

3.5 Consumer and household level

Most of the articles included in this review focus on determinants of FLW behaviour at the consumer and household level. This is not surprising, given that in industrialized countries the majority of FLW is produced by the end users (over 40%;) (Gustavsson, Cederberg et al. 2011). Identified causes for consumers' FLW behaviour are multi-fold: like human behaviour in general, FLW behaviour should be seen as the result of a complex interplay of both conscious and subconscious processes. We will discuss the drivers and barriers for FLW reduction as identified in the articles by categorizing them according to the *Motivation-Opportunity-Abilities* (MOA) model (ölander and Thøgersen 1995). The MOA-framework is a widely applied conceptual framework that combines (conscious, explicit) motivations with (implicit, unconscious) habitual as well as contextual factors to account for consumer behaviour. The model has previously been applied to food waste behaviour (Van Geffen, Van Herpen et al. 2016), addressing determinants on the individual, social and societal level. Motivational drivers

(M) to prevent food waste refer to a person's willingness to perform actions that reduce the likelihood or amount of food waste being generated food waste. Relevant aspects of motivation are attitude, awareness, and social norms. Ability (A) to prevent food waste is explained in terms of a person's proficiency to solve the problems that he or she encounters when performing actions that help prevent food waste. Relevant aspects of ability are knowledge and skills. By opportunity (O), the availability and accessibility of materials or resources required to prevent food waste are meant. Relevant aspects of opportunity are time and schedule, material and technologies, and infrastructure. The lack of opportunity is also included in the model, caused by the influence of technologic developments, the food infrastructure, as well as work and leisure schedules.

Motivation

Motivation is a necessary (though not necessarily sufficient) requirement for FLW reduction behaviour. An important motivational barrier for reducing FLW is this general lack of awareness of the FLW problem, as FLW happens largely unnoticed (Quested, Marsh et al. 2013, Aschemann-Witzel, de Hooge et al. 2015, Stangherlin and De Barcellos 2018). Moreover, consumers' food quality standards are high, which contributes to the generation of FLW: there is little tolerance for food imperfections (Aschemann-Witzel, de Hooge et al. 2015, Stangherlin and De Barcellos 2018) and a tendency not to purchase and consume suboptimal foods (Rohm, Oostindjer et al. 2017). Anxiety about food safety has also been mentioned as a motivational barrier (Parfitt, Barthel et al. 2010, Aschemann-Witzel, de Hooge et al. 2015, Principato, Secondi et al. 2015). Other motivational causes of FLW include the dislike of eating the same meal twice or to eat leftovers (Aschemann-Witzel, de Hooge et al. 2015), as well as social motivations related to hospitality: the wish to be a good provider for one's family or a good host leads consumers to prepare more food than is eaten (Graham-Rowe, Jessop et al. 2014, Aschemann-Witzel, de Hooge et al. 2015, Aktas, Sahin et al. 2018, Liao, Jin et al. 2018, Stangherlin and De Barcellos 2018).

Many motivations that positively contribute to FLW reduction relate to awareness of the FLW issue: personal attitudes and values towards food waste (such as guilt feelings, environmental concerns, ethical considerations and strong personal norms) have been argued to drive consumers to wasting less food (Quested, Marsh et al. 2013, Schanes, Dobernig et al. 2018). Such personal motivations are especially pronounced in the generation of consumers who have experienced scarcity (Aschemann-Witzel, de Hooge et al. 2015). Anti-wastage social norms, that is, the extent to which consumers believe FLW to be prevented, or disapproved of, by others (Van Geffen, Van Herpen et al. 2016), have also been mentioned as positive contributors to FLW reduction, albeit to a lesser extent because people's FLW behaviour is largely invisible to others (Quested, Marsh et al. 2013, Principato, Secondi et al. 2015). Moreover, it is suggested that a different perception of food, that is, considering food as a gift rather than a product, may help consumers in reducing their waste behaviour (Aschemann-Witzel, de Hooge et al. 2015, Stangherlin and De Barcellos 2018). Finally, numerous articles mention perceived behavioural control, that is, consumers' trust in their own ability to reduce food waste, as a motivational driver for FLW reduction (Stancu, Haugaard et al. 2016, Russell, Young et al. 2017, Aktas, Sahin et al. 2018, Porat, Lichter et al. 2018, Schanes, Dobernig et al. 2018).

Opportunity

Opportunity in the MOA framework refers to the external, situational conditions that are necessary for engaging in the intended behaviour. A lack of opportunity can affect behaviour either directly (preventing consumers from reducing FLW despite their intrinsic motivations to do otherwise) or indirectly (moderating consumers' motivations to reduce FLW). For instance, financial motives typically outrank consumers' FLW concerns, which can both facilitate and inhibit FLW reduction behaviour (Quested, Marsh et al. 2013, Aschemann-Witzel, de Hooge et al. 2015, de Koning, Crul et al. 2015, Falcone and Imbert 2017, Schmidt and Matthies 2018). Financial incentives can result in consumers buying food that would otherwise be thrown away; at the same time, bulk purchases may lead consumers to buy more food than they need, which shifts the FLW problem from the retail to the household level. Other external factors that make consumers care less about FLW are a lack of time for purchasing and preparing foods (Aschemann-Witzel, de Hooge et al. 2015) and dissatisfaction with the taste or freshness of already purchased foods (Koivupuro, Hartikainen et al. 2012, Stangherlin and De Barcellos 2018).

Abilities

Abilities refers to the knowledge and skills required to bridge the gap between intention and behaviour. Even if consumers are motivated to reduce FLW and all situational pre-conditions are met, a lack of ability may still prevent consumers from changing their FLW behaviour. A lack of ability to reduce FLW partly results from the fact that human behaviour is for a large part driven by automatized and often unconscious processes. Given that habitual behaviour typically happens outside of our awareness, it forms a barrier for any behavioural change, including FLW reduction behaviour (Quested, Marsh et al. 2013). More specific ability-related determinants of FLW behaviour concern (a lack of) knowledge about proper food management at home (Parfitt, Barthel et al. 2010, Quested, Marsh et al. 2013, Stefan, van Herpen et al. 2013, Principato, Secondi et al. 2015, Aktas, Sahin et al. 2018, Stangherlin and De Barcellos 2018). For one, many consumers do not know the difference between 'best before' dates (which refer to food quality) and 'use by' dates (referring to food safety), leading them to throw away foods unnecessarily (Parfitt, Barthel et al. 2010, Aschemann-Witzel, de Hooge et al. 2015, Principato, Secondi et al. 2015, Stangherlin and De Barcellos 2018). A lack of knowledge on how to properly store fresh foods (Parfitt, Barthel et al. 2010, Lanfranchi, Calabro et al. 2016, Porat, Lichter et al. 2018, Schmidt and Matthies 2018) or forgetting about stored foods (Martindale 2017, Stangherlin and De Barcellos 2018) causes foods to go bad unintendedly. In addition, multiple articles refer to planning, shopping and cooking routines as ability-related predictors of FLW behaviour (Parfitt, Barthel et al. 2010, Quested, Marsh et al. 2013, Stefan, van Herpen et al. 2013, Porpino, Parente et al. 2015, Principato, Secondi et al. 2015, Lanfranchi, Calabro et al. 2016, Aktas, Sahin et al. 2018, Stangherlin and De Barcellos 2018). Checking one's food stock, making a shopping list and sticking to it may prevent consumers from making impulse purchases and overbuying foods in the supermarket; improved home-cooking skills (such as knowledge about how to prepare foods or how to recombine leftovers into a new meal) may help prevent FLW in the kitchen.

3.6 Whole chain

Initiatives for surplus food redistribution along the chain are arising in several European countries (Facchini, Iacovidou et al. 2018). However, the unpredictable nature of surplus food availability acts as a barrier to some actors in the chain, for the expansion of food reuse initiatives. In addition, redistributing foods offers little incentive to change industry behaviour (Midgley 2014). In addition, food surplus redistribution initiatives remain largely fragmented and independent from each other (Facchini, Iacovidou et al. 2018). Furthermore, according to a paper of Gaiani (2019) there is a disconnection between food governance, the global food supply chain and consumer demands. Furthermore, food over time has evolved from a local resource, into private, transnational commodity. This includes more food miles in the whole supply chain, leading to more FLW (Gaiani, Rolle et al. 2019).

3.7 Summary of findings on barriers and drivers of FLW

The findings per actor are summarized in table 1. The drivers and barriers on the consumer level are categorized according to the Motivation-Opportunity-Ability framework, as explained in section 3.5.

Table 1: Main drivers and barriers for FLW per actor level of the food value chain. At the consumer level, these drivers and barriers are categorized according to the Motivation-Opportunity-Ability framework.

Actor level	Drivers to reduce FLW	Barriers and causes of FLW
AGRICULTURAL PRODUCTION	Re-using unsold crop (animal feed, compost, ploughed back into soil, redistribution) (Beausang, Hall et al. 2017)	Lack of communication and cooperation between farmers, impossible to redistribute crops (Stuart 2009)
	Better interaction with retailers on forecasting of production (Beausang, Hall et al. 2017)	FLW is not considered an issue of primary concern and is perceived as an intrinsic part of farming (Beausang, Hall et al. 2017)
		Careless handling of produce (CFS 2014)
		Redistributing surplus crops to other processors or as animal feed is often not financially profitable (Gustavsson, Cederberg et al. 2011)
		Overproducing due to problematic agreements with retailers on contractual penalties, products take-back clauses and demand forecasting (Parfitt, Barthel et al. 2010, FAO 2015, Priefer, Jörissen et al. 2016, Dou, Cochran et al. 2018)
	Strict quality standards from retailers for perishable products like fruits and vegetables (Priefer, Jörissen et al. 2016)	
MANUFACTURING	Optimization of storage and logistic conditions (Facchini, Iacovidou et al. 2018)	Costs – cheaper to discard food that does not meet the standards for retailers or supermarkets (Devin and Richards 2018)
		Problematic relationships between manufacturers/producers and retailers contractual requirements, product standards and poor demand forecasting (Facchini, Iacovidou et al. 2018)
		Irregular size products trimmed to fit or rejected entirely (Priefer, Jörissen et al. 2016)
		Surplus production of supermarket's own brands that cannot be sold elsewhere and excess stock due to cancellation of orders (Priefer, Jörissen et al. 2016)
		Contamination, accidental spoilage, technical limitations on production and operation, and process losses (Parfitt, Barthel et al. 2010)
		Production processes like trimming for use in end products, leading to edible parts going unused: e.g., ends and skins (Dou, Cochran et al. 2018)
		Food packaging: too large, difficult to empty (Aschemann-Witzel, de Hooge et al. 2015)
RETAIL	Moral responsibility (corporate social responsibility) (Aschemann-Witzel, Hooge et al. 2016, Devin and Richards 2018)	Setting high aesthetic standards for fruits and vegetables, but also other products, resulting in large-scale rejection of edible food on

Actor level	Drivers to reduce FLW	Barriers and causes of FLW
		cosmetic grounds (Priefer, Jörissen et al. 2016, Devin and Richards 2018)
	Financial motives (more profitable to sell foods instead of discarding them) (Devin and Richards 2018)	Marketing and market-based strategies, like 'buy one, get one for free' (Priefer, Jörissen et al. 2016, Devin and Richards 2018)
		Overstocking, improper storage, improper quality control and improper handling of products (Thyberg and Tonjes 2016, Buisman, Haijema et al. 2017, Porat, Lichter et al. 2018)
		Obligations to order a wide range of products and brands from the same producer, to get beneficial prices (Priefer, Jörissen et al. 2016)
		Failure to comply with minimum food safety standards (causing microbial contamination, pesticide residues) (Priefer, Jörissen et al. 2016)
		Supermarkets often request products with a too high portion of shelf-life remaining (Canali, Amani et al. 2017)
		Specific for fruit and vegetables: inadequate cold storage and overstocking (Porat, Lichter et al. 2018)
HOSPITALITY & CATERING SECTOR	Allowing customers to take home leftovers, willingness to provide 'doggy-bags' (Miroso, Liu et al. 2018, Principato, Pratesi et al. 2018)	Compliance with food-safety requirements and hygiene rules (Priefer, Jörissen et al. 2016)
	Smaller plate sizes (Reynolds, Goucher et al. 2019)	Difficulties in assessing the demand (number of customers) (Priefer, Jörissen et al. 2016)
	Knowledge and skills on fridge colour coding and product labelling (Reynolds, Goucher et al. 2019)	Offering buffet-style dinners at fixed prices, encouraging customers to take more than they can eat (Priefer, Jörissen et al. 2016)
	Knowledge about (the amount of) food waste (Reynolds, Goucher et al. 2019)	Serving large portion sizes (Kallbekken and Sælen 2013, Priefer, Jörissen et al. 2016)
	Day-to-day purchasing management (Principato, Pratesi et al. 2018)	Poor management of reserves and deterioration of products due to poor handling (Facchini, Iacovidou et al. 2018)
		Behavioural intention not to leave food on plate (Lorenz, Hartmann et al. 2017)
		Palatability of foods, meal likes and dislikes (Lorenz, Hartmann et al. 2017, Derqui, Fernandez et al. 2018)
		Scheduling or time constraints during lunch in the canteen (Lorenz, Hartmann et al. 2017, Derqui, Fernandez et al. 2018)
		Use of individual portion packs that are too large, for example for jam, cereals, milk etc. (Priefer, Jörissen et al. 2016)
		Kitchen waste due to way of preparation: peeling, cutting, expiration, spoilage, overcooking (Principato, Pratesi et al. 2018)

Actor level	Drivers to reduce FLW	Barriers and causes of FLW
CONSUMER & HOUSEHOLD LEVEL		
	Motivation	
	Social norms:	Social relationships relating to hospitality, wish to be 'good provider' (for family) or a 'good host' (Graham-Rowe, Jessop et al. 2014, Aschemann-Witzel, de Hooge et al. 2015, Aktas, Sahin et al. 2018, Liao, Jin et al. 2018, Stangherlin and De Barcellos 2018)
	1) Injunctive norms: the extent to which consumers perceive wasting food as a behaviour that is disapproved by others who are important to them	
	2) Descriptive norms: the extent to which consumers think others prevent food waste (Van Geffen, Van Herpen et al. 2016)	
	Awareness and knowledge of the food waste issue (environmental concerns) (Quested, Marsh et al. 2013)	Little tolerance for imperfections of food (Aschemann-Witzel, de Hooge et al. 2015, Stangherlin and De Barcellos 2018)
	Perceived behavioural control (trust in ability to reduce waste) (Stancu, Haugaard et al. 2016, Russell, Young et al. 2017, Aktas, Sahin et al. 2018, Porat, Lichter et al. 2018, Schanes, Dobernig et al. 2018)	Dislike of eating the same meal or leftover foods (Aschemann-Witzel, de Hooge et al. 2015)
	Environmental concerns (Quested, Marsh et al. 2013, Stangherlin and De Barcellos 2018)	Anxiety about food safety (Aschemann-Witzel, de Hooge et al. 2015, Principato, Secondi et al. 2015)
	Having experienced scarcity (generational difference) (Aschemann-Witzel, de Hooge et al. 2015)	
	Attitudes and values towards the topic of food waste: guilt, ethical considerations, strong personal norms (Quested, Marsh et al. 2013, Schanes, Dobernig et al. 2018)	
	Connection with food, experiencing food as 'a gift' (Aschemann-Witzel, de Hooge et al. 2015, Stangherlin and De Barcellos 2018)	
	Ability	
	Knowledge and skills related to meal and food planning (Quested, Marsh et al. 2013, Stefan, van Herpen et al. 2013, Principato, Secondi et al. 2015, Aktas, Sahin et al. 2018)	Not understanding 'use by' or 'best before' dates (Parfitt, Barthel et al. 2010, Aschemann-Witzel, de Hooge et al. 2015, Principato, Secondi et al. 2015)
	Knowledge on the proper storage of (fresh) foods (Porat, Lichter et al. 2018)	Habits (Quested, Marsh et al. 2013)
		Poor home-economic skills (recombining leftovers into new meal) (Parfitt, Barthel et al. 2010, Lanfranchi, Calabro et al. 2016)
		Bulk purchases because of perceived financial benefits (Schmidt and Matthies 2018)
		Overbuying and impulsive purchase, not sticking to a shopping list in-store (Parfitt, Barthel et al. 2010, Stangherlin and De Barcellos 2018)

Actor level	Drivers to reduce FLW	Barriers and causes of FLW
		Generally low tendency to purchase and consume suboptimal foods (Rohm, Oostindjer et al. 2017)
		Doing grocery shopping only once a week (Lanfranchi, Calabro et al. 2016)
		Inappropriate storing (Parfitt, Barthel et al. 2010, Schmidt and Matthies 2018) or forgetting about stored foods (Martindale 2017)
	Opportunity	
	Saving money, financial motives (Quested, Marsh et al. 2013, de Koning, Crul et al. 2015, Falcone and Imbert 2017)	Being unsatisfied with the taste or freshness of purchased foods due to lower product quality (Koivupuro, Hartikainen et al. 2012, Stangherlin and De Barcellos 2018)
		Little time for purchase and preparation of foods, combined with low prices of food, makes consumers care less about wastage (Aschemann-Witzel, de Hooge et al. 2015)
WHOLE CHAIN	Willingness to participate in redistributing surplus food initiatives (Facchini, Iacovidou et al. 2018)	Lack of interaction between stakeholders within and across micro-, meso- and macro-levels (Gaiani, Rolle et al. 2019)
	Availability of novel technologies (Gaiani, Rolle et al. 2019)	Disconnection between food governance, the global food supply chain, and consumer demands (Gaiani, Rolle et al. 2019)
		'Commodification' of food - food for merchandise rather than for nutrition (Gaiani, Rolle et al. 2019)

4 Interventions to reduce FLW

This chapter provides an overview of the interventions that were identified in the literature search. The interventions are described per actor level in the food value chain: from agricultural production to the consumer level.

4.1 Agricultural production

No interventions were identified at this level.

4.2 Manufacturing

On the manufacturing actor level, one intervention to reduce FLW was identified. A food factory producing ready-made meals in the UK, implemented *a real-time digital food waste tracking system*, based on Internet of Things technology, for a period of nine months. This system was coupled *with staff training and engagement in food waste reduction solutions*. During this period, food waste generation decreased by 61% (from 6190 kg in Jan 2017 to 2428 kg in Sept 2017). The more detailed insights into the generation of food waste, had as result that production staff took initiatives for reducing food waste at different stages of the production line. Trim waste was reduced by 89% by re-using it in soups produced for the staff canteen; waste due to product expiration/quality was reduced by 32% as a results of selling remaining products to other factories, local restaurants and charity, and negotiating the minimum order quantity with suppliers. Food waste due to equipment failure was reduced by 80% due to introducing a preventive machine maintenance policy, namely daily machine checks (Jagtap and Rahimifard 2019).

4.3 Retail

Various interventions to reduce FLW can be executed in the retail sector or supermarkets. One study in Denmark examined the retailer actions in 18 supermarkets related to encouragement of buying suboptimal foods (Rohm, Oostindjer et al. 2017). In total, 22 actions were observed. Nearly all supermarkets applied price-related actions, such as best-before date based pricing. Still, the approach in communicating this action, placing the items, and the layout of the stickers varied widely between the retailers. Additional actions were product-related (e.g. product packaging to reduce food waste), unit-related (e.g. selection of items in small packages), communication about food waste issue (e.g. on label or through digital application), collaboration with other actors (e.g. food reuse for new application) and in-store management such as planning and ordering (Kulikovskaja and Aschemann-Witzel 2017). No effect measures were assessed, so no conclusion can be drawn about the effectiveness of these actions. However, according to store managers, *selling price-reduced suboptimal foods* is efficient as 9 out of 10 items are sold.

Highlighting suboptimal foods by using differently designed labels (colours, information on price reduction or taste accentuation) may be an effective strategy to attract consumer attention and force purchase decision whereas *price reductions* seemed to increase purchase intentions (Rohm, Oostindjer et al. 2017). Another study concluded that *discounting and Dynamic Shelf Life* are successful against food waste. Dynamic shelf life outperforms a fixed shelf life in terms of waste, profit, shortages and food safety. The benefits of a dynamic shelf life increase for highly perishable products. Discounting products which are close to expiration is also a successful strategy to reduce food waste, even more when combined with a dynamic shelf life. However, it needs to be taken into account that discounting can still lead to food waste, because consumers choose the discounted product over their 'normal' choice, so overall demand remains equal (Buisman, Haijema et al. 2017).

The work of (Aschemann-Witzel, Hooge et al. 2016) describes three (non-scientific) case studies of retailer actions with the aim to reduce food waste at the consumer level. *Banning multiple-item offers* in 260 supermarkets in Denmark initially led to lower sales, but it improved retailers reputation. The action received positive feedback from customers, media and stakeholders, and triggered competitor actions. A second action in a supermarket in Sweden was *selling lunch and dinner meals* from in-store kitchen *using products that might otherwise have been wasted*. This action boosted employee engagement and improved the store's reputation (positive feedback from customers and media). A third action was *promoting inglorious fruit/vegetables* in Intermarché supermarkets in France. This action increased sales and triggered competitors to do similar actions. It received national and international media attention, and influenced French legislation regarding retailers' dealing with oversupply. In none of these studies, actual food waste reduction was measured.

A living lab study of Wageningen Food & Biobased Research in a supermarket tested whether the implementation of two strategies resulted in increased sales of "Food waste is delicious (=VIV)" products. These products are made from ingredients that otherwise would have gone to waste, and are normally placed in a dedicated shelf in the supermarket. The *second placement strategy* meant placing VIV-products on the dedicated shelf as well as on regular shelves adjacent to their regular counterparts, so customers would encounter the products two times. The *food-saved monitor strategy* consisted of displaying short statements next to the dedicated VIV-shelf, informing the customers with attractive messages on food waste facts and the number of kilos of food rescued through buying these surplus-based products. Both strategies seemed to increase customer awareness to the products and boosted sales, leading to more food being saved from going to waste (Zeinstra; Haar 2019).

The *Too good To Go concept* tackles the potential loss of unsold food from retail and food service industry by selling magic boxes at discount price to users of the Too Good To Go app, with the aim to reduce food waste. A study that explored what happens with the food in magic boxes after they have been picked up by consumers, showed that this concept positively contributes to food waste reduction, as most of the saved food is actually consumed (Van der Haar and Zeinstra 2019).

4.4 Hospitality & catering sector

Several interventions were identified at the hospitality & catering actor level.

In a plant to plate pilot, the effects of *school raised garden produce* on vegetable selection and food waste were studied among high school students. The study showed that when the salad bar contained garden produce, vegetable selection increased (percentage of students selecting salad rose from 2 to 10%), but food waste increased as well compared to the control group (Wansink, Hanks et al. 2015). So, this intervention supported healthy eating, but led to higher food waste, because the percentage of a serving that was wasted increased from 6% to 33%.

In contrast, a *change of dietary school guidelines (changing menu composition)* led to less vegetable waste in canteens by 15% up to 28% (Reynolds, Goucher et al. 2019). These results indicate that a healthy diet can be part of food waste reduction strategies.

Interventions that *changed the size (smaller plates) or type of plates* (permanent rather than disposable plates) were shown to be effective in food waste reduction (19% up to 57%) in hospitality environments (Reynolds, Goucher et al. 2019).

Two nudging interventions were tested for a period of five weeks at breakfast buffets in hotel restaurants in Norway (Kallbekken and Sælen 2013). One intervention consisted of a *reduction of plate size* from 24 to 21 cm. The second intervention *displayed a sign at the buffet encouraging consumers to help themselves more than once with smaller portion sizes instead of taking one big serving*. The sign was stated in seven languages: "Welcome back! Again! And again! Visit our buffet many times. That's better than taking a lot at once". Both interventions resulted in less food waste, which was reported daily. Relative to the control group (mean food waste 33.82 kg), reducing the plate size reduced food waste by 19.5%, and introducing the sign reduced food waste by 20.5%. The

effect of the plate size reduction intervention was corroborated by a positive correlation between plate size and amount of food waste within the control group. Consumer satisfaction scores were not no different between intervention hotels and control hotels.

4.5 Consumer and household level

The identified interventions on the consumer and household level were categorized at macro-, micro- and individual level. Interventions at macro-environment level reflect interventions that practically focus on all consumers in a certain country or area, so a population-based intervention. The micro-environment focusses on a specific group of consumers, such as a group of students in schools. The last category focusses on interventions that target the individual consumer or household.

Macro-environment

It seems that the *Campaign 'Love food, hate waste!'* which was launched in the UK in 2011 was effective as the household food waste was lower in these years (Quested, Marsh et al. 2013). The campaign focused on raising awareness, highlighting benefits of reducing waste such as money saving and reducing environmental concerns, creating a personal conviction to act, as well as on increasing knowledge and skills, and engaging with people on a one-by-one basis. Although it is difficult to draw conclusions on cause and effect, the results showed positive changes in food waste behaviours in households over this time period, such as planning meals and making lists. Econometric modelling showed that a sizeable proportion of the food waste reduction is closely associated with the increased awareness of food waste and other engagement work in this area.

The review from Reynolds showed that several *information-based interventions* led to significant reductions in food waste, varying between a 12% self-reported reduction in the home due to an information campaign, a 19% reduction in the home due to e-newsletters, up to a 33% waste reduction from main meals in canteens due to a student-focused education campaign. However, sample sizes were often small (Reynolds, Goucher et al. 2019).

A similar situation occurred in Sweden, where a municipality introduced *a near-property collection system* for food waste from all households, restaurants and childcare centres. After the introduction of this food waste sorting policy, a reduction of 9% in 2012 and 19% in 2013 was observed in food waste (absolute + per capita). Also in this study, it is impossible to state cause and effect, and the analysis did not find any single important demographic or external factor (unemployed rate, tourism intensity, socio-demographics and fees) that could alone explain the observed waste trends. In contrast, the increasing tourism intensity should have led to more waste, but this was not the case. Presumably improved awareness among the residents about the amounts of wasted food played a role (Miliute-Plepiene and Plepys 2015).

Micro-environment

A *two-week education programme* was implemented in a small group of middle and high school students, fostering behaviour change by targeting diverse knowledge domains (declarative, procedural, effectiveness and social) with regard to food & waste behaviours. The programme utilized experiential, real-world, problem-based methods in order to increase competence in sustainability and promote pro-environmental actions. The six students' sustainability knowledge increased in all four domains in terms of food and waste. However, waste behaviour changed more than food behaviour, which was more resistant to change. During the follow-up measure one year later, still substantial changes were observed in terms of their waste decisions, whereas sustainable food behaviours were more resistant to long-term change due to the students' social and cultural environment. Students indicated that the easiest behaviours to maintain were the ones their household members were participating in (Redman 2013).

Individual level

Positive taste experiences with visually suboptimal foods may positively influence overall liking, the perception of the sensory attributes, purchase intention, as well as preferences for these suboptimal foods (Rohm, Oostindjer et al. 2017).

A small group of 9-10-year-old children (N=4) received a "*Tamagotchi*" *plant* with emotions to grow and take care of themselves. The aim was to teach children how to grow their own food, mixing real and virtual reality, connecting something natural like a plant to the Internet of Things. The expected Tamagotchi effect was the development of an emotional attachment with both material (machines) and artificial beings (avatars) that otherwise do not really have any real emotions. All of the children reacted very positively to the avatar and could easily interpret the state of the plant based on the mood the plant-avatar expressed. However, a longer user test revealed that the children got bored of the avatar after longer use (Valpreda and Zonda 2016). No food waste behaviour or sustainability effects were measured.

An experimental study indicated that *communication such as brochures and fridge magnets* were not convincing tools to impact consumer attitudes and food-waste related behaviour (Rohm, Oostindjer et al. 2017). Nevertheless, the authors conclude that communication could work as initial step to raise awareness and interest.

Finally, the review of (Reynolds, Goucher et al. 2019) mentions that *cooking classes, additional technologies such as fridge cameras or apps, and advertising and information sharing* were all reported as being effective in food waste reduction at the consumer level, but with no accurate quantification provided. Rohm (2017) also reported on the effect of *an app to enhance food waste knowledge and awareness*. This app was found useful by some, but not by others. Very small behavioural effects were observed. This implies that the effectiveness of apps is not yet clear and may help certain segments of consumers, but not all (Rohm, Oostindjer et al. 2017). These findings are in line with an explorative study on the potential of apps for changing consumers' food waste behaviour (Vogels, Van der Haar et al. 2018). This study concluded that research so far indicates that apps and ICT tools can raise awareness, but that further research is needed to investigate the effects of apps and ICT tools on actual food waste behaviour of consumers.

4.6 Summary of findings on interventions

Below, the identified interventions are summarized in a table. Similarly to table 1, the findings on consumer level are categorized according to the Consumers Food Waste Model (MOA) of van Geffen et al. (2016). The interventions on the retail and hospitality/ catering sector are also categorized according to the Motivation-Opportunity-Ability framework from the point of view from the consumer, as these interventions mainly focus on the consumer as end-user (target actor).

Table 2: Identified interventions and their effectiveness per actor level of the food value chain.

Actor level (source)	Target actor	Intervention	Effectiveness
AGRICULTURAL PRODUCTION		No intervention identified	
MANUFACTURING	Manufacturing company including staff	A real-time digital food waste tracking system, based on Internet of Things technology, coupled with staff training and engagement in food waste reduction solutions (9-month period)	Food waste generation decreased by 61% (Jagtap and Rahimifard 2019)
RETAIL			
Ability + Motivation			
	Consumer	Food-saved monitor strategy: informing customers with attractive messages on food waste facts and the number of kilos of food rescued through buying these surplus-based products	This strategy seemed to increase customer awareness to the products and boost sales, leading to more food being saved from going to waste (Zeinstra; Haar 2019)
Opportunity			
	Consumer	Highlighting suboptimal foods by using differently designed labels	Seems to attract consumer attention and force purchase decision (Rohm, Oostindjer et al. 2017)
	Consumer	Promoting inglorious fruit/vegetables	Increased sales and triggered competitors to do similar actions (Aschemann-Witzel, Hooge et al. 2016)
	Consumer	Second placement strategy: having a special shelf as well as regular placement of products that are made from ingredients that otherwise would be wasted	This strategy seemed to increase customer awareness to the products and boost sales, leading to more food being saved from going to waste (Zeinstra; Haar 2019)
	Consumer	Selling price-reduced suboptimal foods in supermarkets	Efficient according to store-managers as 9 out of 10 items are sold (Kulikovskaja and Aschemann-Witzel 2017)
	Consumer	Price reductions for suboptimal foods	Seemed to increase consumer purchase intentions (Rohm, Oostindjer et al. 2017)
	Consumer	Discounting products which are close to expiration and Dynamic Shelf Life	Successful against food waste (Buisman, Hajjema et al. 2017)
	Consumer	Banning multiple-item offers in supermarkets	Initially lower sales, but it improved retailers reputation (Aschemann-Witzel, Hooge et al. 2016)

Actor level (source)	Target actor	Intervention	Effectiveness
	Consumer	Selling lunch and dinner meals from in-store kitchen using products that might otherwise have been wasted	Boosted employee engagement and improved the store's reputation (Aschemann-Witzel, Hooge et al. 2016)
	Consumer	Too good To Go concept: selling foods that would be wasted in magic boxes via an app	This concept positively contributes to food waste reduction, as most of the saved food is actually consumed (Van der Haar and Zeinstra 2019)

HOSPITALITY & CATERING SECTOR

Motivation			
	Consumer	Display a sign at the buffet encouraging consumers to help themselves more than once with smaller servings than with one very large serving	Reduced daily food waste by 20.5% (Kallbekken and Sælen 2013)
Opportunity			
	Consumer	Adding school raised garden produce in the salad bar at high school	Vegetable selection increased (from 2 to 10%), but food waste increased as well (Wansink, Hanks et al. 2015)
	Consumer	Change of dietary school guidelines (changing menu composition)	Less vegetable waste in canteens by 15% up to 28% (Reynolds, Goucher et al. 2019)
		Change the plate size (smaller) or type of plates	Effective in food waste reduction: 19% up to 57% (Kallbekken and Sælen 2013, Reynolds, Goucher et al. 2019)

CONSUMER & HOUSEHOLD LEVEL

Motivation & Ability			
MACRO-environment	Consumer	Campaign 'Love food, hate waste!' focusing on raising awareness, highlighting benefits of reducing waste such as money saving and reducing environmental concerns, creating a personal conviction to act, as well as on increasing knowledge and skills, and engaging with people on a one-by-one basis.	Positive changes in food waste behaviours in households over this time period, such as planning meals and making lists (Quested, Marsh et al. 2013)
MACRO-environment	Consumer	Information-based interventions	Significant reductions in food waste between 12 and 33% in small sample size intervention (Reynolds, Goucher et al. 2019)
INDIVIDUAL level	Consumer	Positive taste experiences with visually suboptimal foods	Seems to positively influence overall liking, the perception

Actor level (source)	Target actor	Intervention	Effectiveness
			of the sensory attributes, purchase intention, as well as preferences for these suboptimal foods (Rohm, Oostindjer et al. 2017)
INDIVIDUAL level	Consumer	Communication such as brochures and fridge magnets	These were not convincing tools to impact consumer attitudes and food-waste related behaviour (Rohm, Oostindjer et al. 2017)
INDIVIDUAL level	Consumer	An app to enhance food waste knowledge and awareness	App was found useful by some, but not by others. Very small behavioural effects were observed, effectiveness of apps not yet clear (Rohm, Oostindjer et al. 2017)
INDIVIDUAL level	Consumer	Cooking classes, additional technologies such as fridge cameras or apps, and advertising and information sharing	These were all reported as being effective in food waste reduction at the consumer level, but with no accurate quantification provided (Reynolds, Goucher et al. 2019)
INDIVIDUAL level	Consumer	Children receiving a "Tamagotchi" plant with emotions to grow and take care of themselves	Children reacted positively to the plant, although they got bored after a longer period. No behaviour food waste or sustainability effects were measured (Valpreda and Zonda 2016)
Ability			
MICRO-environment	Consumer	Two-week education programme fostering behaviour change by targeting diverse knowledge domains (declarative, procedural, effectiveness and social) with regard to food & waste behaviours	Sustainability knowledge increased in all four domains in terms of food and waste. However, waste behaviour changed more than food behaviour, which was more resistant to change (Redman 2013)
Opportunity			
MACRO-environment	Consumer & retail actors & catering/ hospitality actors	New municipality policy: a near-property collection system for food waste from all households, restaurants and childcare centres	A reduction of 9% in year 1 and 19% in year 2 was observed in absolute + per capita food waste (Miliute-Plepiene and Plepys 2015)

5 Discussion

The aim of this literature overview was to identify drivers and barriers for food loss and food waste behaviour from an actor perspective, and to explore possible behavioural interventions for diminishing food waste and food losses at multiple stages of the food supply chain. The main findings are summarized below. Strengths and limitations of the literature study are discussed and practical and research recommendations are provided.

More papers on drivers and barriers and less on interventions

The overview shows that most of the papers describe determinants of FLW and proposing potential interventions based on these determinants. A smaller number of papers is focused on assessing the effectiveness of interventions that are actually implemented. This finding is in line with the review paper of Reynolds (2019), who concludes that only a minor part (5%) of the consumer food waste studies are actual interventions showing reductions in food waste whereas the majority of papers aim to quantify food waste. The majority of interventions that reported to reduce food waste occurred in developed countries (USA 6x, UK 3x, The Netherlands 2x) and have focused on small groups with time-limited evaluations.

Most known about drivers and barriers on consumer actor level and largest focus on motivation and ability of MOA framework

The overview of drivers and barriers along the food value chain in chapter 3, shows that most of them relate to the consumer level. This makes sense, since with an estimated contribution of 53%, the consumer is the primary contributor to food waste across the food value chain in higher income countries (Stenmarck, Jensen et al. 2016). It seems that most drivers and barriers as identified in literature are related to the abilities and motivations of the consumer, i.e. knowledge and skills (Ability) and attitudes, awareness and social norms (Motivation). It seems that Motivational factors are mainly described as drivers, whereas Ability factors are mainly described as barriers. However, it is important to note that the determinants usually have two sides: a lack of knowledge on proper storing is a barrier, whereas good knowledge on proper storing is a driver of preventing food waste. Similarly, awareness on the FLW problem is a driver of preventing FLW, whereas lack of awareness is a barrier.

Whereas the consumer actor level is most prominent, the second most prominent level is the retail and hospitality sector, where quite some insights on behavioural drivers and barriers were described. At the agricultural production and manufacturing level, less drivers and barriers were found, with the ones that were identified mainly defined as barriers. It seems that the current literature provides less insights into the behavioural drivers and barriers at the agricultural and manufacturing level.

Most interventions at retail and consumer level, largest focus on opportunities of MOA framework at retail level and motivation & ability at consumer level

The literature overview shows that the majority of interventions are focused on the consumer level or with the retail level as source with a focus on the consumer as end-user. Less interventions focus on the actors at the other level in the chain. A recent review also concluded that the majority of FLW interventions are at the consumer or whole supply chain level (Reynolds, Goucher et al. 2019).

Nevertheless, there are some examples that show positive behavioural change at other actor levels than the consumer. For example, selling lunch and dinner meals from in-store kitchen using products that might otherwise have been wasted boosted employee engagement (Aschemann-Witzel, Hooge et al. 2016). A real-time digital food waste tracking system, based on Internet of Things technology, coupled with staff training and engagement in food waste reduction solutions was also effective in reducing food waste at the manufacturing level (Jagtap and Rahimifard 2019).

The interventions at the retail level focus mainly on opportunity of the MOA framework, so providing the consumer an opportunity (time, material, infrastructure) to participate in FLW reduction behaviour. A large focus is on promoting and increasing sales of suboptimal foods, or reusing food ingredients that otherwise would have been wasted. At the consumer level, the majority of interventions focus on a combination of motivation and ability via promoting awareness, knowledge and skills.

Room for improvement in effectiveness of interventions

Current interventions - focused at the consumption stage - seem to achieve a 5-20% reduction in food waste (Reynolds, Goucher et al. 2019), which indicates that there is room for improvement. Although the match between consumer determinants (drivers and barriers for Motivation and Ability) and consumer interventions (main focus on Motivation and Ability) seems well when looking at the MOA categorisation, this does not automatically provide a full fit. To illustrate, the barrier of not understanding 'use by' or 'best before' dates (Parfitt, Barthel et al. 2010, Aschemann-Witzel, de Hooge et al. 2015, Principato, Secondi et al. 2015) can only be overcome when people learn the difference between the two and act according to this, but increasing knowledge on another topic will not be effective to overcome this barrier. Additionally, consumers' generally low tendency to purchase and consume suboptimal foods may be overcome by positive taste experiences with visually suboptimal foods (Rohm, Oostindjer et al. 2017) only when low quality expectations of suboptimal foods is the barrier. Besides an actual fit between the drivers and barriers and the intervention focus, Van Geffen et al (2016) also indicate that interventions should target all aspects of the model, so motivation, ability and opportunity.

Limited number of interventions measure actual FLW

Only a few studies actually measure the effects on real FLW behaviour (Valpreda and Zonda 2016, Rohm, Oostindjer et al. 2017, Reynolds, Goucher et al. 2019). Therefore, effects of various interventions are currently unknown. Previous studies show that positive as well as (unintended) negative effects are possible, which need to be monitored. To illustrate this point, some examples will follow. Falcone & Imbert describe the concept of food sharing as a promising theoretical concept, but also conclude that the assumption that the adoption of food sharing practices automatically leads to food waste reduction is not yet proven (Falcone and Imbert 2017). Priefer proposes that strong economic instruments could be a key lever for behavioural changes in industrialised countries, but a main concern is that this evokes protest among citizens and the relevant stakeholders. Moreover, little is known about their effectiveness to reduce food waste. Another example with potential negative side effects is that the intervention of taxing food waste may stimulate illegal dumping. When European marketing standards would be changed to focus only on product quality and less on the appearance of the product (odd-shaped), logistic processes may be more difficult and it still has to be proven that this will lead to less food waste (Priefer, Jörissen et al. 2016). Certain food waste reduction interventions are effective due to a greater consumption of foods or shifts in the types of foods consumed. If such shifts are in the direction of overconsumption of unhealthy foods, or a lower consumption of unhealthy foods, this could result in negative health effects (Reynolds, Goucher et al. 2019). Finally, although discounting has been shown to be a successful strategy to reduce food waste, implementing discounting can still lead to food waste. If consumers chose the discounted product over the product they normally buy, the overall demand may remain equal (Buisman, Haijema et al. 2017). So, these examples clearly indicate that monitoring effects of FLW reduction interventions should measure actual effects on FLW, and include multiple other measures at various levels to assess (unintended) positive and negative effects.

Food waste behaviour occurs often unintentional, is a complex result of multiple behaviours, with each behaviour its own determinants, of which part are unconscious

At the actor level of the consumer, the complexity of changing food waste behaviour becomes pretty clear from the results. The overview shows that most consumers are reluctant to food waste (Rohm, Oostindjer et al. 2017). In The Netherlands, seven in ten people are willing to reduce their food waste and 90% of consumers intend to reduce food waste (Temminghoff and Damen 2013). However, the intention not to waste food does not transfer directly into anti-waste behaviour (Stefan, van Herpen et al. 2013). Reasons for this may be the fact that wasting food does not always occur intentionally in consumers (Van Geffen, Van Herpen et al. 2016) and food waste behaviour is the result of different behaviours (Quested, Marsh et al. 2013, Van Geffen, Van Herpen et al. 2016) and each of these behaviours is a complex interplay of different drivers, of which part are unconscious such as habits, emotions (Quested, Marsh et al. 2013, Russell, Young et al. 2017).

5.1 Identified challenges

Our literature study identified some challenges that are encountered in current FLW interventions:

- 1) Various food waste intervention have poor public participation (Thyberg and Tonjes 2016).
- 2) There is a lack of homogeneous methodologies to collect and compare food waste /waste reduction data (Thyberg and Tonjes 2016, Gaiani, Rolle et al. 2019, Reynolds, Goucher et al. 2019).
- 3) There is a lack of uniform food waste terminology globally, as well as across the food supply chain (Gaiani, Rolle et al. 2019).
- 4) Household food waste studies vary greatly, so comparison between studies is difficult (Koivupuro, Hartikainen et al. 2012, Reynolds, Goucher et al. 2019).
- 5) Although information-based interventions may be relatively cheap and reach a relatively large public, and can be effective (Quested, Marsh et al. 2013, Reynolds, Goucher et al. 2019) some care is also needed as information messages are not always read or recognized (Rohm, Oostindjer et al. 2017) and not all types of information are effective in changing consumer behaviour (Grunert 2002, Kosa, Cates et al. 2007).
- 6) Including emotions may yield greater understanding of food waste behaviour, but it may be challenging. Arousing negative emotions may do more harm than good (increase food waste) (Young, Russell et al. 2017) & negative emotions underpin consumer motivation as well as barriers (Graham-Rowe, Jessop et al. 2014).
- 7) Food redistribution initiatives have limited outreach, and are largely fragmented and independent from each other. In addition, they received much less attention than food waste prevention initiatives (Facchini, Iacovidou et al. 2018).
- 8) There seems to be a lack of interaction between stakeholders within & across micro-, meso- and macro-levels (Gaiani, Rolle et al. 2019).
- 9) There is also a disconnection between food governance, the global food supply chain, and consumer demands (Gaiani, Rolle et al. 2019).
- 10) The 'commodification' of food results in that food is used for merchandise rather than for nutrition (Gaiani, Rolle et al. 2019).
- 11) Large-scale food retailers should take responsibility for their impacts elsewhere in the supply chain, but it is difficult how far corporate social responsibility should extend? Retailers engage in social responsible actions, but also shift the problem to elsewhere in the chain (Devin and Richards 2018).

5.2 Strengths and limitations

A strength of the current study is that it focused on drivers and barriers of FLW, as well as on the effectiveness of behavioural interventions. Using a whole chain approach led to a more comprehensive picture than focusing on one actor only. Still, the picture is scattered.

A potential limitation could be the term '*behaviour*' in the search strategy. The project aimed to get insight into behavioural success factors and challenges related to reducing FLW. Therefore, the search strategy included the term '*behaviour*'. Whereas '*behaviour*' is a common term when talking about consumer behaviour (end user of the chain), it is possible that this term is less common for other actor levels, and that papers were missed. On the other hand, the search results did include papers from multiple actors, although less papers than at the consumer level. This may indicate that behavioural aspects of FLW have not received so much attention in FLW research at the other stages of the food supply chain.

Finally, the MOA-framework was used to categorize the consumer drivers and barriers, as well as the interventions that were targeted at the consumer. The researchers discussed the categorization until agreement was achieved. Nevertheless, it is important to recognize that the three categories of the framework do not stand alone, but are interrelated to each other.

5.3 Recommendations

Monitor effectiveness of interventions by assessing actual FLW, along other positive or (unintended) negative effects to enhance our understanding of intervention effectiveness

Because a limited number of studies actually investigate effectiveness of FLW interventions, such measures are important to include in future studies to enhance the understanding of effective elements of FLW interventions. To strengthen current results, a greater number of longitudinal and larger sample size intervention studies are required that actually assess FLW effects. Furthermore, it is advised that interventions that have shown effectiveness and are proposed to be effective are implemented, combined, refined, and further tested at different scales, for different products and settings, and in different parts of the world (Kulikovskaja and Aschemann-Witzel 2017, Reynolds, Goucher et al. 2019). Assessing the effects on FLW should occur at multiple actor levels, and it is also important to assess the positive, neutral as well as unintended negative effects of these interventions. For example, if a retailer increases sales of suboptimal products due to multi-item offers, promotions on single items or other price lowering strategies, this implies an initially positive effect at retailer level. However, it is important to understand what happens with these products at the consumption stage (consumer/ household level). Are these pricing strategies effective or do they generate more food waste in the consumer households? Do food redistributions or donations of different suboptimal food items reach consumers timely so that they are not discarded by them (Kulikovskaja and Aschemann-Witzel 2017)? A nice example is the Too Good To Go magic box. The popularity of magic boxes were a success at the retailer level, but a recent study also showed that consumers used most of the magic box for consumption, and only very little food was discarded by the consumers (Van der Haar and Zeinstra 2019).

Use multi-component interventions, with different conscious and unconscious behavioural change techniques, using a combination or large population and more individual tailored approaches

Due to the complex interaction of multiple behaviours, it is recommended to use multi-component & holistic interventions (Van Geffen, Van Herpen et al. 2016, Evans, Welch et al. 2017); focusing on the individual, social environment and material context of food practices. This is also recommended for policies that should be multi-faceted (Thyberg and Tonjes 2016) focussing on values, skills for behaviour change and logistics. Because not all actors are aware or motivated to reduce FLW, it is also important to use unconscious behaviour change techniques to reach a larger group of actors. Similarly, on the one hand, it is recommended to achieve a large group of actors by using campaigns, such as the Campaign 'Love food, hate waste!' which was successful (Quested, Marsh et al. 2013), but at the meantime it seems beneficial to also engage with people one-to-one, using a more tailored approach. Because actors at a similar level still form a heterogeneous sample, each segment may need different interventions (Quested, Marsh et al. 2013, Rohm, Oostindjer et al. 2017, Gaiani, Rolle et al. 2019). Some studies identify & characterize different consumer segments as endpoint of the study (Rohm, Oostindjer et al. 2017, Gaiani, Rolle et al. 2019), but these segments are generally not used as starting point for interventions.

Use theoretical frameworks to develop interventions

Our overview indicated that not all interventions are guided by theory, which is also concluded in a recent review (Reynolds, Goucher et al. 2019). In general, theory-based interventions seem to be more effective (Michie, van Stralen et al. 2011, Kohl, Crutzen et al. 2013), so it would be useful to include theoretical frameworks about behaviour, such as the MOA-model, to guide intervention development. It would be interesting to apply such a behavioural theory – originally developed for consumers – also to other actor levels in the chain.

Also for these actors, food waste behaviour may be the result of different behaviours, with each behaviour being a complex result of various drivers, of which part of it may be unconscious. It would be interesting to investigate whether effective interventions at the consumer level can be translated – based on the determinants of their FLW related behaviour – to other actor levels in the chain.

Provide or show the benefits of food waste reduction efforts

A few studies indicate that showing the benefits or the positive effects of food waste reduction may be a good strategy. One study showed that there was more kitchen food waste in restaurants where managers do not perceive food waste reduction as a cost-reduction opportunity (Principato, Pratesi et al. 2018). In addition, a study on the effectiveness of apps to reduce consumer's food waste indicated that including a direct insight or showing the economic and/or ecological effects of consumers' food-waste related behaviours in an app could work as a motivational reward (Vogels, Van der Haar et al. 2018).

In line with this, the results suggest that individual engagement of actors along the chain may work beneficial. One food waste reduction intervention resulted in increased employee engagement (Aschemann-Witzel, Hooge et al. 2016), whereas staff engagement in food waste reduction solutions was one component of an effective intervention at the manufacturing level (Jagtap and Rahimifard 2019). These two studies indicate that it may be essential to use bottom-up approaches for reducing FLW, challenging and engaging actors in finding solutions.

6 Conclusion

The aim of this literature overview was to identify drivers and barriers for food loss and food waste behaviour from an actor perspective, and to explore possible behavioural interventions for diminishing food waste and food losses at multiple stages of the food supply chain.

This literature study showed that most studies focus on drivers and barriers of FLW behaviour, and less on behavioural interventions to reduce FLW. Furthermore, the overview of drivers and barriers along the food value chain shows that most of them relate to the consumer level, with the retail and hospitality as second. It seems that the current literature provides less insights into the behavioural drivers and barriers at the agricultural and manufacturing level. Most identified interventions were focused at FLW of the consumers as end-user, with the retail level focusing on providing consumers with options to reduce FLW (opportunity of the MOA-framework), and the household-level interventions focusing on enhancing motivation and abilities of consumers to reduce FLW. Because a large part of FLW occurs at the consumer level, this focus is understandable. Still, action is required at the other actor levels to achieve the UN Sustainable Development Goal of reducing FLW with 50% in 2030.

The overview shows that there is room for improvement, concerning the effectiveness of interventions as well as assessing the actual effects on FLW behaviours at multiple actor levels, including potentially unexpected positive and negative effects. Although the picture is scattered and various challenges were identified regarding FLW interventions, the current intervention overview indicates that promoting and tracking attention towards suboptimal foods or towards products made of ingredients that otherwise would be wasted is an effective strategy to reduce FLW at the retail level. Price reductions of suboptimal foods, and discounting products which are close to expiration as well as Dynamic Shelf Life seem effective to reduce FLW at the retail level, but the FLW effects at the consumer/ household level are currently not yet clear. Reducing portion sizes via smaller plates or smaller portions seem effective interventions to reduce FLW at the hospitality and catering level. Positive taste experiences with visually suboptimal foods seems to enhance preferences and buying intention, whereas the effect of information-based interventions seems somewhat mixed. Due to the complex interaction of multiple behaviours that lead to FLW, it is recommended to use multi-component & holistic interventions with different conscious and unconscious behavioural change techniques. In addition, it is recommended to use a theoretical framework in the development of interventions. It would be interesting to explore whether consumer models for (FLW) behaviour change can be applied to other actors in the chain.

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