

State of the knowledge on Food Waste in the World

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Abstract

Food waste refers to the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers, and consumers. Since the United Nations have made halving food waste a Sustainable Development Goals target, food waste has captured public attention. The Food and Agriculture Organization of the United Nations (FAO) estimates that up to 811 million people were hungry in 2020, and with a staggering 3 billion people that cannot afford a healthy diet (FAO, 2021), therefore the reduction of food waste becomes even more important. By reducing waste, we can improve food availability and food access without increasing agricultural inputs, scarce natural resources, or affecting our environment more. However, waste can only be reduced if we understand its causes. In developed countries they are more related to consumer over consumption behavior and lifestyle, to legislation, to business management and economies setting standards which could by itself end creating big waste. In developing countries, they are linked to inappropriate packaging, unpurchased holiday foods, inadequate storage, and overstocking, mishandling of products by (potential) consumers, and to technology which is not design to minimize waste. Up to today there is very limited evidence of impacts of interventions to reduce waste, and even less on their cost effectiveness. The introduction of technologies, innovative solutions, new working methods, and good practices to manage food quality and reduce food waste are essential to progress on the achievement of SDG 12.3.1 of halving food waste by 2030.

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1. Introduction

Since the United Nations have made halving food waste a Sustainable Development Goals target, food waste has captured the public attention, and its significance to the development community is growing every day. The Food and Agriculture Organization of the United Nations (FAO) estimates up to 811 million people were hungry in 2020, and with a staggering 3 billion people that cannot afford a healthy diet (FAO, 2021), therefore the reduction of and waste becomes of huge relevance and importance. Yet, policies to address food insecurity due to growing populations and changing diets have aimed mainly at increasing agricultural yields and productivity and not to giving priority to the reduction of food waste as a tool to help meet the growing food demand.

By reducing food waste, we can improve food availability and food access without increasing the use of agricultural inputs, scarce natural resources, or improved technologies on the production side. At the same time, will reduce global greenhouse gas emissions. Today, 8 to 10 percent of global greenhouse gas emissions are directly associated to food not consumed (FAO, 2015; Mbow et al., 2019). A study developed by FAO, 2014; explained that if food waste is represented as a country, it would be after USA and China on the top three greenhouse gas emitters.

Recent reports, however, highlight that success stories of decreasing food waste (WRAP, 2009) are not many, and figures on food waste remain highly inconsistent. Thus, while various governmental, research and civil society initiatives have been launched to address this important issue, significant results are yet to be seen.

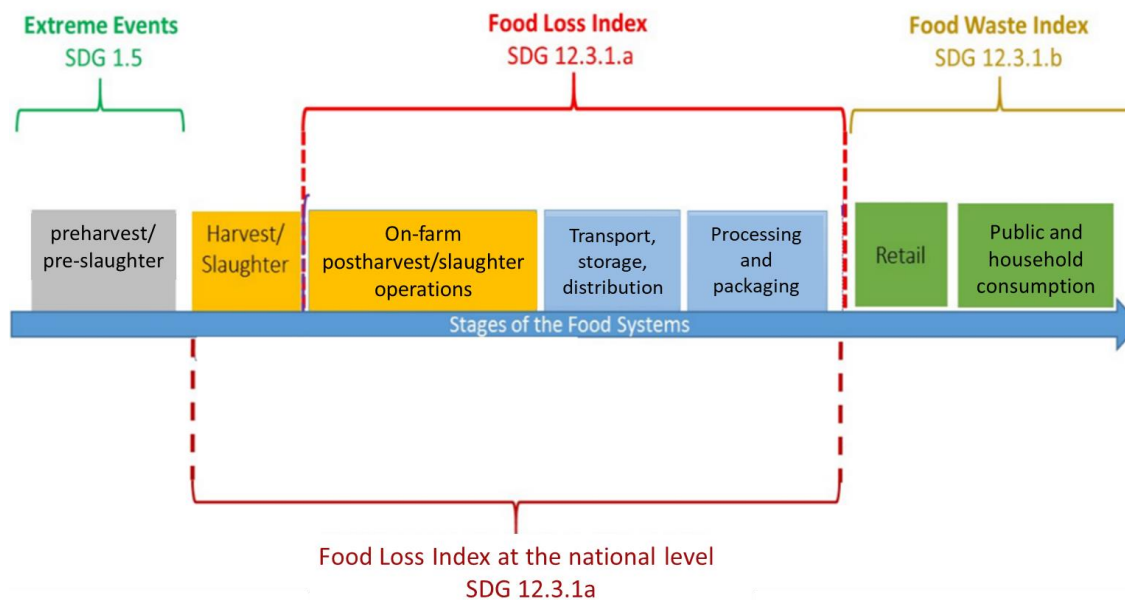
Food waste occurs at different stages from the retail to the consumer (FAO, 2011; HLPE, 2014; Lipinski et al., 2013), and in each step, there are different causes and potential solutions. The distribution of waste along these stages depends on the commodity and the geographical location in question. However, food waste is commonly underlying inefficient, unequal, and unsustainable food systems.

In the last years, there has been an enormous confusion on the definition of food waste and it has normally been mixed with food losses. Delgado et al. (2021) bring some clarity to the differences and the definitions of food loss and food waste given 'Food Loss and Waste' (FLW) had been used interchangeably, but they hardly ever refer consistently to the same concept (Delgado et al., 2021). FW refers to food that is fit for human consumption but is deliberately discarded and is most common at the end of the value chain, at the retail and household level.³ There is an official definition used to monitor progress towards the SDGs. SDG 12.3.1 defines losses from on-farm post-harvest up to processing and packaging, including wholesale. Food waste happens at the retail and household levels (Figure 1). Food waste is defined as the food (this includes drinks and any substance that has been used in the preparation of food) and the associated inedible parts removed from the human food supply chain during retail, foodservice and/ or households.

³ Bellemare et al. (2017) use the food life cycle approach (which includes- grower, processor, retailer, and consumer) to give a new and contrasting definition of food waste. According to this definition, food waste is the "difference between the amount of food produced and the sum of all food employed in any kind of productive use, whether it is food or non-food." Based on a simple theoretical relationship and numerical examples, the authors explain that food waste's quantity and value are overstated by other definitions of FAO, EPA, ERS, and FUSIONS.

Therefore, food waste includes both edible and inedible parts. The reduction is good for people and the planet because it improves food security, addresses climate change, saves money, and reduces pressure on land, water, and biodiversity (UNEP, 2021).

Figure 1: Scope of the food loss index along the food supply chain



Source: FAO (2019).

2. How food waste has been measured

Most of the estimations of global food waste have relied on the extrapolation of data from some countries (data which is in many cases outdated). Still, there are some exceptions where governments have robust and detailed data on food waste. Global food waste data availability is low, and measurement approaches have been highly variable (UNEP, 2021). Figure 2 shows the prevalence of studies addressing food waste at different value chain stages. We find that the distribution of papers studying food waste are mostly focused on retail and hospitality, followed by studies at the household level, similar to what was found by Amicarelli et al., 2021. On the other hand, there is not enough evidence to be able to split the papers between developed and developing countries. In the case of the later, the evidence is extremely limited.

In 2011, a report made by FAO estimated that around one-third of the food produced globally was lost or wasted without differentiating how much was loss and how much was waste. This is equivalent to a total of 1.3 billion tons of food lost or wasted per year (Gustavsson et al., 2011). Each year, 670 million tons (Mt) of food is discarded in developed countries, and less than 630 Mt is discarded in developing countries. Between regions of the world, North America and Oceania waste more than 110 kg/capita at final consumption yearly, but sub-Saharan Africa wastes less than 10 kg/ capita/year, and the European Union waste approximately 130 Mt/per year (Amicarelli et al., 2021). The carbon and water footprint of this FLW is estimated to be 4.4 gigatons (Segrè et al., 2014). Stenmarck et al., 2016, estimated that 47 million tons of food waste arise from households.

In a review done by Amicarelli et al., 2021; which analyses 58 articles; it was found similar to our analysis of Figure 2 that most of the food waste measurements are at the household level (45%) and at the hospitality industry (26%); this includes school and university canteens, hotels, hospitals, restaurants, and elderly care homes. In these articles, 43% applied questionnaires and surveys; 37% did direct measurements (garbage streams or plate waste), and 19% did diaries.

Figure 2: Heat map of papers studying food waste



Source: Author's elaboration based on topical filtration of the literature from FAO FLW database. **Note:** Topical filters for the data were created for two categories: The main themes (Agricultural production, Income, Natural Resources/Environment, Food Safety/Nutrition) and their respective sub-themes (Production practices: Soil, pests and inputs; Socio-economic characteristics of the farmer; Storage and transport; Mechanization and technology; Climatic condition; Marketing, infrastructure overstocking; Behavioral, social practices). From the FAO FLW database, 530 articles were relevant to the study. A separate search was done on external websites to harvest more articles starting from 2010. A total of 832 articles relevant for the study were retained, with some overlaps between the topics.

A report by Møller, et al., 2014 and Amicarelli et al., 2021; explore the different methodologies used to quantify food waste over time. They identified eight ways in which food waste information is collected:

- Direct measurement and scanning:* There are two ways of measuring food waste directly: Weighting or volume (rarely used). This type of measurement is mostly used in food services like schools and restaurants, daycares, hospitals, etc. It is also used in retail and the market to register the value or mass of waste flows. It includes the food that was sorted out and discarded due to past their best-before, or use-by date or quality is too bad.
- Waste composition analysis:* It includes weighing and analyzing the different fractions of the food waste regarding types of a food product or edible/inedible fractions etc. Waste composition analysis measured food waste for short or longer times and different levels of detail. This method applies to food services and households.
- Mass- and energy balances:* This is a way of structuring data from different sources and not a data source. It can calculate food waste by using data for raw material input and produced amount.

- d) *Questionnaires*: It is a formal, structured way to collect respondents' quantitative and/or qualitative data. This methodology is used when a contact person is available and has been widely used in food processing companies in Norway and Swiss.
- e) *Food waste diary*: This method is implemented by one or more members of the household who weigh the food waste and make notes on quantity, type, and cause. This methodology allows identifying quantities, sources, and reasons for disposal.
- f) *Interviews*: This can also be conducted face-to-face or over the telephone. This methodology is used to fill data gaps or to have both a quantitative and qualitative estimation of food waste. It has been used in manufacturing companies, retail markets, the hospitality sector, and households in Europe.
- g) *Calculation methods from statistical data*: This methodology uses the statistical data from authorities or waste management companies representing a data source.
- h) *Combination of methods*: Most studies often use combinations of different methods. Economic or production statistics can be used to overview the sector and total turnover as a starting point for identifying sample units, whether surveys, questionnaires or waste audits are used.

Table 1 present the pros and cons for each of the studies that use these eight methods.

In 2021, UNEP following the Food Loss Index developed by FAO developed the Food Waste Index as a three-level methodology to increase the accuracy and usefulness of food waste measurement. The first level uses modeling and extrapolation to estimate FW and approximate estimations. However, these are not suitable for tracking purposes. The second level is the recommended approach because it involves direct measurement and is sufficiently accurate for tracking. The third level provides additional information on policy and other interventions to support the FW prevention strategy.

Although the progress of UNEP on the Food Loss Index, it is still important to continue improving this work to avoid overestimating food waste because of the inclusion of some elements of food loss as defined in Figure 1.

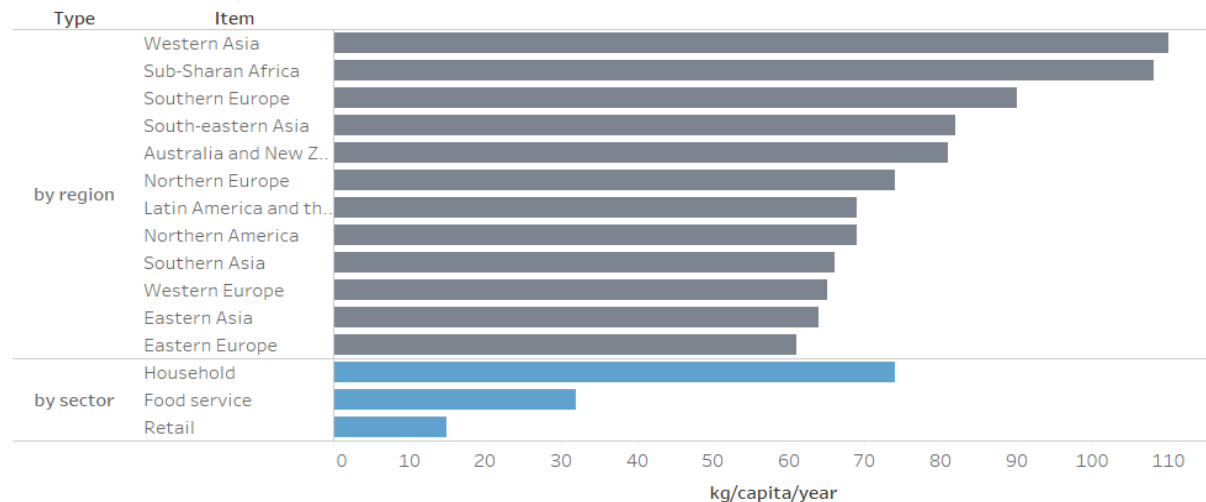
3. What we know about the magnitude of food waste

The measurement of the quantity and value of food waste remains a contentious issue (Bellemare et al., 2017). However, to tackle the problem of food waste is very important to define a methodology for food waste quantification to monitor progress towards the achievement of reduction targets (Corrado et al., 2019)

In 2021, UNEP developed the first food waste index report to provide insights into the magnitude of food waste and a methodology to measure the baselines for countries and track the progress to accomplish the SDG 12.3.2 target. It was estimated that the food waste from households, retail, and the foodservice industry was 931 million tons in 2019, where 61 percent occurred at the household level, 26 percent occurred at the foodservice, and 13 percent were from retail. This means that 17 percent of total global food production is wasted. Estimations of food waste from the FWI (Figure 3) range from 61 kg/capita/year in Eastern Europe to 110 kg/capita/year in Western Asia. And from 15 kg/capita/year at the retail level to 74 kg/capita/year at the household level (UNEP, 2021), suggesting that any action to

reduce FW is equally relevant in high, upper-middle, and lower-middle-income countries. This calculation seems to be more than twice the previous estimation made by Gustavsson et al., 2011.

Figure 3. Estimates of Food Waste by region and sector



Source: Author's elaboration, based on UNEP (2021)

Yu et al. (2020) estimate that the average household wastes 31.9% of the food bought in the US. Principato, 2018; shows that in a study by BIO Intelligence Service, 2010; 42 % of all food produced in Europe gets lost at the consumption level; this means 88 million tonnes of food is wasted every year approximately. Finally, Coldiretti (2017); shows that 54% of food is wasted in the households in Italy, and 21 % is wasted in restaurants.

When excluding loss at the agricultural production level, Monier et al. (2010) arrive at an estimate of an annual average of 89 million tons of waste (179 kg per capita) along different stages of the food value chain for 27 EU member states. WRAP (2010) finds that 18.4 million tons of total food and drink are wasted annually across processing, distribution, and consumption stages in the UK, where households are responsible for the largest share, wasting 22% of their purchases.

As clearly shown, there are still important differences in food waste measurement. There is a clear need to standardize the methodologies and make them consistent across countries as the effort started by UNEP. Finally, it is also important not only to measure the total magnitude of waste but also to identify where the major hotspots of food waste are and the causes and determinants.

Table 1: Methodologies used to quantify food waste

Method	Description	Pros	Cons	Studies
Direct measurement and scanning	Two ways: Weighting or volume. Volume is rarely used. Used in food services like schools and restaurants, day cares, hospitals etc. Used in retail and market to register the value or mass of waste flows. Food that was sorted out and discarded due to pass their best-before or use-by date or quality is too bad.	*Primary data collected directly from relevant companies. *If the scanning has bar codes it will turn easy for traceability	*Costly and time intensive *Large number of measuring points are necessary. *Only suited for parts in the supply chain in which the product is packed	Engström & Carlsson-Kanyama, 2004; Silvennoinen et al., 2012; Hanssen & Schakenda, 2010/2011; Eriksson, 2012; Costello et al., 2015; Brancoli et al., 2017; Eriksson et al., 2017; Boschini et al., 2018; Beretta and Hellweg 2019; Giboreau et al., 2019; Khalid et al., 2019; Pflugh Prescott et al., 2019
Waste composition analysis	Studies where the components of the different fractions of the food waste are weighed and analyzed with regards to types of food product or edible/inedible fractions etc. Waste composition analysis can be used for measuring food waste for short or longer times and for different levels of detail. This method applies to food service and households.	* Provides a direct weighing of food waste, and is used where the number of waste points is large	*One of the important issues is to find the right sample size and representative samples	WRAP, 2011a; WRAP, 2011f; Lebersorger & Schneider, 2011; Hanssen et al., 2016; Rajan et al., 2017; Delley and Brunner 2018; Elimelech et al., 2018; van del Werf et al., 2018; van Dooren et al., 2019;
Mass- and energy balances	Mass balance is a way of structuring data from other sources, and not a data source in itself. It can be used to calculate food waste by using data from raw material input and the produced amount	* Representative for large region and good comparability * Cheap and straightforward implementation	The calculation is demanding in having available representative and good quality data on food waste percentages per tonne of food produced or tonne of total waste generated	FAO, 2011; Gustavsson et al., 2013; Beretta et al., 2013; Pirani and Arafat 2016; Caldeira et al., 2019; Amicarelli et al., 2021
Questionnaires	a formal, structured way to collect quantitative and/or qualitative data from respondents.	* Used as a structured way of getting figures for food waste and in some cases also additional information	is difficult to get a large enough proportion of responses and it imposes a major responsibility on the contact person to provide reliable data.	Hanssen & Schakenda, 2010/2011; Marthinsen et al., 2012; Beretta et al., 2013; Brunner and Rechberger, 2017; Wang et al., 2017; Zaghdaoui et al., 2017; van Herpen et al., 2019; Pflugh Prescott et al., 2019; Eriksson et al., 2020; van Dooren et al., 2020; Kasza et al., 2020

Method	Description	Pros	Cons	Studies
Food waste diary	A food waste diary is implemented by one or more of the households' members who weighs the food waste and makes notes on quantity, type and cause.	* Can compile both qualitative and/or quantitative data from households and enable researchers to determine quantities, disposal routes (what is poured into the kitchen sink, home composted, or fed to animals) and reasons for disposal.*it can give more insight and valuable data with a great level of detail from day to day, waste categories and the reason for disposal of the waste.	* Costly and time-consuming* Need precise and reliable data*Only can be used for short sampling periods and for selected areas with small sample sizes.	Katajajuuri et al., 2012; Silvennoinen et al., 2014; Richter and Bokelmann 2017; Delley and Brunner 2018; Giordano et al., 2018; Ilakovac et al., 2020; Moreno et al., 2020; Qusted et al., 2020
Interviews	An interview can also be conducted by using a questionnaire face-to-face or over the telephone. Interviews are often used in combination with other approaches in order fill data gaps or to have both a quantitative (amount) and qualitative (how often is food wasted, who is wasting food etc.) estimation of food waste.	* Can give best estimates or expert judgment of how much food is wasted within a given part of the food chain * Can also be conducted by using a questionnaire face-to-face or over the telephone.	The response rate might be low	Gunnerfalk, 2006; Mejdahl et al., 2011; Pirani and Arafat 2016; Amato and Musella 2017; Chakona and Shackleton 2017; Hartikainen et al., 2018; Baker et al., 2019; Djekic et al., 2019; Wesana et al., 2019
Calculation methods from statistical data (topdown)	Statistical data from authorities or waste management companies represents a data source, which can be used as a top-down method for calculation of food waste.	* Databases can provide large amounts of data collected in a similar way, which will increase comparability. * Data may generally be of good quality	The data quality depends on the methods used for collecting the data in the national or regional databases.	Monier et al.,2010; FAO, 2011; Almeida, 2011; Venkat et al., 2012
Combination of methods	Studies often use combinations of different methods. Economic or production statistics can be used to get an overview of the sector and total turnover as a starting point for identifying sample units, whether surveys, questionnaires, or waste audits are used.			C-tech Innovation, 2004; Hanssen & Schakenda, 2010/2011; Hartikainen et al., 2018; Beretta and Hellweg, 2019; Giordano et al., 2019; Pflugh Prescott et al., 2019

Source: Authors' elaboration

4. Causes and determinants

Identifying the causes of food waste (FW) is key to identifying solutions to reduce FW and defining priorities for action. The identification of causes calls for an integrated value-chain approach, where the different stages of the value chain are not seen in isolation but as part of a system. To reduce food waste successfully is necessary to have a clear understanding of the factors influencing food waste-related consumer perceptions and behaviors (Aschemann-Witzel et al., 2015)

Blakeney (2019) identifies that the causes of food waste are complex and interlinked and are different between industrialized and developing countries. In a study on food waste conducted by Canali et al. (2014) on the European Economic Area and described by Blakeney (2019), it was found that of the 105 factors identified as causes of food waste, 15% were related to consumer behavior and lifestyle, 22% were related to legislation, 36% were related to business management and economics, and 27% to technology.

Morland, 2014; stated that food waste most happens in developed countries and these countries during wholesale and retail because the market concentration in food distribution allows them to decide what to offer and discard

The wholesale and retail sector, particularly in developed countries, is said to serve as the gatekeeper to the food system (Elg & Hultman, 2011) but waste is still extremely important in that sectors. The market concentration at this stage allows distributing companies to set the standards of food to be offered for sale (Morland et al., 2014) but this does not necessarily go in the needed direction. At this stage 'ugly' food is discarded (Burt & Sparks, 2003; Monier et al., 2010; Halloran et al., 2014), and expiry dates are set (Lebersorger & Schneider, 2014; Gruber et al., 2016). Therefore, it is needed for governments and regulatory agencies to look in detail at these sectors and try to understand how to compensate for the abuse of market power in setting standards.

At the level of value chain infrastructure, Buzby et al. (2014) identify inappropriate packaging, unpurchased holiday foods, inadequate storage, and overstocking as potential causes for losses. At the retail level, waste is mainly caused by the mishandling of products by (potential) consumers.

Food waste in the hospitality sector (including restaurants, staff canteens, and cafeterias at school and hospitals) is fast becoming a key concern in both developed and developing countries (Dhir et al., 2020). Its contribution to total food waste has been recently estimated to be nearly 12% (Tostivint et al., 2016). Key causes identified for the loss are the nature of the food menu, the use of prepared versus whole food products, the production procedure, portion size, as well as the skills of employees. Gössling et al., (2011) and Murphy et al., (2018) studied waste in tourism specifically. They found that people tend to overconsume, especially at buffets.

With regard to household consumption, most studies focus on developed countries. In developed countries, most factors are behavioral. Some specific behaviors such as not planning meals, throwing away food that is past its expiry date or being reluctant to eat leftovers have been identified as contributing to household food waste (Parfitt et al., 2010; Graham-Rowe et al., 2014). The literature has extensively studied different aspects on household waste. The aspect analyzed range from aesthetic preferences (e.g.,

de Hooge et al., 2017; Loebnitz et al., 2015 and Aschemann-Witzel et al., 2017); to uncertainty about health risks (e.g. Cox & Downing, 2007; de Jonge et al., 2007 and Watson & Meah, 2013) and the confusion about date labeling (e.g. Woodburn & Van Garde, 1987; Kantor et al., 1997; Miles & Frewer, 2001; Tsiros & Heilman, 2005; Wansink & Wright, 2006; Theotokis et al., 2012; van Boxtael et al., 2014; Newsome et al., 2014; Wilson et al., 2017).

5. Interventions

Cattaneo et al., 2021, found that reducing food loss and waste always improves the efficient use of resources like land, water and reduces greenhouse gasses (GHG). However, reducing waste at the consumer level is more effective in reducing emissions.

Many interventions have been designed to minimize food waste at the local, regional, and global levels. Governments and authorities around the globe are introducing regulatory and economic measures to eliminate food waste at the household level (Chalak et al., 2016). Table 2 shows some of the strategies used to reduce food waste. Most of these interventions require funding to be implemented, and jointly working between governments, the private sector, and individuals are crucial to deal with the food waste problem.

In an environment of constant shelf replenishment, retail, and hospitality, foods that reach the "sell-by date" are easily discarded (Stuart, 2009). To avoid this is helpful to remove duplicate products or label products according to their maturity level (Lebersorger & Schneider, 2014). Other options include the elaboration of sub-products (Calvo-Porral et al., 2017).

At the level of value chain infrastructure, Buzby et al. (2014) found that initiatives or newly adopted processes (packaging or storage technologies) could reduce food waste generation. Kotzab & Teller (2005) compare different instore logistics processes within a retail outlet and find that a more efficient return, disposal, recycling, and redistribution process can lead to waste reduction while at the same time supporting charitable institutions. At the hospitality level, Pirani & Arafat (2014) calculate the carbon and water footprints of the event food waste and find that waste from serving dishes tends to be the greatest component of event food waste.

For behavioral social practices (at households), most of the household waste is related to the behavior. In a comprehensive literature review made by Blakeney (2019), he identified that the careful planning of grocery shopping (by using list, inventories, and meal plans) would minimize overbuying (Mallinson et al., 2016; Stancu et al., 2016). Organized food storage by date of purchase can also reduce food waste (Farr-Wharton et al., 2014), while refrigeration or freezing could reduce waste by half (Martindale, 2017). Leftovers are considered the most effective way to reduce FW at the household level.

Table 2: Strategies to reduce Food Waste

Variable	Remedial action	Initiatives	proposals
Marketing	Product choice	Eliminate duplicate food products	Lebersorger & Schneider, 2014
		Offering different levels of ripeness: 'ready to eat vs. ripen at home'	Lebersorger & Schneider, 2014
	Revised food product standards	'ugly' food movement'	Calvo-Porrall et al., 2017
	Price reductions	For food products close to the expiration date	Halloran et al., 2014
		For food products with visual flaws	Lebersorger and Schneider, 2014
	Sale promotions	Cutting back multi-buy promotions	Halloran et al., 2014
		Removing discounts on bulk purchases	Halloran et al., 2014
Food Distribution	Development of new promotion offers	'Buy One, Get One Later'	Calvo-Porrall et al., 2017
		Feeding America	Schneider, 2013
		'Rock and Wrap it up' (US)	Segrè & Gaiani, 2012
	Food banks	Fare Share association (UK)	Segrè & Gaiani, 2012
		Reduce number of courses	Pirani & Arafat, 2014
Hospitality sector	Industry Guidelines		HOTREC (2017)
	Industry campaigns	'No Food to Waste' campaign (Flanders)	
		'Partnership on Less Food Waste' (Denmark)	
		United Against Waste' (Germany)	
	Non-profit		Cordingley et al., 2011
	Institutional Initiatives	School education	Dehghan et al., 2005; Adams et al., 2012; Redman & Redman, 2014
		Food waste auditing	Marlette et al., 2005; Byker et al., 2014; Falasconi et al., 2015; Derqui & Fernandez, 2017

Variable	Remedial action	Initiatives	proposals
Hospitality sector	Institutional Initiatives	Higher educational institutions	Thiagarajah & Getty, 2013; Lazell, 2016
		Hospitals	Sonnino & McWilliam, 2011; Goonan et al., 2014; Chardoul & Coddington, 2012; Cohen et al., 2014; Levin, 2017
	Modifying catering practices	Discontinuing 'All-you-can-eat' restaurants	Lipinski et al., 2013
		Reduced portions	Halloran et al., 2014
		Small serving plates	Betz et al., 2015
	Modifying Behaviours	Social Innovation	FUSIONS 2016
		Modifying shopping behaviours	Parfitt et al., 2010; Graham-Rowe et al., 2014
Conversion of food wastes	Awareness Raising	UN Secretary-General's Zero Hunger Challenge	HLPE, 2014
		Waste and Resources Action Programme (WRAP) Love Food Hate Waste (LFHW) campaign	
		Food Waste Challenge (USA)	
		'Empty Plate' Campaign (China)	
		'Half-bowl' Campaign (Republic of Korea)	
		'Stop Wasting Food' Campaign (Denmark)	
		Fermentation	Kim et al., 2011
		Anaerobic digestion	McKendry, 2002
		Incineration	Autret et al., 2007
		Hydrothermal carbonization	Ren et al., 2006; Kaushik et al., 2014

Source: Based on table 7.1 from Blakeney, 2019

Reynolds et al. (2019) review the effectiveness of interventions to prevent food waste at the consumption stages of the food system. The interventions studied were categorized into a) Information-based interventions; where information was provided to change the behavior of a target group; b) Technological solutions; where new technology or serving was introduced; and c) Policy/system/practice change; where policies or systems are altered, and the population changes food waste behaviors. They found that changing the type or size of plates had a 57% effectiveness in reducing food waste in hospital settings. In schools, both the change of nutritional guidelines and information campaigns reduce the vegetable waste to up to 28%. All other interventions were reported as effective but with little or no robust evidence.

Both Reynolds et al. (2019) and Aramyan et al. (2020) find that different types of innovations have a high potential in reducing and preventing FW along the supply chain. Yet, information on their cost-effectiveness and economic feasibility are still largely missing, making scale-up and policy makers' adoption difficult.

6. Conclusions

Food waste is not acceptable in a world where more than eight hundred million people are hungry and where GHG have to be reduced. When food is wasted, all the resources that were used to produce this food - including water, land, energy, labor, and capital - go to waste. In addition, the disposal of food waste in landfills leads to greenhouse gas emissions, contributing to climate change. Food waste can also negatively impact food security and food availability and increase the cost of food.

The causes of food waste are complex and interlinked and are different between industrialized and developing countries. The normal causes are related to consumer behavior and lifestyle, related to legislation, related to business management and economies setting standards which could by itself end creating big waste, inappropriate packaging, unpurchased holiday foods, inadequate storage, and overstocking, mishandling of products by (potential) consumers, and to technology which is not designed to minimize waste. In addition, there is a need to research the relationship between market concentration in the retail sector and standards-setting which are not guided by the need of reduction of food waste but on the contrary to increase market power.

Food waste in the hospitality sector (including restaurants, staff canteens and cafeterias at school and hospitals) is also a major concern both developed and developing countries defined by the way it is managed, portion sizes, technology used and skills of workers.

With regard to household consumption, most studies focus on developed countries and on behavioral issues as diets, not storing food not consumed, aesthetic preferences, mismanagement of labelling, health risks, overstocking within others.

In summary, our food systems cannot be resilient if they are not sustainable, hence the need to focus on adopting integrated approaches designed to reduce food waste. Actions are required globally and locally to maximize the use of the food we produce. The introduction of technologies, innovative solutions (including e-commerce platforms for marketing, extending the shelf life of products, policies and regulations to optimize the use of our food and behavioral change of consumers), new working methods, and good practices to manage food quality and reduce food waste are essential to implementing this transformative change.

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