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# How Can Food Loss and Waste Management Achieve Sustainable Development Goals?

**Abstract**

The main purpose of this literature review is to establish a state of the art of food loss and waste management system that addresses the United Nations' Sustainable Development Goal number 12: sustainable consumption and production. The paper constitutes a detailed summary of recent literature on the concepts, product categories, causes, solutions, and research challenges surrounding food loss and waste management. The contribution of this article is a new classification of the causes, solutions and research challenges, based on diverse existing classifications. Solutions for reducing food loss and waste include awareness raising, business process redesign, integrated supply chain models, redistribution, recovery, and disposal. Several research direction propositions came out of this literature review: developing standardised and up-to-date data collection and concept definitions; analysing the 'awareness of the need' concept in redistribution; studying consumer behaviour; examining the performance of local versus global logistics networks in terms of food loss and waste; and identifying the role of packaging in food loss and waste and greenhouse gas emission reduction.
*Keywords:* Food Loss and Waste, Sustainable Development Goals, SDG 12.3, Food Waste Prevention, Sustainable Food Supply Chain.

## 1. Introduction

In September 2015, the 193 member states of the United Nations (UN) set an ambitious agenda for 2030, including the establishment of 17 sustainable development goals (SDGs) meant to achieve economic growth, social integration, and environmental protection (UN Department of Economic and Social

Affairs, 2015). The 12$^{th}$ goal, which refers to 'Responsible Production and Consumption', connects to the concept of food loss and waste (FLW) management through SDG 12.3: 'By 2030, halve per capita global Food Waste at the retail and consumer levels and reduce Food Losses along production and supply chains (SC), including post-harvest losses' (UN Department of Economic and Social Affairs, 2015).

The food sector is a major sector. For instance, in Europe, the food industry is comprised of about 310.000 companies, most of which (99%) are small and medium sizes enterprises. Each year, the food sector contributes more than 750 G euros to the European Economy (European Union, 2014). It represents 8.3% of total employment in the European economy and 4.4% of Gross Domestic Product (The European Parliament, 2013).

Worldwide, demand for food is growing. The demand for dairy and meat products is especially expected to increase. This will lead to a rise in demand for food production, from 60% to 110% by 2050 (estimations from 2011-2012) (Garnett, 2013), and a need for an expansion of global food production. In the meantime, food is lost and wasted all over the world (Richter & Bokelmann, 2016) while undernutrition persists in developing countries (Pingali et al., 2017).

The food system as a whole contributes considerably to greenhouse gas (GHG) emissions and resource usage. In developed countries, it accounts for 15 to 28% of total GHG emissions (national studies between 2007 and 2010) (Garnett, 2011). According to Foley et al. (2011), food production accounts for about 70% of the global freshwater use. It requires resources and has an adverse impact on the environment, whether it is consumed or not. FLW is a sensitive issue in the context of competition for limited natural resources (land, water, energy, fossil fuels, and mineral fertiliser) (Eriksson et al., 2014) and even threaten the livelihood of future generations (Göbel et al., 2015).

Estimations help illustrate the amplitude of the FLW issue. Globally, about one third of all food produced for human consumption is wasted each year (1.3 Gt) along the SC (FAO, 2019a). Stancu et al. (2016) state that 25% of the supplied food is wasted, 50% of which happens at the household level in high

income countries. According to Porter et al. (2016), households represented more than 40% of total FLW in Europe in 2006.

FLW is forecast to grow. Developing countries will have a bigger impact on FLW in the coming years as their populations and economies are growing (Melikoglu et al., 2013), and their diet is moving from one based on cereal to one based on fat, sugar, and animals (Porter et al., 2016). Per capita meat consumption in developing countries is expected to rise by 40% by 2050 (Fox & Fimeche, 2013). If no measures or actions are taken, a 42% increase of food loss is expected in the 27 member states of the European Union (reference year of 2006), which represents 126Mt (Mirabella et al., 2014).

According to the Food and Agriculture Organisation (FAO) of the UN (FAO, 2014), global wasted food requires 0.9 M ha of land and 306 $km^3$ of water each year. This represents 49 Gt of equivalent carbon dioxide. As food consumption increases rapidly in low-income countries, the food sector's contribution to GHG emissions is expected to rise (Li et al., 2014). Even if developing countries require attention about this subject for the above-mentioned reasons, FLW is still, for example, twice as high in the United States of America as in China (Porter et al., 2016).

Minimising FLW is critical due to its consequences on the economic, societal, ecological, and health-related domains (Göbel et al., 2015). According to the ReFED (2016), this impact would be significant and rapid. Reducing FLW would have a positive impact on the economy (producer income, consumer expenses) (Lipinski et al., 2013), food security (Ingram et al., 2013), the fight against hunger (Garrone et al., 2014), and the global environmental footprint (Eriksson et al., 2014).

On the basis of the food related issues reported above, the goal of this paper is to explore how FLW management can help achieve the SDGs by 2030. To this end, a systematic review of the literature is carried out. The aim of this article is provide theoretical insights into decreasing the production of food waste by achieving one aspect of SDG number 12: Sustainable Consumption and Production.

The flow chart (Figure 1) summarises the organisation of this paper. In Section 2, the methodology used to carry out the review is explained, and the necessary concepts related to FLW are defined. The different criteria for food classification encountered in the selected scientific articles are highlighted in section 3. Section 4 proposes a detailed summary of the causes of FLW for each stage in the SC. Section 5 organises the possible solutions for improving FLW prevention around different aspects of management. Section 6 summaries a selection of the most restrictive barriers to research on this topic. A brief discussion gives some research questions for future studies and precedes a general conclusion drawn from the findings of this paper.


Figure 1: Flow chart summarising the structure of the paper (created with free Xmind software)

## 2. Methodology and definitions

This study identifies the links between FLW and UN SDG 12.3 by classifying the causes and solutions to FLW through a literature review. FLW occurs at all stages of the SC. We reviewed the literature to identify the causes and classify the proposed solutions to help reach the UN SDG number 12.3: 'By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses'.

### *2.1. Material and structure*

To begin this literature review, 95 articles, published between 2008 and mid-2018, were collected through Google Scholar. As the topic is studied in the context of the SDGs, the key words used to search for literature were selected from SDG number 12.3: global food waste, global food waste at the retail level, global food waste at the consumer level, food loss along production, food loss along SCs, post-harvest losses, and global food loss index. Suitable resulting articles are presented in this paper. Additional articles were included when the selected articles referred to non-mentioned articles that were relevant for our purpose.

### *2.2. Definitions of food loss and waste*

Waste can be defined according to the European Waste Framework Directive as 'any substance or object the holder discards, intends to discard or is required to discard' (European Comission, 2017). Any product can be wasted so the topic is widely studied and relevant to all sectors, e.g. electrical and electronic equipment waste, also referred to as E-waste (Song et al., 2015), or concepts such as extended producer responsibility, which seeks to incorporate environmental features in product design (OECD, 2001). In this study, we will focus on the specific causes of FLW that would not necessarily be applicable to other sectors.

FLW occurs in the food supply chain (FSC), which can be defined as an SC with continuous and significant change in the quality of the products from production to consumption (Bloemhof & Soysal, 2017). The FSC is unique

and complex due to the following aspects: logistic processes, manufacturing and processing, distribution, and consumption of food. Some dimensions of an SC are especially critical in the FSC: quality, safety, sustainability, and logistic efficiency (Manzini et al., 2014). Li et al. (2014) summarise the challenges of the food industry as food security, waste, farming, public health, climate change, oil dependency, fair trade, and localism.

The definition of FLW is not unique. Many authors propose their own definition, most of them differentiate between food loss (FL) and food waste (FW). As a consequence, some studies cannot be compared to one another (Lebersorger & Schneider, 2011). The lack of clarity in the definition of FL might create misleading policies for reducing FW (Koester, 2014).

Differentiation can be made between FL and FW. Parfitt et al. (2010) define FL as food discarded post-harvest. They differentiate it from FW occurring at the consumer level. FAO (2013) defines FL as a decrease of food quantity originally intended for human consumption and FW as discarded food. The term 'Food Wastage' refers to both concepts. Even though differences are exposed among the two concepts, FL and FW are sometimes used interchangeably in the literature. Wikström et al. (2018), for example, do not differentiate between the two concepts. The term used can refer to one or both concepts depending on the context. The same choice is made for this study. The term 'FLW' will refer to Food Wastage in general. Precision is used when we want to refer solely to FL or FW.

## 3. Classification of food

Classification of food helps differentiate food types based on intrinsic characteristics, including seasonality in production, quantity and quality processes depending on biological variation, quality constraints in each step of the SC (higher chance of stock-out), requirements for transportation and storage (temperature, waiting time), and traceability requirements (Bourlakis & Weightman, 2008).

Priefer et al. (2016) studied the share of FW generation in the household sector across the EU according to the classic food group classifications (Figure 2). Fruit, vegetables, and cereal contribute most to FLW. This is corroborated by the next two studies. Lanfranchi et al. (2014) identified the fruit and vegetable sector as the one that contributes most to FW, whereas Cicatiello et al. (2017) provide a meta-analysis of the retail FW quantification studies. Their paper focuses on one retail store in Italy and identifies the categories with the most wasted food as bread & fresh fruit and vegetable, while wasted edible food (about 35%) consisted mainly of fresh meat and bakery food.

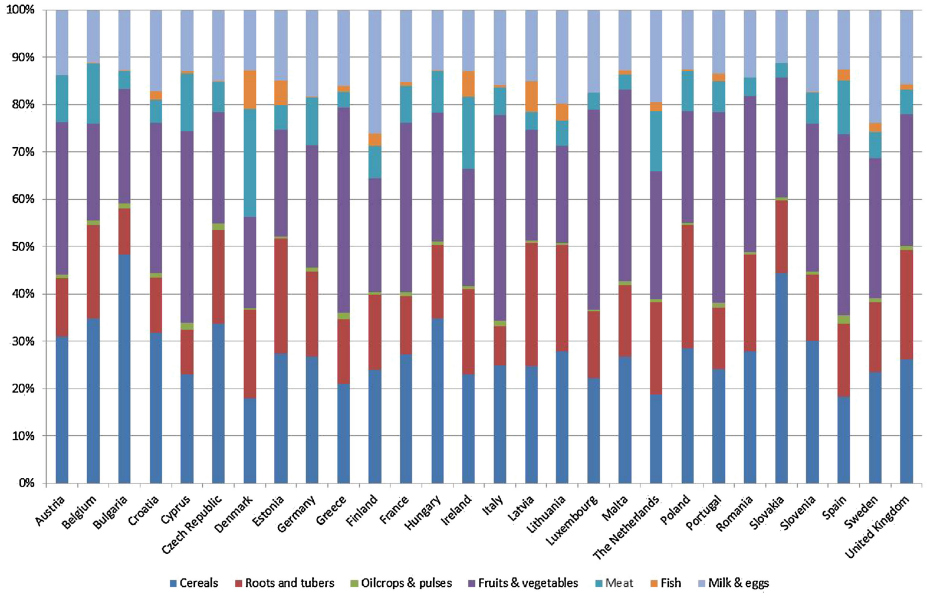


Figure 2: Share of different food groups out of total FW generation in the household sector across the EU in 2011. Source: Priefer et al. (2016)

The case study developed by Mena et al. (2014) includes all stages in the SC, except. Two food categories were selected corresponding to the two largest consumer food expenditures in the United Kingdom (UK): fruit & vegetables and meat products. The classification of fruits and vegetables in the study was made based on its storage life and condition. For example, strawberries were in the 'short storage life, short shelf life products' group, whereas potatoes were

in the 'storage life, medium shelf life products' group and bananas were in the 'tropical' group. According to Bloemhof & Soysal (2017), most studies consider food products as having a fixed shelf life and deterioration based on time (linear or exponential, depending on temperature, or other specific quality models), such as Soysal et al. (2014), where emissions are considered, and Ahumada et al. (2012) where uncertainties are considered.

Another classification system could be made on the basis of the origin of the food: plant-based food (vegetables or bread and bakery items) and animal food (milk & dairy products and meat & sausages). This is done in the qualitative study of Göbel et al. (2015) to identify and interpret the effect of causal factors for FL along the entire SC, with a focus on its interfaces. The findings are that plant-based foods are mainly wasted due to failing to meet standards (vegetables) or a loss of freshness (bread and bakery), whereas animal food are mainly wasted due to the production process (milk and dairy) or health and cost pressures (meat and sausages).

Bloemhof & Soysal (2017) propose a classification system based on the type of activities linked to the food: fresh (main processes: handling, conditioned storing, packing, transportation, and trading of goods) or processed. Another classification system could take the environmental effect of the product groups into account. The amount of wasted meat or dairy products is low compared to the amount of wasted grain-based products or vegetables (Figure 2). However, as considerably more resources are needed for the production of meat products and their environmental impact is bigger (with beef being the heaviest GHG emitter), reducing the waste of meat products would not lead to a substantial reduction in the total FLW but would contribute considerably to the reduction of adverse environmental impacts (Scholz et al., 2015).

FLW quantities, impacts, and causes depend on the product groups, so a unique solution will not lead to notable change (Li et al., 2014). A branch-specific approach based on the characteristics of different food categories is advised by Richter to reduce FL in manufacturing companies (Richter & Bokelmann, 2016). The next section proposes a classification system for the causes

Table 1: Food classification criteria

| Authors (Year) | Method | Main topic | Classification |
|---|---|---|---|
| Priefer et al. (2016) | Review | Food waste prevention | Classic product groups, Stage in the SC |
| Bloemhof & Soysal (2017) | Review | Sustainable food supply chain design | Food origin, Fresh or processed, Sustainability attributes |
| Lanfranchi et al. (2014) | Case study | Reduction of food waste | Grocery store sectors, Value of wasted food |
| Cicatiello et al. (2017) | Case study | Retail food waste | Food origin, Edible/not edible |
| Scholz et al. (2015) | Case study | Supermarket food waste | Environmental impact |
| Bourlakis et al. (2014) | Survey & Case study | Sustainable performance in food supply chain | Size of retail store |
| Mena et al. (2014) | Survey & Case study | Multi-tier supply networks | Storage life and condition, Consumer expenditures |
| Göbel et al. (2015) | Survey | Cooperation along the food supply chain | Food origin (plant/animal), SC stage |
| Richter & Bokelmann (2016) | Survey | Food industry | Food origin |
| Ahumada et al. (2012) | Quantitative model | Planning of the production and distribution of food under uncertainty | Fixed shelf live & time based deterioration |
| Soysal et al. (2014) | Quantitative model | Modelling food logistics networks | Fixed shelf live & time based deterioration, Environmental impact |

of FLW at all stages of the SC.

Table 1 provides the food classification criteria on which the papers based their analyses.

## 4. Causes of FLW at all stages of the SC

Identification of the causes of FLW is a prerequisite for the study of possible solutions. Case studies estimating quantities and causes of FLW along the SC have been carried out in Europe and in some Western countries. For example, Eriksson et al. (2012) analysed FL in some Swedish retail stores. Each stage

of the SC contributes to the total FW (Priefer et al., 2016) and meets different factors causing FLW. Stakeholders can have conflicting strategies for reducing FLW and incompatible objectives.

Most occurs at the production stage in developing countries, while most FLW occurs at the consumer stage in developed countries (FAO, 2011). According to FAO estimations, 95-115kg/year/capita of food is wasted in Europe and North America, whereas 6-11kg/year/capita of food is wasted in Sub-Saharan Africa and South/Southeast Asia (FAO, 2019a). A possible reason for the higher FL in developing countries could be a lack of technology or infrastructure, and a possible reason for the higher FW in developed countries could be the low percentage of income spent on food (Porter et al., 2016). An average household has to spend between 10% and 20% of its disposable income for food across the EU (Gerstberger & Yaneva, 2013).

Figure 3 shows that the last stage (consumption) contributes most to total FLW, which was also stated in the study by Parry et al. (2015). One can also observe the importance of the first stage of the SC in Europe.

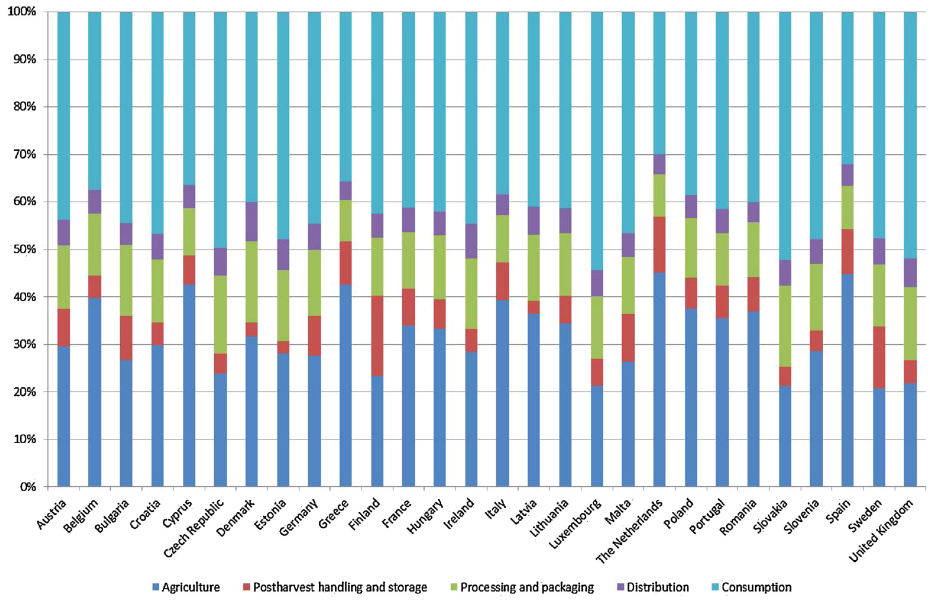


Figure 3: Share of FW at each stage of the SC in the EU in 2011. Source: Priefer et al. (2016)

### *4.1. Among the whole SC*

Some factors can create FLW independently from the stage of the chain. Some exogenous causes were identified by Mena et al. (2014) as being weather, the natural variability of food products, seasonal effects on supply and demand, and regulation (e.g. meat products). There also exist causes at the strategic level: 'poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of SC actors, and lack of access to markets' (FAO, 2013). Göbel et al. (2015) analysed the interfaces between the levels of the food value chain and identified them as a significant cause of FLW.

Bourlakis et al. (2014) studied Greek small and medium-sized enterprises. They show that, largely, small firms perform better regarding many sustainability measures, such as flexibility and responsiveness, whereas large firms perform better in terms of product conservation time and traceability. Due to the good performance of small firms in many performance measures of sustainability, firm size should be taken into consideration when studying FSCs.

### *4.2. Field, production, and agriculture*

At the first stage of the SC, various causes of FLW can already be identified. According to the FAO, natural disasters play a major role at this stage (FAO, 2013). Other causes are bad weather conditions, quality standards set by large-scale distributors (weight, size, shape, and appearance), damages during harvesting and market price. When the market price is lower than the harvesting cost, the products are left on the field. To prevent such losses, farmers may produce more than requested and not market the surplus to avoid a price decrease (agreements with retail chains) (Priefer et al., 2016).

In meat production, according to Mena et al. (2014), the causes of FL at this stage (abattoir) are legislation (beef and lamb), contamination (beef, pork, lamb, and poultry), poor recovery from cutting rooms (beef), poor process controls (beef, pork, and poultry), carcass evisceration and dressing (pork), quality

rejections (pork), poor stock control (lamb), management of product shelf life (lamb), poor operational performance (lamb), death on arrival (poultry), damage in processing (poultry), returns by customers (poultry), and line stoppages (poultry).

### *4.3. Food industry, processing, and manufacturing*

The food industry consumes large amounts of natural resources and faces increasing demand (Li et al., 2014). According to a survey by Richter & Bokelmann (2016) in the German food industry, the main reasons for the amount of FL at this stage are product defects (73%), technical faults (54%), and expiry of the best-before date (43%).

A difference in pattern occurs in the fruit and vegetable industry for which high trading standards and retail regulations are the main causes of FLW (Richter & Bokelmann, 2016). Other causes of FW in manufacturing companies in the food industry have been identified in the United States by Buzby & Hyman (2012) and in the UK and Spain by Mena et al. (2011). These are spoilage, damage, poor demand forecasting, overproduction, excess stocks, inefficient management, exogenous factors (weather, seasonal effects, supply and demand, etc.), processing, contamination, and packaging problems.

In meat production, according to Mena et al. (2014), the causes of FL at this stage (cutting) are operations (beef), weather (beef, pork, and lamb), demand forecasting (beef, pork, and lamb), inventory management (beef), promotions (beef, pork, and lamb), quality specifications (beef and pork), and lead times (pork).

### *4.4. Shipment, Storage, Distribution, and Wholesale*

Globalisation, urbanisation, and agro industrialisation have led to complex, international and interconnected networks with impacts on the production process and delivery of food. Perishable food products can come from very far and yet have fairly competitive prices (Bloemhof & Soysal, 2017). Food harvested

and manufactured in a place can be delivered worldwide (Li et al., 2014). Globalisation involves greater distances between producers and consumers (longer cold chains, more intermediaries, and increased risks of losses (Priefer et al., 2016)). Packaging, handling, and transportation decisions have an impact on the quality and taste of food products (Li et al., 2014). FLW can occur due to packaging damage, non-respect of food safety requirements, marketing strategies, or logistical constraints (Priefer et al., 2016). Following this trend, the market seeks improved coordination among stakeholders and continuous innovation.

According to Mena et al. (2014), the specific causes of FL in the fruit and vegetables sector at this stage are variation in temperature (strawberries, tomatoes, potatoes, etc.), storage pushing (lettuce, apples, potatoes), weather related sales variability (lettuce), demand forecast inaccuracy (lettuce, tomatoes, and broccoli), storage deterioration (onions and broccoli), destructive quality control (onions and avocados), distance travelled (citrus), and shipping delays (bananas).

As retailers have short-term order possibilities, wholesalers need to have a constant supply of products and high delivery capacities, which leads to FLW unless volumes are precisely managed (Göbel et al., 2015).

The next step of the SC brings another cause of FLW: many products are rejected by retailers due to short remaining shelf live or quality standards.

### *4.5. Retailing*

The motivations of retailers for reducing FW are economic and moral (Gruber et al., 2016). Retailers maintain high standards to avoid quality scandals (Priefer et al., 2016).

The food sector requires high inventory availability. Stenmarck et al. (2011) pointed out in local studies that full shelves and broad variety is demanded by customers before the closing time of stores. On-shelf availability is more critical than waste avoidance from the retailer's point of view. Local optimisation leads retailers to ask suppliers for food products with at least 70% of their shelf lives

remaining, which leads to additional waste for suppliers. Suppliers are also measured on their 'on time in full' performance. Therefore, they prefer waste to stock outs, which leads to high safety stocks (Mena et al., 2014). Demand uncertainty, coming from a lack of transparency in the demand and the local focus on optimisation, lead to excessive safety stocks to cover for stock-out feared by suppliers and retailers. It also leads to excessive FW. The demand has an influence on the waste rate at the current stage of the value chain and on waste rates at earlier stages (Göbel et al., 2015).

Promotions are seen as a competitive factor in the UK and are planned according to specific events. From interviews in the study by Mena et al. (2014), it seems that promotions lead to additional uncertainty. A focus on internal maximisation of profit paired with a lack of transparency in managing promotions lead to more FW. Promotions lead to waste as consumers tend to buy more than needed (Gruber et al., 2016).

Lebersorger & Schneider (2014) studied a panel of 612 retail outlets in Austria over one year and analysed the FL rate which amounted to '1.3% of the sales of dairy products, 2.8% for bread & pastry and 4.2% for fruit & vegetables'. They provide some insights on the variation in the FL rates, 33% of the variation can be explained by the sales dimension: the higher the sell rate, the lower the FL rate. FLW rates in retail are lower than the rates in private households, so an effort might be to be made at that stage instead of the retail stage. Retailers are considered pivotal actors between producers and consumers by Cicatiello et al. (2016).

In the meat and fruit & vegetable sectors, specific causes of FL exist at this stage according to Mena et al. (2014): weather, forecasting, promotions, stock rotation, temperature, standards, quality control, display management, stock management, code-life management, poor handling (consumers and staff), slow rate of sale, seasonality of demand, limited access to information from retail, variability in ordering, forecasting accuracy, one diseased item causing a whole pack to be thrown away, stock keeping unit's proliferation, and retailer inflexibility in promotions. Other causes that concern all product groups are mar-

ket demand (e.g.: holidays), natural causes (e.g. short-term weather changes), management, cold chain interruption, packaging defects, and overstocking (inaccurate ordering, forecasting, and marketing) (Mena et al., 2011).

### *4.6. Food service provider*

The food service provider is a wide sector representing the hospitality industry, catering, restaurants, fast food chains, cafes, cafeterias, canteens, and dining halls (Martin-Rios et al., 2018). Among others, it concerns hospitals, nursing homes, hotels, school canteens, enterprises cafeterias, and prisons. It is worth noting that hospitals are estimated to be responsible for more than two times the FW of other food service sectors (Dias-Ferreira et al., 2015).

This stakeholder faces specific FLW causes. Portion size is not always aligned with the customer. When the portion size is too big, some restaurants offer the possibility to take the rest of the food back home in a Doggy bag. Sirieix et al. (2017) studied the behavioural reasons for refusing Doggy bags in the Czech Republic. The findings are that the consumers have mixed feelings. On the one hand, the consumer regrets and feels guilty about leaving left-overs on the plate; on the other hand, social norms prevent him or her from asking to take the rest home (Sirieix et al., 2017). Secondly, the EU has strict hygiene rules (Priefer et al., 2016) as well as intrinsic conservation rules that limit storage and reuse possibilities during meal preparation (Martin-Rios et al., 2018). The management system also creates FLW (Heikkilä et al., 2016). Staff is not well trained for internal routines, purchasing, storing, and freezing (Priefer et al., 2016). Martin-Rios et al. (2018) state that the rate of FLW in the food service sector depends mainly on the management's beliefs, knowledge, goals, and actions. The underlying reason for this is that this sector is labour-intensive, which leads to slower innovation.

In their study carried out in Pakistan to identify the cause of FW in restaurants, Aamir et al. (2018) find that overproduction and liability concerns lead to excess food preparation and improper disposal.

Additional causes are exceeding internal sell-by dates, varying demand (Strotmann et al., 2017), buffets at fixed prices, menu and demand planning, low forecasting accuracy, weather conditions (Priefer et al., 2016), and unintentional misinformation by manufacturers (Heikkilä et al., 2016).

Using food services also indirectly causes FW. Landry et al. (2018) studied the relationship between the number of food-at-home retailers, the number of food-away-from-home retailers, and municipal solid waste in Mississippi from 2007-2012. The food-at-home retailer's density is negatively correlated to the solid waste volume. On the contrary, the food-away-from-home retailer's density is positively correlated to the solid waste volume.

### *4.7. Household consumption*

In the last stages of the SC, there is a moving pattern in the demand for food as a consequence of global factors such as the growing population and increasing urbanisation (Richter & Bokelmann, 2016). The highest quantity of FLW occurs at the consumer stage in industrialised countries (Principato et al., 2015). Each author presents different causes and solutions to this problem, depending on the region and stakeholders.

Some causes of FW at this stage have been identified in developed countries. High consumer expectation in terms of aesthetic characteristics (fruit sizing), remaining storage time (expiration date), and diversity and availability have an impact on the selection of food products in the other levels of the SC (Beretta et al., 2013). Farr-Wharton et al. (2014) identified three main behavioural causes for FW at the customer level: the customer lacks knowledge about the availability of the food, the location of the desired food, and the customer's past experience with wastage practices. Loss and waste also occur due to the shopping and eating habits of each consumer (FAO, 2013). Priefer et al. (2016) identified the causes of food wastage at this stage of the SC as being all linked to the consumer. Some consumers are not aware of the impact of FW. Other consumers feel guilty when wasting food but face the 'attitude-behaviour' gap (Schanes et al., 2018). On the contrary, Evans (2011) argues that the customer

is influenced by the system: more and more convenience products are available in stores and replace the preparation of food at home, which can have an impact on the basic coocking skills of consumers and lead to more FW (Göbel et al., 2015). Jörissen et al. (2015) give societal and economic trends that have an impact on food wastage at the household level: 'growing prosperity, decreasing food prices, urbanisation, rising number of single households and increasing employment of women including multiple burdens in work and family life'.

The consumer is also influenced by visual incentives when purchasing such as the presentation of goods. It can lead to purchases beyond the necessary demand, which can turn into FW at home (Monier et al., 2010), such as impulse purchases.

It is worth noting that food wasted in the last stages of the SC causes more adverse environmental impacts than food lost in the field for example. Indeed, the bill at one stage of the SC includes the environmental costs of all the previous stages (Beretta et al., 2013).

## 5. SC levers for FLW reduction

There are different fields of actions to decrease waste. Papargyropoulou et al. (2014) establish a FW hierarchy and conclude that prevention-minimisation of food surplus and avoidable FW-would have the biggest impact on the three dimensions of sustainability (environmental, economic, and social). The next levels are re-use, recycle, recover, and disposal. Göbel et al. (2015) recommend focusing on the prevention of waste. In accordance, this section focuses on the prevention level by showing how SC management can help improve FLW prevention and management. More specifically, various aspects of business process redesign are analysed in section 5.4 to 5.8, which is an optimisation tool companies use to minimise FL (Richter & Bokelmann, 2016). Thereafter, some alternatives for the other levels of the waste hierarchy are proposed: 'Reuse, recycle, recover and disposal' in sections 5.9 and 5.10.

Table 5 sums up the solution proposition categories of the authors that will

be discussed in more details in the next subsections.

Table 2: Categories of solution propositions by author

| Solution | Authors |
|---|---|
| Awareness raising and Consumer education | Aschemann-Witzel et al. (2015), European Commission (2011), Hermsdorf et al. (2017), Lehmann (2011), Parfitt et al. (2010), Priefer et al. (2016), Quested et al. (2013), Quested & Johnson (2009), Richter & Bokelmann (2016) |
| Global coordination and information sharing | Abbey & Guide (2017), Göbel et al. (2015), Lebersorger & Schneider (2014), Li et al. (2014), Lipinski et al. (2013), Mena et al. (2014), Mena et al. (2011), Priefer et al. (2016) |
| Sustainable SC | Bourlakis et al. (2014), Göbel et al. (2015), Koester (2014), Lanfranchi et al. (2014), Li et al. (2014), Mena et al. (2011), Parfitt et al. (2010), Richter & Bokelmann (2016), Schanes et al. (2018) |
| Standards and specifications in product design | Blanke (2015), Buder et al. (2014), Göbel et al. (2015), Hermsdorf et al. (2017), Mena et al. (2014), Priefer et al. (2016) |
| Shift in responsibility | Göbel et al. (2015), HellstrÃ et al. (2017), Lebersorger & Schneider (2014), Priefer et al. (2016), Wikström et al. (2018) |
| Logistic network design | Ala-Harja & Helo (2015), Bloemhof & Soysal (2017), Dekker et al. (2012), FAO (2011), Manzini et al. (2014), Mena et al. (2014), Priefer et al. (2016), van der Vorst et al. (2011) |

| | |
|---|---|
| Inventory management models and Lot sizing | Akkerman & van Donk (2008), Bushuev et al. (2015), Janssen et al. (2016), Li & Teng (2018), Melega et al. (2018), Önal et al. (2015), Priefer et al. (2016) |
| Packaging and conservation means | Bloemhof & Soysal (2017), Clune et al. (2017), Heller et al. (2018), Licciardello (2017), Lindh et al. (2016), Plumb et al. (2013), Priefer et al. (2016), van Sluisveld & Worrell (2013), Verghese et al. (2015), Wikström et al. (2018), Williams et al. (2012) |
| Redistribution | Beretta et al. (2013), Booth & Whelan (2014), Buzby et al. (2011), Cicatiello et al. (2017), Giuseppe et al. (2014), Gruber et al. (2016), Hermsdorf et al. (2017), Holweg et al. (2016), Holweg et al. (2010), Lebersorger & Schneider (2014), Lorenz (2012), Priefer et al. (2016), Richter & Bokelmann (2016), Rombach & Vera (2015), Vlaholias et al. (2015) |
| FW recovery and disposal | Bourlakis et al. (2014), Kim & Kim (2010), Lee & Tongarlak (2017), Melikoglu et al. (2013), Mena et al. (2014), Priefer et al. (2016), Richter & Bokelmann (2016), Watkins et al. (2012) |

### *5.1. Awareness raising and consumer education*

Despite its challenges and impacts, the perception of FL issue is low, as Richter & Bokelmann (2016) showed in an exploratory study among the food industry. The study also showed that the issue is being raised in discussions and assessed with high relevance in the food industry. Currently, no communication

about FLW reduction policy during production process of companies is done as it is not seen as a competitive advantage.

Sensitisation in the form of collaboration among institutions; synergistic actions between governments, societal stakeholders, and retailers; suitable communication to consumers; and consumer education (best-before-date, expectations and perceptions, and consumer household food management behaviour) can lead to FW decreases (Aschemann-Witzel et al., 2015). Consumer education is central to knowing the proportion of consumer's FLW along the SC (Parfitt et al., 2010). For this aim, Lehmann (2011) suggest incorporating the topic of FLW in education curricula to reach attitudinal change and a reduction of wasteful consumption. Hermsdorf et al. (2017) also propose creating awareness campaigns and educating children in the EU schools. This already happens in the educational programmes in the UK, France, and the Netherlands (European Commission, 2011).

Even if this issue has not yet widely spread in political agendas, various private initiatives have emerged worldwide. Some positive aspects of informational and cooperative instruments are their relatively low cost and quick implementation (Priefer et al., 2016). There are also many awareness campaigns such as: 'Love Food Hate Waste' in Great Britain launched in 2007, that led to a 21% reduction of household FW (2007-2012) (Quested & Johnson, 2009), 'Stop Wasting Food' in Denmark, 'Too Good for the Bin' in Germany, 'Qui jette un oeuf, jette un boeuf' in France, 'Of a meal do not even waste a tiny bit' in Catalonia, and 'Zero Waste Movement' in Portugal (Priefer et al., 2016). Globally, there is gaining awareness of the positive impacts of FLW reduction (Quested et al., 2013).

### *5.2. Global coordination and information sharing*

The literature expects integrated models and approaches to decision-making for the whole SC, including management and control of reverse flows (Li et al., 2014) such as in closed loop supply chains or reverse logistics. Those two concepts can add a new dimension to the waste management issue by focusing on

new value sources from products delivered to clients (Abbey & Guide, 2017). Those concepts will lead to a more circular economy.

Food is wasted at all stages of the SC so the solution and efforts to tackle the FLW problem should take all stakeholders into the equation (Lipinski et al., 2013).

High quality information flows for good planning and forecasting are especially central in FLW prevention due to the seasonality of the product and the high uncertainty of demand and supply. For instance, fruits and vegetables grow following a cyclical pattern. A stable supply of those goods requires rotating sourcing locations as well as accurate planning and forecasting to match supply and demand. Poor forecasting leads to waste due to the short shelf life characteristics of the products (Mena et al., 2014).

The complexity of the SC leads to mutual lack of knowledge, by which FLW is generated in the interfaces (Priefer et al., 2016). Each stakeholder seeks local optimisation for waste reduction which may lead to non-optimal results for the entire SC. This comes from poor communication, and it emphasises poor forecasting. Internal performance focusing on waste reduction leads to inaccurate forecasting. For those reasons, information should be more transparent in the up-stream of the SC (Mena et al., 2014). Enhancement of interface management through information sharing is a solution proposed by Göbel et al. (2015) to cut FLW along the SC. Priefer et al. (2016) propose applying integrated SC management models to enhance coordination along the FSC. For example, Gharaei (2016) propose a four-level integrated SC model using sequential quadratic programming. Those models require information sharing. Therefore, mutual trust is required. Collaboration and communication between stakeholders can improve forecasts and promotion management (Mena et al., 2011).

Lebersorger & Schneider (2014) showed that large differences exist among comparable retailers, and among different assortment groups within a retailer. The study suggests that sharing best practices would have a positive impact on FLW. 'Best practices sharing' is not considered in companies because initiatives with good results are perceived as a competitive advantage (Mena et al., 2014).

### *5.3. Sustainable SC*

Waste is considered by Parfitt et al. (2010) to be among the biggest barriers to FSC sustainability, which consists of supplying, distributing, and consuming food in a more sustainable way, without compromising costs, while setting standards and using technology to improve sustainable development, reduce operating costs, and minimise FW (Li et al., 2014).

Companies could be motivated to investigate this field through the incentive of efficient use of resources and saving money (Richter & Bokelmann, 2016). Indeed, at the household level, Schanes et al. (2018) states that money saving is the predominant intention behind FW reduction, before environmental concerns. Lanfranchi et al. (2014) suggest taking negative externalities into account while calculating the economic loss of FLW, not only the selling price. Costs of FLW and related hidden costs are under evaluated (Mena et al., 2011) or not taken into account at all (Koester, 2014).

Propositions for sustainability measures in food chains that help reduce waste and resource consumption are quality of the firm's product, product conservation time (to be balanced with the storage costs), food traceability, and good quality packaging (Bourlakis et al., 2014).

Göbel et al. (2015) advise considering the key performance indicators of resources utilisation and others that would measure the environmental impacts of the upstream chains to assess the management of FLW, which should be applied to each stage of the value chain and its interfaces.

### *5.4. Standards and specifications in product design*

Tights product specifications such as colour or size have been developed in reaction to the rigorous expectations of consumers, such as appearance for fruit & vegetable and fat content for meat (Mena et al., 2014). Those standards also come from former EU standards that lead to customers only being familiar with perfectly shaped products (Hermsdorf et al., 2017). Products with a poor appearance are priced lower due to visual standards (Göbel et al., 2015). Even products with small visual impairments are neglected by consumers

(Buder et al., 2014). They are seen as low-quality products (Hermsdorf et al., 2017). In this approach, appearance is more significant than taste quality or nutritional value. Standardised products are proposed to consumers in limited variety (Göbel et al., 2015). Among the consumer and retailer, it has not yet been determined which one is responsible for the high visual standards for food (Priefer et al., 2016).

Not allowing variability of natural products can lead to unnecessary waste. This waste is attributed to earlier SC stages. On the contrary, standardised products can lead to more efficient logistic operations (Göbel et al., 2015). Acquaintance could be a clue for consumer acceptance of products with visual impairments (Blanke, 2015). It happens in organic markets for which the motivation of lowering quality standards is not FLW reduction but income opportunity. The marketing argument is the naturalness of the product. Retailers could be motivated to introduce products with visual impairments as part of a customer relationship system strategy (Hermsdorf et al., 2017). Göbel et al. (2015) noticed that the surplus or reduced supply also conditions the rejection rate.

Other general standards are the labels, cleanness, development of product, and soundness. Retailers adhere to those high-quality standards to avoid food contamination scandals. The European food hygiene regime could be reviewed to evaluate if the regulation norms are necessary for food safety or lead to unnecessary waste such as through short deadlines for storing open packages/already prepared food, the 2-hour guarantee on unrefrigerated products, and the obligation to discard food once supplied (catering service). A relaxation of norms on quality requirements may not counter-balance retailer fears of contamination scandals (Priefer et al., 2016).

As a solution, Göbel et al. (2015) suggest identifying rejection reasons: personal consumer specification, health risks, and cost standardisation.

### *5.5. Shift in responsibility*

Göbel et al. (2015) propose sharing responsibility for cutting FLW along

the SC with all stakeholders because activities in the SC are inter correlated and have an impact on one another, both regionally and globally. For example, Lebersorger & Schneider (2014) considered bread sold in bakeries, that could be returned to the retail outlet if not sold. According to the authors, this shift of responsibility to the retailer could incite retailers to better manage demand planning, ordering, and information sharing. Priefer et al. (2016) suggest setting mandatory reduction targets. This could lead to a share of responsibility depending on how targets are settled.

Wikström et al. (2018) suggest conducting a stakeholder incentives analysis for FLW reduction. It worth noting that only a few actors gain by reducing FW as their revenue does not depend on the food wasted down the SC. On the contrary, a FW reduction downstream will lead to a sales reduction upstream, if everything else is unchanged. Even the consumer sometimes economically gains from buying large quantities of food, even if a portion of it is wasted (HellstrÃ et al., 2017). To solve this problem, Wikström et al. (2018) suggest sharing risks and gains among the SC actors to decrease FLW in the system.

### *5.6. Logistic network design*

As the quality of food declines during the whole SC (before production, during production, storage, transportation, and consumption), inadequate process controls in the food supply network cause FLW, such as problems linked to the cold chains (Mena et al., 2014). Therefore, van der Vorst et al. (2011) claim that quality control is key in improving product availability, constant quality, and product loss reduction.

Due to urbanisation, a combination of global low-cost agrifood production with local sustainable high-quality agrifood production could be expected for the future (Bloemhof & Soysal, 2017). There are recent studies that present logistic network design and optimisation in the food industry, among them is Manzini et al. (2014).

Priefer et al. (2016) suggest establishing a closer linkage between producers and consumers by opening alternative marketing channels for agricultural prod-

ucts. FAO (2011) agree that this technique leads to an efficient use of food. However, the impact of this technique on FLW generation is questionable. For example, if vegetable boxes are sold, what happens if the consumer does not know how to prepare vegetables or does not like them? (Priefer et al., 2016). Another question mark of the author is whether this direct marketing alternative can be extended or if it is solely a niche for customers that are conscientious about the environment and food quality. Energy and cost-efficient mass delivery can be more sustainable than local production and distribution (Ala-Harja & Helo, 2015).

Dekker et al. (2012) provide alternatives to decrease GHG emissions by integrating the environmental aspects of logistic network design in operation research. For example, the paper asserts that a small decrease in the speed of container ships can substantially reduce fuel use.

### *5.7. Inventory management models and lot sizing*

Inventory management and lot sizing problem solving can prevent FLW. Lot sizing is a lever for action in food management. For example, in suitable cases, large batches can lead to FL reduction due to longer planning horizons (Akkerman & van Donk, 2008). On the contrary, offering individual portion sizes could lead to FL reduction in the hospitality sector (Priefer et al., 2016).

Extended research has been carried out concerning both perishable and deteriorating inventory models, as the literature shows (Janssen et al., 2016). One can find extended and recent research in the field of inventory lot sizing of perishable products (Bushuev et al., 2015). Melega et al. (2018) proposes a classification and literature review of the integrated lot-sizing and cutting stock problems. Önal et al. (2015) add the dimension of consumption order preference, and Li & Teng (2018) add dimensions of varying demand depending on selling price, reference price, product freshness, and displayed stocks.

### *5.8. Packaging and conservation means*

Packaging's role is related to marketing, psychological function, attraction, physical and barrier protection, convenience, information transmission, security,

and portion control, which influences FLW. A research agenda identifying issues relating to the topic of packaging and FW is proposed by Wikström et al. (2018). The 'Packaging Saves Food Research Group' was established to study the role of packaging in FW prevention and proposed a research agenda to provide 'an overall saving in resources, reduce environmental impact, and increase overall system efficiency' and defined several research axes.

The identification and collection of data on packaging functions that have an impact on FLW is advised. Packaging that does not meet consumer's needs represents more than 20% of the wasted food in a household study in Sweden (Williams et al., 2012).

Consideration of the total environmental burden of a product/package by modelling a trade-off between product protection/preservation and environmental footprint is proposed. Indeed, packaging minimisation is not necessarily a solution that decreases the overall food footprint (Licciardello, 2017). The topic is more complex as an increase in packaging materials can be the best alternative for products with a high environmental impact (Verghese et al., 2015). To illustrate the differences among product groups, the GHG emissions associated with the packaging of resource-intensive products such as meat or dairy is low (Clune et al., 2017). For those products, protective packaging is imperative (Heller et al., 2018). The footprint of packaging can be decreased by the 'removal of excessive packaging, smarter product packaging, light-weighting, concentration of liquid products, refill packaging' (van Sluisveld & Worrell, 2013), 'renewable or recyclable materials, and increased recycling' (Plumb et al., 2013). An end of life analysis could also be included in the trade-off between packaging investment and FLW reduction (Wikström et al., 2018).

A third proposed study direction is the analysis of how to include identified packaging functions that have a direct or indirect impact on FW in the environmental footprint evaluation of the packaging. Another research direction is an improvement of packaging design processes to decrease FW (e.g. better portion sizing, resale opportunity, empty-ability, or clearer expiration information) and a validation of the impacts through life-cycle assessment.

Conservation and conditioning processes usually extend the shelf life of food products (Bloemhof & Soysal, 2017). Technical innovations in the packaging of food is an opportunity for FLW reduction along the SC (protection, transport, and storage) (Wikström et al., 2018). Verghese et al. (2015) say that the causes of FLW are often unavoidable, but inefficiency of SCs and damage in transport and handling could be improved by rethinking the packaging. They suggest that the packaging should take into account the required conditions for conservation of the product with the circumstances of the entire SC, including at the household level (e.g. portion sizes, date labels, and retail-ready packaging). For example, the shelf life of meat can be extended thanks to the use of Modified Atmosphere Packaging and vacuum and skin packs.

Beside the physical, chemical, and microbiological aspects of the packaging, other functions influence the needs, attitudes, and behaviours of consumers. They can have a more significant impact on FW prevention (Lindh et al., 2016).

A component of the packaging is the label of the product that contains information such as the expiration date, and it can be adapted to improve food management. A solution shared among many authors is the streamlining of food date labelling for the consumer to better understand the meaning of expiry dates (Priefer et al., 2016).

### *5.9. Redistribution*

Even with efficient food prevention, food surpluses will still remain (Priefer et al., 2016). It is not possible to donate all food surplus to people in need (Richter & Bokelmann, 2016). Cicatiello et al. (2017) state that a great portion of FW in retail may still be suitable for human consumption. The donation of unsold products to undernourished people is a possible solution to reduce FW. Food donation can lead to FLW reduction and social and ecological improvement (Beretta et al., 2013). It is part of the reuse level of the ladder of waste. It is a common practice in the retail sector (Lebersorger & Schneider, 2014), especially in Europe (Hermsdorf et al., 2017). For example, in France, food donation is an obligation for retail stores larger than 400 $m^2$ (Rombach & Vera, 2015).

Company's motivations for donating are that food donations can contribute positively to the company's image (Buzby et al., 2011), can lead to a cost reduction if the cost of the donation is lower than the cost of disposal (Holweg et al., 2010), and can lead to tax deductions in countries where applicable (Booth & Whelan, 2014). Companies also have psychological and social motivations such as reputation gain, superior feeling, or the joy of giving (Lorenz, 2012).

In contrast, reputation could be compromised in cases of improper handling of the donated products (Giuseppe et al., 2014). Barriers to food donation are economic, infrastructural, and legal constraints (Priefer et al., 2016). For instance, according to the EU Regulation 178/2002, documentation is mandatory for traceability throughout the SC (EC Regulation, 2002). The amount of surplus and FW can be considerable. It is perceived negatively by the society and some retailers do not want to draw attention to this issue in their stores inefficiency of logistical management that retailers to not want to make public (Holweg et al., 2016).

Legal challenges are considerable. For example, retailers in the UK fear litigation (Gruber et al., 2016), additional costs for administration, and logistical challenges (Holweg et al., 2010). In Italy, donors are legally protected (Priefer et al., 2016) and the 'Good Samaritan Act' limits a donor's liability in the United States of America (Priefer et al., 2016). Hermsdorf et al. (2017) propose taking inspiration from this policy to increase the number of retailers that donate unmarketable food.

Another solution is proposed by Vlaholias et al. (2015) to increase food redistribution. The study shows that 'awareness of need' is necessary for charitable donation. Therefore, the distributors should communicate with the retailers about the needs of the recipients because the retailers are not directly in contact with the benefactors of the donation process. They do not acquire the required awareness of need.

*5.10. FW recovery and disposal*

Fresh products face uncertainty in both demand and supply. A solution is to freeze the product when possible. This action leads to a loss in the value of the product (Mena et al., 2014). Except for the meat and fish industry, the processing and use of the rest of the food are not often considered in companies (Richter & Bokelmann, 2016). Processing and use of the rest of the food is seen as an essential sustainability measure in the FSC by Bourlakis et al. (2014). The flexibility of the firm in re-assigning food products to avoid waste has a growing impact in the later stages of the SC, considering the resources already attributed to the product for its delivery along the SC.

At the retail level, Lee & Tongarlak (2017) talk about by-product synergy. Making a by-product from a primary product provides an opportunity for the retailer to avoid the price of the disposal of the primary product and capture the price of the raw material of the by-product. They find that interest in this method is at its highest level when the demand uncertainty is high for a primary product and low for its by-products. In this case, the FW decreases, and the food donated also decreases. This is only true if tax credits for donations are low. Otherwise, the FW and the food donated increase.

When food is no longer edible, the FW should be treated. Kim & Kim (2010) propose, through an avoided impact analysis, that animal feeding and composting are potential treatment options with low energy consumption and low GHG production, when done correctly. Melikoglu et al. (2013) propose processing FW via landfill bioreactors or using bio refinery technology to recover the energy that would otherwise be lost if the FW ends up in landfill sites, which is the case for 95% of FW. Financial support for energy production from waste may lead to conflicting incentives and be counter effective in the objective of FW prevention. A policy lever could be the review of the EU tax regulations to make the generation of FW less attractive and FW reduction more appealing, such as by introducing taxes and fees on FW treatments, making separate collection of FW mandatory, and imposing different valued-added tax rates depending on the environmental impact of the food items (high rates for meat, dairy products, and

convenience food and low tax rates on fruit and vegetables) (Priefer et al., 2016). Some positive results for similar local policies were shown by the relationship between taxes on landfills and recycling and composting rates for municipal waste (Watkins et al., 2012). Still, Priefer et al. (2016) consider that the impact of taxes is yet to be evaluated. This includes the impact on behavioural changes in industrialised countries, possible protests among citizens and stakeholders, and the impact on FW generation quantities.

## 6. Barriers to research in this topic

The identified barriers preventing FLW reduction include a lack of data, an unclear definition of FLW, a lack of public awareness, undervaluation of the hidden costs of unsustainability, and global negative ecological impacts non-representative of the economic impact of each stakeholder.

The serious lack of data on the subject is considered in the literature as one of the biggest obstacles for scientists in studying this emerging issue and preventing them from tackling the FLW problem. Data are old, non-reliable, and only estimations, or the quality is poor (Parfitt et al., 2010). This issue is such that SDG 12.3 has not yet been quantified (FAO, 2019b). The post-harvest loss data in developing countries might be overestimated, or at least not quantifiable, because data are from 30 years ago. Eurostat provides data on food wastage (generation, recovery, and disposal) every two year, but countries are free to define how to collect data and measure their wastage (Priefer et al., 2016). There are also barriers to data collection. Small enterprises do not have automatic inventory and ordering systems, while big operators fear a loss in reputation if data become publicly available. On the contrary, making programmes to combat FLW generation public can positively impact the reputation of the entrepreneurs (Priefer et al., 2016).

A clear definition of FLW is needed in addition to a standardisation of the methods of data collection and calculation. Separate collection and measurement for each stage of the SC will increase transparency (Priefer et al., 2016).

To improve data collection, the FUSIONS-project was created to establish recommendations for this issue in Europe, and in the United States, the ReFED database is being developed (ReFED, 2016). Other projects for measuring and sharing FLW data are being carried out by Non-Governmental Organisations, governments, and companies in the food sector (Wikström et al., 2018).

Stakeholder pressure from customers and Non-Governmental Organisations, competition and economic concerns, and legislation has led to an increasing interest in the subject, as demonstrated by the growing number of studies in recent years (Bloemhof & Soysal, 2017). A lack of public awareness on the FLW issue leads to less interest in the subject than it would receive otherwise (Section 5.1). This situation is positively evolving with regard to the dynamic of the SDGs. Another barrier that may stop stakeholders from jumping into the subject is that enterprises do not realise the hidden costs that FLW represents. Therefore, the topic is underestimated and not properly taken into account (Section 5.3).

FLW is globally visible but are not necessarily visible at the scale of a single actor within the SC who does not directly suffer from a waste down the SC. In the short term, this also counts for the consumers who pay less by buying high quantities of food and by wasting a part of it (Section 5.5). The complexity of the FLW issue is partly related to the fact that the causes of FLW are numerous and can happen at all stages of the SC (Section 4), and they can be stage dependent or product group dependent, which also depends on the classification choices in the establishment of product groups (Section 3). It is therefore complex to study this issue globally.

## 7. Discussion

While reviewing the literature, we tried to be as neutral as possible to learn about the subject without taking position. Nonetheless, we could identify several strong barriers that could bring difficulties to further study the topic. The research and barriers led us to propose several research axes.

FLW occurs at all stages of the SC and faces a growing concern and amplitude. We identified five possible research directions regarding the lack of knowledge and the foreseen impact of the proposed research on FLW.

The concept of FLW is difficult to measure as scarce data is available and there are no unique definitions or standard measurement procedures. We propose conducting research into achieving standardised, reliable, and up-to-date data collection and defining the concepts of FLW. FL and FW have their own causes and solutions. Separating the concepts of FL and FW in terms of definition, measurement, and action plans could lead to objective and quantifiable improvements in FLW.

We propose analysing the 'awareness of the need' concept in redistribution and the impact of 'in store donation' on the costs and quantities of FW as well as on the image of the store. This could also be a solution to decreasing the complexity of the network design of food redistribution. One could study the benefactors of this solution, whether FW goes to needy people or to regular clients, which has a different ecological and social impact.

Another research direction proposition is to study consumer behaviour through surveys and statistical analyses. For example, the following dimensions could be analysed: the level of awareness of the consumers, their level of acceptance of visual impairments and their motivation for buying 5.4, the behaviour drivers leading to high quantity purchases and the level of consumer acceptance for stock outs 5.5, consumers's motivation for purchasing from alternative channels such as local businesses. This research direction proposition is supported by the three following papers. Stancu et al. (2016) suggest exploring the behavioural determinants of FW at the consumer stage and Richter & Bokelmann (2016) suggest investigating how to raise public awareness and perception of the issue of FLW. Hermsdorf et al. (2017) suggest studying the impact on the consumer at the retail stage by studying the 'consumer's willingness to pay for products with visual impairments' in a retail location.

One could explore the performance of the logistic networks of local businesses in terms of FLW compared to global businesses. Concerning inventory manage-

ment at the retail stage, Lebersorger & Schneider (2014) suggest studying a price reduction policy at the retail level. Bloemhof & Soysal (2017) advise further focusing on redesigning the FSC network to improve its efficiency (time-dependent environmental conditions for improving food quality, process redesign to reduce carbon emissions and energy consumption, and multiple product route optimisation). Along the entire SC, those authors also suggest further focus on reduced packaging in terms of its environmental impact (plastic packaging and recycling rates) and resource efficiency (by-products, shelf life extension, biomass materials conversion into valuable products, and circular economy), while Göbel et al. (2015) suggest further study of relationships and automatism in the FSC to reduce waste generation along the entire FSC.

A last aspect is the role of packaging in FLW and GHG emission reduction. Packaging management can extend the product shelf life and improve transportation, but it consumes resources for packing and storage. Life-cycle assessments could evaluate this research challenge and focus on answering the following questions: To what extent is it sustainable to pack food products? How does the packaging improve the shelf life and reduce FLW? Since packaging also has a cost and an impact on the environment, how can good trade-off decisions be made?

## 8. Conclusion

This literature review attempted to establish a state of the art of FLW system that addresses the UN SDG number 12: sustainable consumption and production. The main findings of this paper are that FLW occurs at all stages of the SC and faces several stage dependent causes. We listed many solutions and classified them into categories (awareness raising, business process redesign, integrated SC models, redistribution, recovery, and disposal). Those solutions can be applied to the food sector to reduce FLW and help move toward more sustainable consumption and production patterns. To further address the 12.3 SDG, five research questions were identified from several gaps in the literature:

a lack of standardised and up-to-date data collection and concept definitions; 'awareness of the need' concept in redistribution; the consumer behaviour related to FLW; the performance of local versus global logistics networks in terms of FLW; and the role of packaging in FLW and GHG emission reduction.

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## 10. List of abbreviations

**FL:** food loss;

**FLW:** food loss and waste;

**FSC:** food supply chain;

**FW:** food waste;

**SDG:** Sustainable Development Goal;

**SC:** supply chain.