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Review

A critical review on food loss and waste quantification approaches: Is there a need to develop alternatives beyond the currently widespread pathways?

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ABSTRACT

In a context of increasing concern regarding food loss and waste (FLW) generation, different attempts have been made to standardize quantification methodologies. On the one hand, an important number of small-scale studies have been published that constitute direct measurement methodologies. On the other hand, the FAO Food Balance Sheets, which aggregate some of the prior studies, provides an indirect metric that has been applied using FLW coefficients in numerous food-related studies. However, to date, no standard methodology has been agreed upon to quantify FLW. This study performs an assessment of 237 studies in the field, aiming to identify existing FLW quantification methodologies, and if there is a need of developing alternative paths. Firstly, a descriptive review was performed. Secondly, an assessment of critical point of views was presented. For this, different critical voices in the scientific literature were retrieved, some of which highlight the high level of uncertainty and a certain degree of opacity in some of the most widespread FLW quantification and assessment reports. In this line, essential elements of quantification are being omitted. Moreover, the focus is being excessively placed on the role of the consumer, compared to the role played by agribusiness and large distribution chains.

1. Introduction

1.1. Evolution of food loss and waste (FLW) studies

The generation of food loss and waste (FLW) has become an increasing concern worldwide (Vázquez-Rowe et al., 2020), accelerating in the last decade since the publication by FAO of two reports on global FLW, one for medium and high income countries and another for low-income countries (FAO, 2011; FAO, 2013). The main purpose of these reports was to provide a scientifically-informed basis for the international conference named "Save Food!" in May 2011. The event resulted in the first global campaign aiming at raising awareness on global FLW, as well as on the impact of FLW on worldwide problems, such as poverty, hunger, climate change and the extraction of natural resources. Thereafter, discussion on this problem became mainstream at a social, scientific and governmental level, and an increasing number of studies emerged on the issue with all kind of approaches to quantify and assess FLW generation (Corrado and Sala, 2018). As a key reference, the first global estimation of FLW generation presented by FAO (FAO, 2011) has been widely used in the scientific literature, highlighting that a third of all food produced worldwide is being lost or wasted, which roughly translates into an annual generation of 1.3 billion metric tons of organic waste alone.

Shortly after, Kummu et al. (2012) estimated the nutritional energy lost worldwide, equivalent to feeding approximately 1.9 billion people. With appropriate policy interventions, around 50% of this loss could have been prevented. The adoption of the Sustainable Development Goals (SDG) Agenda in 2015 at a global level (UN, 2015), and more specifically SDG 12.3, aiming to halve food waste and to reduce food loss by 2030, has been highlighted as another important milestone that triggered a surge in scientific studies linked to FLW (Spang et al., 2019). At a European level, the Fusions Project estimated an annual generation of 88 million metric tons and 143 billion euros of FLW, representing approximately 20% of total food production (Stenmarck et al., 2016). In the same line, for the past decade, national or regional studies have multiplied, such as Griffin et al. (2009) focused on the USA, Nahman and

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Lange (2013) in South Africa, Reynolds et al. (2016) in New Zealand, or García-Herrero et al. (2018) in Spain.

1.2. Definition and quantification of FLW

FLW estimations, however, have been considered by several critical voices in the scientific community as conservative (Montagut and Gascón, 2014). Consequently, the total amount of FLW may be higher than current estimations based on the loss ratios presented and recommended by the FAO methodology in 2011, where a distinction between edible and non-edible food is performed. Moreover, it should be noted that certain fractions can be considered edible or non-edible for different reasons such as cultural differences, or potential health risks, as is the case of the possible presence of agrochemicals in the skin of apples from conventional agricultural production (Mladenova and Shtereva, 2009). Moreover, a differentiation between food loss, in the early stages of the food supply chain (FSC) and food waste generation, in the later stages of the FSC, is also promoted (as explained in Fig. 1). Concerning food loss generation, which includes agricultural production, post-harvest and processing and packaging, the loss of animal and plant fractions that are non-edible or not originally intended to be used for direct human consumption, are not being computed as FLW, despite the associated implications in terms of food security and nutrition, as well as related environmental impacts (FAO, 2019). In addition, other FLW issues that are not being considered in statistics are the removal of food to maintain market prices (Thorsen et al., 2022), overproduction to ensure the sales required by the industry (Herzberg et al., 2022), losses due to excessively strict hygienic and sanitary regulations (Gascón et al., 2021), food removed due to the damage caused by endemic and recently emerging plant diseases and certain pests (Ristaino et al., 2021), or food loss generation as a response of not meeting the standardized size, shape or visual appearance that demand (Van Giesen and Hooge, 2019). Hence, it appears as if the FAO definition (2011) of FLW quantification is prone to a series of subjective methodological interpretations that could lead to its over- or underestimation. In this line, in 2014 the EU Fusions project introduced a definition of FLW that included aspects of the phenomenon not considered by FAO (Gascón et al., 2022), such as food liquid waste, fish discards or some non-edible food stuffs with potential for economic added value, namely compost or biofuel (Östergren et al., 2014). As a response, FAO modified its 2011 definition by excluding fractions such as sugar, honey, salt, coffee, cocoa or alcoholic beverages, considering them irrelevant foodstuffs for food security (FAO, 2014). Moreover, other public institutions and authors have provided their own definitional framework of FLW, as in the case of the Economic Research Service of the US Department of Agriculture states, considering only edible parts of food stuffs as FLW (Buzby et al., 2014).

In the midst of this uncertainty where there is no general agreement on what should be considered within the concept of FLW, transparent and accessible databases are lacking, as the data collection mechanisms are highly limited and expensive, especially when developing studies with a national or a global approach. Moreover, when data are available, the quantification is still challenging, leading to databases that are not always comparable and transparent in relation to the FLW fractions included (Östergren et al., 2014). As a result, there are different measurement calculation mechanisms, based on diverse databases with different methodological assumptions, which include, but are not limited to: i) the computation of different stages of the FSC within system boundaries or the partitioning of the FSC in different stages; ii) the inclusion of edible/non-edible food fractions; or, iii) the accountability of end-of-life treatment or final destination of FLW (Parfitt et al., 2010). These methodological differences complicate the process of making comparisons and gathering data (Stuart, 2009), as well as hamper the solutions needed to combat the challenges linked to FLW management.

An additional source of misguidance in the FLW quantification process is the fact that the definition of FLW suggested by FAO only accounts for the problem in terms of edible mass. In fact, FAO (2014) defined food loss as the reduction in the quantity or quality in edible food mass, intended exclusively for human consumption, that occurs in the primary stages of a given supply chain (e.g., production, postharvest and processing stages). In contrast, food waste was considered as the discarded fraction of food occurring at the end of the FSC (e.g., retail and final consumption – related to retailers ́ and consumers ́ behavior). However, several studies have introduced different or complementary approaches considering nutritional energy (Kummu et al. 2012; Aldaco et al. 2020; Abbade, 2020) or embedded primary energy loss quantification (OECD, 2017; Hoehn et al., 2019), as the most suitable measure to address the problem. In fact, FAO has recently suggested the possibility of changing the measurement from mass to monetary units (FAO, 2019). In this context, it is important to note that a first definition of FLW dates back to 1943, when Kling included nutritional loss and non-edible FLW quantification concepts in the definition: "food waste is a less than maximum use of nutrients for human consumption (…) food waste is the destruction or deterioration of food or the use of crops, livestock and livestock products in ways which return relatively little human food value" (Kling, 1943).

In this framework, at any research level, and regardless of the

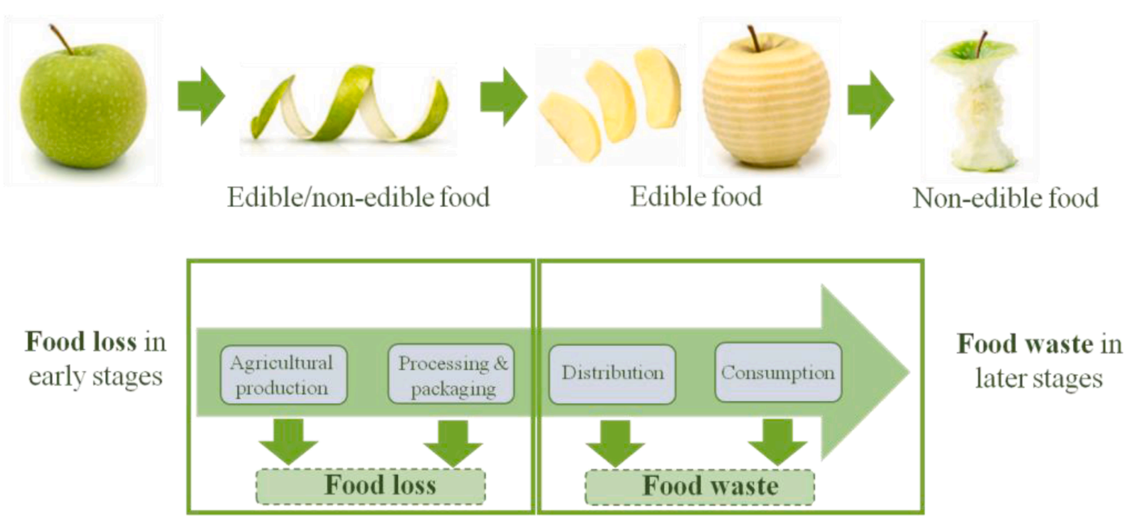

Fig. 1. Representation of the edible and non-edible fractions of an apple as a way to depict the distinction of food loss and food waste (FLW) according to the FAO definition (2011). The concept "non-edible" refers to the parts of the food item that are socially considered inedible. Inorganic materials linked to the packaging are not considered within the definition scope.

approach, there does not seem to exist a consensus or at least a universally accepted definition of what FLW is. In fact, a debate has flourished on how to establish a standardized quantification method in which all researchers seem to agree only on the fact that metrics to calculate FLW should be improved significantly. It is argued, on the one hand, that potentially inflated estimations (Koester, 2013) could be presenting an overstatement of the problem (Bellemare et al., 2017). On the other hand, opposing views stress the importance of further studies to adequately discuss FLW (Chaboud and Daviron, 2017). In this line, the United Nations Environment Programme (UNEP) published the Food Waste Index Report (UNEP, 2021), in which the results obtained suggest that previous estimates of consumer food waste had been significantly underestimated. More specifically, the report states that food waste generation at a consumer level (i.e., household and food service) appears to be more than twice that calculated in the previous FAO estimate of 2011. In any case, it is important to consider that data provided in some studies constitute only approximations (Hoehn et al., 2020), and there is a current lack of a robust methodology to assess the volumes of FLW that are actually being generated in reality.

Scientific consensus exists, in contrast, on the fact that FLW generation is a wide-ranging phenomenon that must be tackled from a comprehensive perspective (García-Herrero et al., 2018). However, although it is undoubtedly a complex issue that affects multiple agents along the whole FSC (Díaz-Ruiz et al., 2018), a highly extended vision in the literature links the problem with consumption habits and preferences (FAO, 2011), as well as to societal trends such as growing affluence, rising number of single households (Monier et al., 2010), increasing employment of women (Priefer et al., 2016), or more recently societal behavior during lockdowns (Aldaco et al., 2020). Moreover, some authors, however, have alerted about the need of improving technological innovation in the system to reduce FLW, and certain logistical inefficiencies of the FSC (e.g., in cold chains or storage facilities) are also highlighted as some of the main reasons behind FLW generation (Parfitt et al., 2010; Soysal et al., 2012). In this framework, multiple initiatives and campaigns concerning the FLW generation problematic have been promoted in recent years. Most of these have focused on the reduction of FLW generated in households or in the services sector through improving consumer behavior, the efficiency of resource use at production and processing levels, the promotion of food donations, and innovative ways to add value to food surplus and FLW (Montagut and Gascón, 2014). As illustrated in Hoehn et al. (2020), some examples of these programs include "More Food, Less Waste" in Spain (2013), "Love Food, Hate Waste" from the Waste & Resources Action Program (WRAP) in the UK (2013), the Milan Protocol promoted by the Barilla Foundation for Food and Nutrition in Italy (2014), or more recently, the Farm to Fork strategy of the European Union (EC, 2020).

As a response to the widespread techno-optimistic view, critical voices suggest that reality does not adjust to the generalized assumption of a need of improving technological innovation: since the 1980s, investment in agricultural innovation and development has increasingly grown, and in parallel, food loss has continued increasing (Gascón et al., 2021). Consequently, instead of focusing on looking for innovations in the FSC and its logistics, it has been highlighted to address the problem as a response of the industrial agri-food system, and its operating logics (Contreras and Verthein, 2018), as well as the marketing standards requested by the retail sector (Göbel et al., 2015).

1.3. Main objective of the review

In order to contribute to the ongoing debate described above, the aim of this critical review is to analyze the scientific studies that have been developed in the field of FLW generation to understand how FLW definition and quantification should be steered in the near future in order to obtain a deeper understanding of this complex phenomenon and the existing challenges. All of this, in a context in which the lack of a standard methodology in quantifying FLW had led researchers to employ numerous methods that would generate incomparable results (Withanage et al., 2021), and with the objective of including existing points of view, from those that are most mainstream to those that are currently more marginal. For this, three different searches in the scientific database selected (i.e., Scopus) were performed. Additionally, other articles, reports and books in the field, found mainly in the bibliography of the studies previously selected, were added to the assessment.

In summary, two key questions were analyzed:

1 Descriptive review: Which methodologies have been developed for measuring FLW generation in the scientific literature?
2 Critical review: Is there a need for developing alternative pathways beyond the currently widespread methodologies of FLW quantification and assessment approaches?

2. Material and methods

2.1. Literature search strategy and inclusion criteria

Scopus was the main search engine used for the collection of scientific literature in the assessment. In order to implement a complete follow through of all the studies registered around the topic analyzed until November 2021, a first round of searching, using the keywords "*food", "waste", "generation*" and the connector "*and*" was done. Out of the 3,548 documents found in Scopus, 98 documents were initially selected, in which the keywords coincided with topics related to FLW assessment or quantification. A second search was performed, using the keywords "*food", "waste", "quantification*", were 29 documents were selected from 615 papers found. Finally, a third round was carried out in Scopus, using the keywords "*food", "waste", "generation", "quantification*", were 61 additional studies were added for the review assessment. In total, adding the three searches in Scopus, 188 articles were selected. Additionally, 49 papers, books and reports, not found in Scopus, but available in the scientific literature using alternative search engines were added. This additional search was carried out through the analysis of the bibliography of the papers retrieved through Scopus. Consequently, although probably not all the papers, books and reports in the field of FLW quantification are included within the search presented, the studies included have been selected using the same criteria, and it is considered that the sample is representative and robust to achieve comprehensive conclusions for the FLW quantification field of research.

Once these documents were added, a total of 237 studies were used for developing the critical review. A synthesis of the search performed and the number of studies selected is shown in Fig. 2. Only studies strictly focused on FLW quantification were included. Thereby, papers focused on FLW assessment concerning other topics (e.g., FLW management, re-use or valorization) were excluded from the scope of the assessment. It was assumed that these studies do not focus mainly on quantifying, but more on analysing and comparing FLW management options. Moreover, studies that focus on broader topics (e.g., organic waste or general municipal solid waste) were also excluded from the selection. The reason is the fact that the phenomena that generate this waste are assumed to be sufficiently different to avoid including them in the same scope.

Regarding the second research question, Section 3.4 presents an assessment of the studies in the field of research including a critical approach with the currently developed FLW quantification methodologies and the heterogeneous pathways addressing the problem of FLW generation. For the latter, special focus is given to FLW quantification of large-scale loss using the FAO Food Balance Sheets (FAO, 2011; FAO, 2013). An overview of the results assessment structure is included in Fig. 2.

2.2. The development of the analysis of study findings

To provide an answer to the first research question, a descriptive

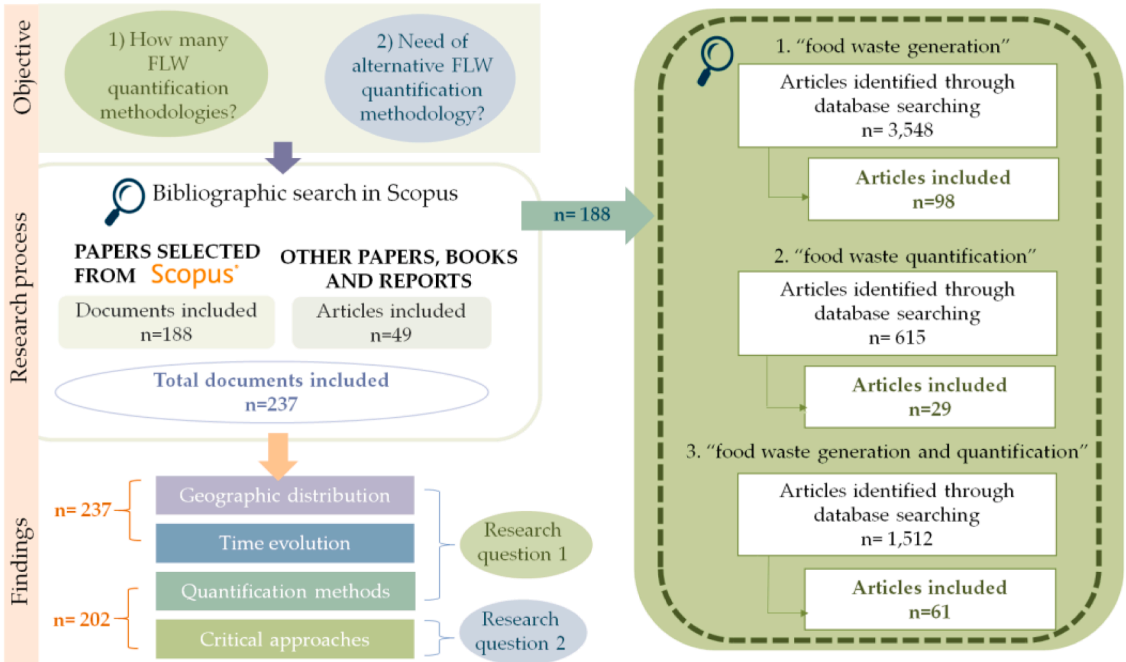

Fig. 2. Graphical representation of the literature review developed and the number of documents in the field selected. The three phases of review in the Scopus database are represented, as well as the 49 additional documents added, extracted from the bibliographies of the 188 papers included in the review.

analysis of the situation and evolution of studies in the field of FLW was performed. Thus, Section 3.1. focuses on analyzing the global location of studies, including the geographical location of the university or research center of the first author in each study. Thereafter, Section 3.2 shows the historical evolution of the studies selected. Finally, Section 3.3 details and assesses the studies with different FLW quantification methodologies (e.g., FLW assessments and estimates based on secondary data, factors, surveys, kitchen diaries, direct weighing, etc.), with a special focus on their scope of study and if they cited the FAO Food Balance Sheets (FAO, 2011; FAO, 2013). This section includes Subsection 3.3.1, describing the reviews previously published assessing FLW quantification. Concerning this subsection, some studies with a similar methodology to a review, but not specifically presented as a review, were not included in Section 3.3.1. These were quantified in Section 3.3 inside the category of "other methodologies". Finally, Section 3.4 analyzes those studies that provide criticisms concerning the pathways to quantify FLW (Section 3.4.1), as well as the analyses of the ways to approach the problem focusing on a qualitative analysis (Section 3.4.2).

3. Results and discussion

3.1. Mapping of the studies selected

The 237 studies selected were developed in 54 different countries worldwide. As shown in Fig. 3a, the United States is the country where most studies were developed (29), followed by Italy (23), the United Kingdom (16), Spain (12), Brazil (11), China (11) and South Africa (10). Per continent, Europe clearly stands out in this field of study (121 studies), followed by Asia (44 studies), North-America (37 studies), South-America (14 studies), Africa (12 studies) and Oceania (9 studies). A description of all studies is available in the Supplementary Material (SM) of this study. The affiliation of the first author of each study was selected as a uniform criterion to follow for dividing the 237 selected geographically. In many cases this criterion coincides with the main research center of the study and also with the data source used or the case of study analyzed. However, some discrepancies exist and must be checked individually in the list provided in the SM. It is also important to bear in mind that, certain reports do not analyze a specific database located in a specific region of the world, but rather are a compendium of various authors gathered in one publication.

In contrast, Fig. 3b, provides a geographical distribution of the origin of the databases used in the studies selected. In this sense, the overview changes considerably, since in some documents (e.g., UNEP, 2021) the case studies analyzed are based on data from different geographical location of the affiliation of the first author. In certain situations, data from various countries were analyzed, and thereby the number of studies per analyzed country increased, with some new countries appearing, especially from Africa where 31 national databases were identified. Studies that do not assess databases (i.e., 67 studies), were omitted, including reviews, reports, opinion articles or methodological articles. Finally, 4 studies that analyzed FLW at a supranational level (e.g., the entire European Union or Europe) were not represented in Fig. 3b.

3.2. Time evolution of the studies

The timespan between the first and last study included in the assessment ranged from 1943 to 2021. Firstly, it is interesting to describe the fact that, although before 1999 no references were found for many years, a reference was found in 1973 (Hasset et al., 1973), and another reference in 1943 (Kling, 1943). The latter, as already explained above, has been highlighted in the literature for presenting a first definition of FLW with a different approach to the one currently used by FAO. Thereafter, as highlighted in red in Fig. 4, in the period 2010-2011, in a context in which FAO's Food Balance Sheets were published (FAO, 2011; FAO, 2013), studies in the field began to emerge. Specifically, the first recent references in this field of study date back to 1999 (1 paper), 2003 (1 paper), 2004 (1 paper), 2007 (2 papers), 2008 (1 paper), 2009 (3 papers), 2010 (3 papers) and 2011 (3 papers). In the following years, however, the number of papers increased substantially: 2012 (5 papers), 2013 (9 papers), 2014 (13 papers) and 2015 (12 papers). Starting in 2017, there has been an almost exponential trend in the increase in papers developed in the field, jumping from 6 papers in 2016, to 24 in 2017 and 54 in 2021. As shown in blue in Fig. 4, this trend could be potentially linked to the introduction of the Sustainable Development Goals Agenda in 2015. As highlighted in green, a new FAO report

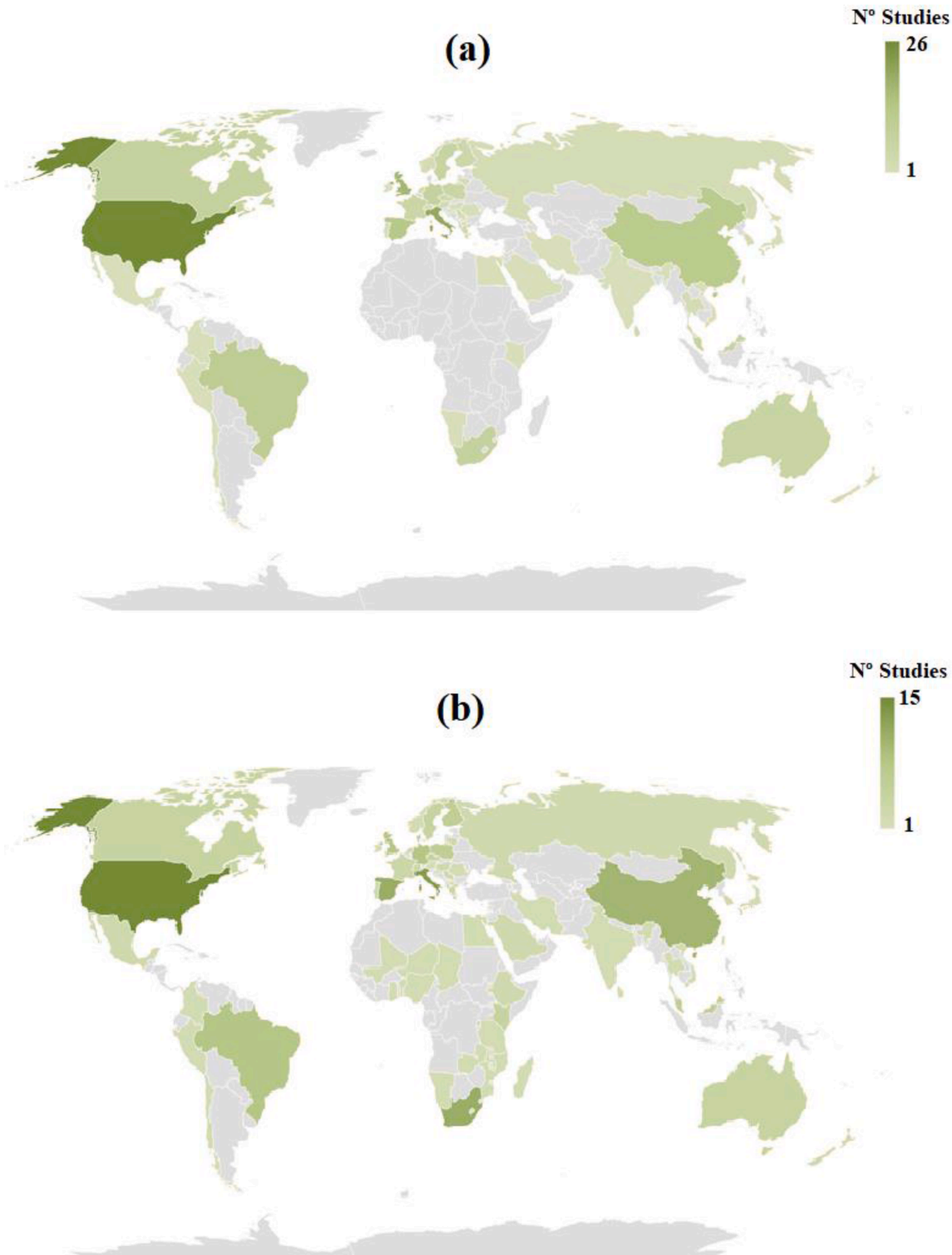

Fig. 3. Geographical distribution of the food loss and waste (FLW) studies included in the review. Figure 3a considers the geographical distribution of the 237 studies selected between 1943 and 2021 (this selection does not represent all studies concerning FLW quantification, but only those that have been found within the presented search criteria of this critical review) based on the affiliation of the first author. Figure 3b considers the geographical distribution of the number of food loss and waste (FLW) national databases analyzed in studies included in the review (i.e., 199 analyzed databases from 166 studies).

(McLaren et al., 2021) and the aforementioned UNEP Food Waste Index (UNEP, 2021) published at the end of 2021, may constitute a new turning point for the future.

3.3. Studies using different FLW quantification methodologies and approaches

When analyzing the content of the reviewed studies in Sections 3.3 and 3.4, access to 34 of the 237 studies was not possible. Therefore, only

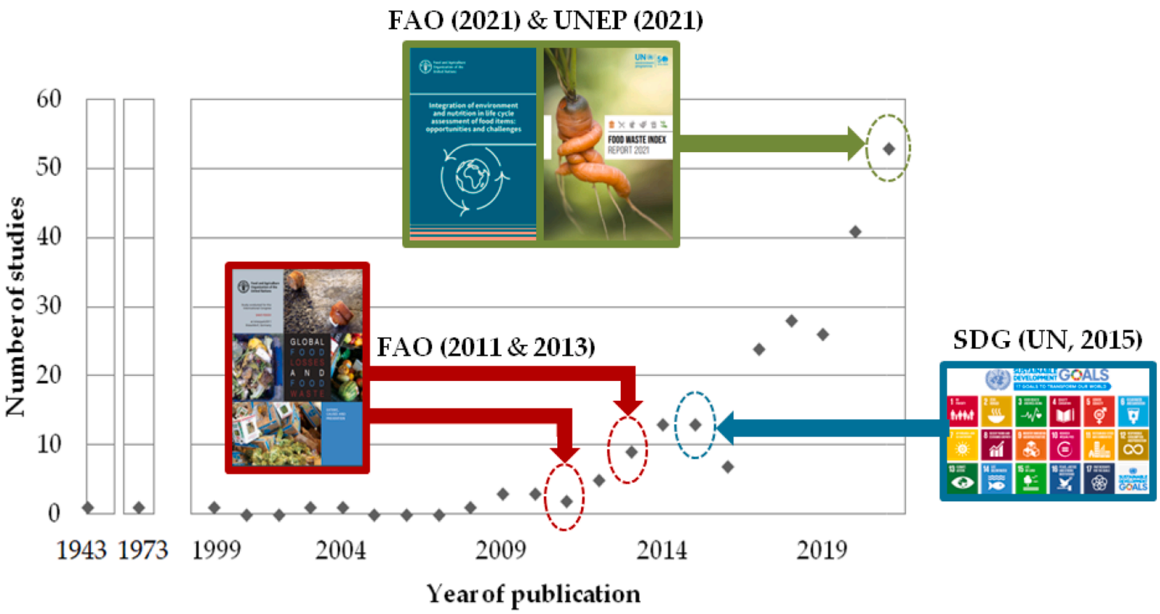

Fig. 4. Temporal distribution of the studies included in the review from 1943 to 2021. The picture framed in red represents the FAO reports published in 2011 and 2013. The picture framed in blue represents the Sustainable Development Goals, introduced in 2015. The pictures framed in green represent the recently published reports by FAO (2021) and UNEP (2021).

202 were analyzed in these sections. Moreover, concerning only Section 3.3, out of the 202 studies analyzed in terms of the methodologies and approaches presented, 10 publications were excluded of the assessment, as they were published prior to the publication of the first of the FAO Food Balance Sheets. Consequently, 192 studies were considered in this section. Of all these studies, 72.4% included at least one mention to the FAO Food Balance Sheets (FAO, 2011; FAO, 2013). In contrast, 27.6% of the articles analyzed did not reference these reports. Regarding the methodology implemented, despite the initial hypothesis of a higher spectrum of existing studies in the literature using indirect measurements (i.e., secondary data) mainly based on the loss/waste ratios provided by FAO (FAO, 2011; FAO, 2013), only 21.3% applied this methodology. In contrast, as shown in Table 1, a higher rate of the studies were developed through surveys (27.2%), the majority using national surveys (35 out of 54), and showing an increasing trend in recent years. Other methodological approaches included reviews (11.4%), the direct weighing of FLW (8.9%) and the use of kitchen diaries (6.4%). A mixture of at least two of the mentioned methodologies represented another 13.9% of the documents assessed, including the combination of weighting and surveys, statistics with surveys and literature, kitchen diaries and surveys, or secondary data and surveys. Moreover, 10.9% of studies were not related to any of the methodologies aforementioned, using literature researches (with similarities to a review approach, but not presented as such), other experimental methodologies approaches, workshop summaries or informative reports. Concerning the scope, while global or international studies mainly used FAO ratios for FLW estimation as the best methodology currently available to quantify FLW generation; studies with a national, regional or local level, presented a wide methodology diversity.

Despite the growing trend detected when using interviews, surveys or questionnaires, there are criticisms in the literature to this way of quantifying FLW, since they may underreport the latter, enhancing uncertainties. This criticism is extensible to the quantification through kitchen diaries, weighing processes, or other combined and novel methods, such as the FoodImage smarthphone app presented by Roe et al. (2020). Within this discussion Van Herpen et al. (2019) stated that surveys for assessing household-related food waste appear to be less valid than other methods, as these lead to large underestimations in the level of food waste, low variance in reported food waste across households compared to the other methods, and low correlations with other measures. Nonetheless, this study developed a survey instrument which aimed at eliminating some of the limitations identified in prior survey assessments, although it still has the drawback of underestimating food waste, making it less suitable for the quantification of absolute values. Moreover, Quested et al. (2020) reported an underestimation when using kitchen diaries from 7% to 40% compared to other quantification methods. Nevertheless, according to the review performed by Withanage et al. (2021), that quantified household food waste, and analyzed the strengths and weaknesses of five different FW quantification methods (i.e., surveys, kitchen diaries, waste audits, weighting and the use of secondary data), there is no 'one best' method for food waste quantification at a household level. In fact, even results of studies using the same method (e.g., surveys) are often non-comparable due to the vast differences in the existing protocols (Withanage et al., 2021). Consequently, they claim a need of developing standardized protocols for each method. In a similar line of thought, Spang et al. (2019)

Table 1
Cross tabulation of the 202 studies analyzed in this section, considering the scope and the methodology of food loss and waste (FLW) quantification.

Scope	Quantification method							
	Surveys	Kitchen diaries	Weighting	Secondary data	Reviews	Combination of methods	Other	TOTAL
Global				6	19	3	15	**43**
International	2			9	4	2	1	**18**
National	35	9	6	26	1	16	6	**99**
Regional	7	2	6			2		**17**
Local	10	2	6	2		5		**25**
TOTAL	**54**	**13**	**18**	**43**	**24**	**28**	**22**	**202**

described key takeaways including the following: i) existing FLW definitions are inconsistent and incomplete, ii) significant data gaps remain (by food type, stage of supply chain, and region, especially for developing countries), iii) FLW solutions focus more on proximate causes rather than larger systemic drivers; and, iv) effective responses to FLW will require complementary approaches and robust evaluation. Moreover, Cahyana et al. (2019), by assessing more than 100 studies, highlighted modeling as the most commonly used method.

Finally, in terms of scope, most were either focused on the complete FSC (34.3%), including the majority of the reviews. Studies specifically focused on consumer or household food waste generation represented 35.4% of the total. In third place, papers focused on food waste generation in food-away-from-home (FAFH) (e.g., canteens, restaurants, hotels, hospitals, supermarkets, etc.) represented 19.2%. Finally, studies linked to food loss generation at an agricultural production level represented 7.1%, at processing and packaging level represented only 2.0%, and those related to food waste generation concerning the distribution stage of the FSC represented another 2.0%. From this last block of data, it is noteworthy that more than half of the studies (54.6%) focused only on the food consumption stage (e.g., FLW generation in households and FAFH). This is striking compared to the lower representation of studies in the other three stages of the FSC, especially those referring to the beginning of the supply chain.

3.3.1. Other reviews in the field

A total of 26 different review studies linked to FLW were identified. As represented in Table 2, from the 26 reviews found, 20 (76.9%) focused on the analysis of studies linked to FLW in general, while four studies were centered on household consumption, one analyzed FAFH, and one evaluated the processing stage. Regarding the location of these studies, the majority (20 out of 26) had a general approach without mentioning any specific region of the world. In addition, three of them were centered in Europe, one in the Middle East, one in Sub-Saharan Africa and one in the United States. Concerning the year of publication, the first review dates back to 2010. Moreover. 38.5% were published in 2021, being the year in which most reviews were published (10), followed by 2017 (6 papers).

Regarding the main results of the reviews, it was generally concluded that FLW generation is a multifaceted problem, interconnected across all stages of the FSC, and distinguishing food waste sources related to: inherent characteristics of food, social and economic factors, other priorities targeted by private and public stakeholders (Muriana et al., 2017), individual non-readily changeable behaviours and demographic issues (Bhattacharya et al., 2021), inefficient legislation, lack of awareness or information, sub-optimal use of available technologies (Canali et al., 2017), buyer−supplier agreements, supply chain interruptions (Chauhan et al., 2021) and mismanagement of perishable food (Santos and Martins, 2021).

Concerning the quantification of FLW generation rates, a high level of heterogeneity in terms of methodological approaches, as well as a high variability in results, were described (Van der Werf and Gilliland, 2017; Dou and Toth, 2021). The reasons were linked to the data gaps, the information sources chosen and the assumptions made (Bräutigan et al., 2014), the lack of a specific, consistent and consensual concept of FLW (Oliveira et al., 2021), and the need of more robust evaluation considering more proximate causes rather than larger systematic drivers (Spang et al., 2019). Therefore, Corrado and Sala (2018) highlighted the need for additional and joint efforts to improve availability, reliability and level of detail in data on FLW generation. Moreover, Withanage et al. (2021) suggested that there is no 'one best' method for food waste quantification at a household level and that comparisons across studies should be interpreted with care. Thereby, researchers should discuss FLW quantification results through the application of multiple methodologies in parallel with the aim of improving the interpretation of results (Lou et al., 2021). In this framework, according to Parfitt et al. (2010), despite data availability limitations, results have shown a higher

Table 2
List of reviews found in the scientific literature linked to food loss and waste (FLW) quantification assessments.

Publication year	Paper reference	Country	Brief description	Main insights/ critical messages
2021	Dou and Toth	USA	Global primary data on consumer food waste	High variability in FLW rates
2021	Withanage et al.	Canada	Households food waste quantification methods	No "one best" method for food waste quantification
2021	Kafa and Jaegler	France	FLW in supply chains	Most studies: downstream supply chains, developed countries, weight methods
2021	Chauhan et al.	India	FLW in supply chains	Key factors of FLW: poor management, stakeholder attitudes, selling agreements, supply interruptions
2021	Oliveira et al.	Brazil	FLW and circular economy	Still no consensual FLW concept
2021	Harvey et al.	UK	Consumer food waste	FLW research is showing signs of maturity
2021	Do et al.	UK	Research on FLW prevention and management	Three research trends emerging: impact assessment, biorefinery, nutrient recycling. Six future research streams described
2021	Bhattacharya et al.	Australia	Taxonomy of antecedents of food waste	Behavioural and demographic issues: relevant for consumer FLW generation
2021	Lou et al.	New Zealand	FLW within FSC	Interpretation of FLW quantification results should be done combining different methods
2021	Santos and Martins	Brazil	Food waste and performance measurement systems	Major factors for FLW generation: poor management, stakeholder attitudes, buyer-supply agreements and supply chain interruptions
2020	Dhir et al.	Finland	Food waste in hospitality and food services	State-of-the-art of studies focused on the field
2020	Bovay and Zhang	USA	Evolution of food waste	FLW shifted downstream in recent decades due to households income, technological improvements

(continued on next page)

Table 2 (*continued*)

Publication year	Paper reference	Country	Brief description	Main insights/ critical messages
				and cultural changes
2019	Spang et al.	USA	FLW measurement, drivers and solutions	Inconsistencies in FLW definitions, significant data gaps, need to seek more proximate causes rather than large scale drivers
2019	Cahyana	Thailand	Food waste in supply chains	Research focused on household or urban food waste has more attention. A significant research increase in 2015
2018	Corrado and Sala	Italy	Food waste along global and European supply chains	High level of heterogeneity of methods and high variability in results. Need to improve the availability, reliability and level of detail of FLW generation data
2018	Schanes et al.	Austria	Household food waste practices and policy implications	Need to coordinate strategies across actors from the production to the consumption stage
2018	Abiad and Meho	Lebanon	FLW in the Arab world	Key points to quantify and mitigate FLW in the Arab world
2017	Van der Werf and Gilliland	Canada	FLW in developed countries	High degree of variability of estimates. Higher consumption food waste rates in North America, compared with European estimates
2017	Hebrok and Boks	Norway	Household food waste	The literature is more focused on knowledge generation on the FLW problem than on finding solutions
2017	Canali et al.	Italy	Food waste drivers in Europe	FLW is a wide and multifaceted problem, interconnected across all stages of the chain. Sources of FLW: food characteristics, social and economic factors, individual behaviours, etc.
2017	Sheahan and Barrett	USA	FLW in Sub-Saharan Africa	Key points to quantify and mitigate FLW in Sub-Saharan Africa
2017	Muriana	Italy	Food waste measurement	Highlighted a lack of mandatory regulations for FLW reduction: need of optimal incentives and penalty schemes
2017	Raak et al.	Denmark	Processing and product-related causes for food waste	Described strategies for FLW reduction such as alternative trade ways and emergency power supplies
2015	Thyberg et al.	USA	Food waste in the United States	National approach
2014	Bräutigam et al.	Germany	Available data on food waste generation in EU-27	Different FLW calculation methods: results differ considerably depending on the data sources and the assumptions
2010	Parfitt et al.	UK	Quantification of food waste and potential for change to 2050	Higher food loss generation for perishable foods at post-harvest stages in developing countries, and in developed countries highest food waste

food loss generation for perishable foods at the immediate post-harvest stages in developing countries, in comparison to food waste generation. On the other hand, in the case of developed countries, post-consumer food waste was identified as the largest FLW contribution (Parfitt et al., 2010), showing some evidence that it has shifted downstream in recent decades, i.e., from producers and processors to retailers and consumers (Bovay and Zhang, 2020). Moreover, these results seem to be higher at a consumption level in North-America as compared to estimates available for Europe (Van der Werf and Guilliland, 2017). In this line, Bovay and Zhang (2020) hypothesized that this downstream shift has been driven by increases in household income, technological improvements (reducing FLW at the early stages of the supply chain), and cultural changes. These claims were in line with those described by FAO reports of 2011 and 2013 (FAO, 2011, 2013). However, other reviews have observed that downstream FSCs are more studied than those upstream, case studies in developed countries are more abundant, and weight tends to be the main metric used to quantify FLW (Cahyana et al., 2019; Kafa and Jaegler, 2021).

Additionally, although most reviews analyzed FLW generation trends from a worldwide perspective, a small group of these focused on specific regions or certain actors along the FSC. For instance, Thyberg et al. (2015) analyzed the FSC in the US, concluding that the proportion of food waste increased significantly with time, with western states presenting consistently and significantly higher proportions of food waste than other regions, and suggesting that no significant differences between rural and urban samples, or between commercial/institutional and residential samples, could be established. Two additional regional reviews, by Sheahan and Barrett (2017) and Abiad and Meho (2018), analyzed FLW generation in Sub-Saharan Africa and in the Arab world, respectively, summarizing key points for guiding more appropriate research and strategies for quantifying and mitigating FLW generation in those regions. Finally, Dhir et al. (2020) critically analyzed the state-of-the-art of food waste generation in the hospitality and food services sector.

In terms of strategies to mitigate FLW generation, while Hebrok and Books (2017) highlighted that the literature is more focused on generating knowledge about the problem than on finding solutions, Raak et al. (2017) described a number of strategies to minimise FLW, such as alternative trade ways for second choice items, or emergency power supplies to compensate for power blackouts. In the same line, Muriana (2017) stated that the main drawback responsible for FLW reduction is the absence of mandatory regulations, which are needed to harmonize strategies. Consequently, it was considered that the introduction of optimal incentives and penalty schemes for the achievement of a common benefit is an attractive strategy for FSC actors (Muriana, 2017). Moreover, according to Schanes et al. (2018), a strategy to coordinate approaches across actors from the production to the consumption stages is needed. This statement was based on the belief that wasted food in households may already be linked to upstream actors in the food chain (e.g., through incomprehensible date labels, excessively large and/or not re-sealable packaging, retailer and sales strategies such as bulk packages, special offers, etc.) which are therefore outside the scope of individual action (Schanes et al., 2018). Adittionally, Do et al. (2021) summarized three main research trends in the field: impact assessment, biorefinery and nutrient recycling. Finally, and despite all the limitations and challenges that have been described, Harvey et al. (2021) maintained that research in FLW is showing signs of maturity as a flurry of review papers help to consolidate knowledge and point towards future challenges and perspectives.

3.4. Studies with a critical approach

3.4.1. Analyzing the limitations in FLW quantification pathways

The two FAO reports developed in 2011 and 2013 (FAO, 2011; FAO, 2013) emphasized the limitations of the studies due to the lack of sufficient data availability, which led to the need of constructing multiple assumptions on FLW generation amounts. Moreover, they identified that the distribution and consumption stages were more challenging to quantify at the time due to the lack of precise data. More specifically, excluding Europe and North America, authors reported lack of data related to household food waste. Therefore, the results in these studies must be interpreted with caution, especially when considering emerging and developing nations (FAO, 2013).

In this framework, a considerable number of studies were identified since 2013 presenting critical voices on different aspects of the current pathways undertaken to quantify or assess the problem of FLW generation. Firstly, Koester (2013) questioned whether different food items measured in kilograms or metric tons could be aggregated. In 2017, Sheahan and Barrett (2017) stated that there are multiple reasons, including methodological issues, to remain skeptical regarding the data shared by the FAO Food Balance Sheets, as well as of other highly aggregated numbers commonly used in current scientific studies. According to Bovay and Zhang (2020), FAO's Food Balance Sheets, which covers the period 1961–2013, comprises the amounts of commodities that are lost at all stages of the FSC from production to household consumption, excluding losses during pre-harvest and harvesting, as well as those occurring in the household. In fact, they emphasized the fact that it is not well documented how these fixed percentages are estimated, and the reason for only considering FLW generation intended for direct human consumption was not clearly explained. On a similar note, Spang et al. (2019) pointed out the inconsistency and incompleteness in the definitions of FLW, as significant data gaps remain (e.g., by food type, stage of FSC and region, especially for developing countries). Additionally, they highlighted the lack of larger systemic drivers for FLW solutions due to a focus on proximate causes. Finally, they bring forward the contradiction that despite all the limitations that have been identified, FAO's Food Balance Sheets conclusions have been widely used in the literature to highlight households as the major source of FLW, and thereby, consumer awareness, good food purchase and consumption planning, and correct household food storage as the key strategies to solve the problem (Beretta et al., 2013).

Some of these criticisms have also been extended to other alternative databases, including the balance-sheet approach used by the USDA Economic Research Service (ERS) and its Loss-Adjusted Food Availability (LAFA) Data Series (Redlingshöfer et al., 2017). In this line, it was stated that the skepticism in FLW quantification databases and methodologies is linked mainly to the fact that FAO and USDA definitions only apply to edible and safe and nutritious food, without a clear specification of what these concepts (i.e., edible, non-edible, safe, nutritious…) actually mean (Redlingshöfer et al., 2017). It was also detailed how data on the extent of FLW and its fate during the first stages of the FSC (i.e., primary production and processing) are currently scarce in industrialized countries, including France, due to lack of available measurements and differences in terms of FLW definitions, especially in the primary sector (Redlingshöfer et al., 2017).

In this sense, Bellemare et al. (2017) highlighted that there is not a universally understood edible food definition, as it is context-dependent with important differences between countries, cultures, age groups, etc. Thus, they argued that the most robust and coherent definition of FLW implies ignoring the concept of edibility, focusing on accounting for whole plants and animals produced for food, considering stalks, leaves, hide, bones, etc. This argument links with the nutritional energy approach to account for FLW, presented by Kling (1943). Kling's definition referred to energy (i.e., nutrients) lost due to edible and non-edible FLW generation, an approach which is currently supported by skeptical voices such as Montagut and Gascón (2014) or Gascón (2019). In fact, this approach has gained support in the past decade (Hall et al., 2009; Cuéllar and Webber, 2010; Chaboud and Daviron, 2017), and includes in the estimation the cost of inputs used to produce the whole food-related products and the disposal of all organic matter generated through the entire FSC. A larger estimate of the quantification of food-related organic waste may result with this treatment. For example, Lipinski et al. (2013), based on the FAO Food Balance Sheets (FAO, 2011; FAO, 2013), estimated that one in four food calories intended for direct human consumption is not ultimately ingested. Hence, if the FAO database estimations are considered conservative, the nutritional losses values could be much higher. Moreover, it has been also stated that recycling in the form of incineration or anaerobic digestion, reduces the breakdown of nutrients and energy embedded in FLW. Nevertheless, Gascón et al. (2021) criticizes this statement, considering that the energy balance would be negative. Additionally, the recently promoted approach to quantify the economic value of FLW (FAO, 2019; García-Herrero, 2018) has been criticized as a potentially new element of discordance due to the fact that the mass of a foodstuff is not always correlated to its sales price, and neither is the price the same in different markets (Gascón et al., 2022).

In this line, Xue et al. (2017) noted that large gaps still remain in nationally-centred FLW estimates. Out of the estimates they analysed, many did not involve new measurements, but were based on outdated or proxy data from other countries. In fact, the authors highlight that the lack of data is not just an issue at a global level: most countries do not have robust data on FLW generation. How much food is lost or wasted? Which sectors (i.e., stages of the FSC) lead to the highest generation rates? What food fractions have the largest impacts? According to Xue et al. (2017), if this information is not available, governments, private companies and other stakeholders struggle to make a case to take action and advance adaptive and informed policies, as they lack the necessary data to prioritize efforts in the correct direction. In this same line, Delley and Brunner (2018) developed a study based on self-reported quantities of FLW by citizens. The data were collected by means of a postal survey delivered to a random sample in the French- and German-speaking areas of Switzerland. The data obtained were compared to extrapolations from a national waste composition analysis report. The authors identified a divergence between the perceived contribution to the problem by citizens and more objective measurements. The results obtained in the self-reported survey suggest that up to 8.9 kg of avoidable and possibly avoidable household food waste per capita may be generated annually, whereas estimates based on the second method reached 89.4 kg of mostly avoidable household food waste per capita per year. This fact highlights how, depending on what is or is not taken into account for FLW quantification, the result can vary enormously.

In this debate, an important novelty is the fact that the consideration of the nutritional energy FLW seems to be gaining interest in the scientific community. In fact, FAO has recently published a report that focuses on the identification of new opportunities for further developing an environmental and nutritional more robust, multidimensional and comparable LCA methodology concerning the assessment of FLW generation (McLaren et al., 2021). Thereby, the report considers that food items should be assessed in terms of their nutritional provision to consumers. Notwithstanding, a food item was defined as "a substance that contributes in whole or in part, or following further preparation (typically in a home or restaurant situation), as a source of nourishment when consumed by humans, i.e., is used to refer to simple and complex foods that are ready to be consumed (with or without cooking)" (McLaren et al., 2021). Hence, it could be argued that this new attempt by FAO to standardize a methodology, considering the definition of a nutritional energy FLW generation, still omits any reference to non-edible FLW generation in the scope, i.e., a revision of the FLW definition is not presented.

In parallel, another important release in 2021 was the already mentioned Food Waste Index Report (UNEP, 2021). It has been presented as the most comprehensive food waste data collection, analysis and modelling available to date, providing an updated estimate of global food waste. For this, country-level food waste estimates were calculated, and a methodology was developed for countries to measure food waste, at household, food service and retail levels, with the ultimate objective of tracking national contributions and improvements in the pathway to 2030, and to report on SDG12.3. Fourteen countries were assessed for a 12-month period, covering their entire geography, accounting for edible and inedible parts of food items, and considering the destination of co/anaerobic digestion, aerobic composting, controlled combustion, land application, landfill, refuse discards and sewer: However, animal feed, biomaterial/processing and non-harvested crops were excluded from the computational framework. All these stages were quantified by direct measurement (waste streams), waste composition analysis, volumetric assessment, mass balance, counting/scanning, or diaries.

The UNEP report highlights that household per capita food waste generation was found to be somewhat similar across country income groups (UNEP, 2021). This conclusion is relevant as it suggests that food waste policy actions are equally relevant in high, upper-middle and lower-middle income countries. This statement diverges from earlier narratives (FAO, 2011; FAO, 2013) which suggested that consumer food waste was predominant in developed countries, while food production, storage and transportation losses were more relevant in developing countries. Moreover, another novel aspect of this approach is the definition of "food waste" as food and the associated inedible parts removed from the human FSC in the following sectors: retail, food service and households (UNEP, 2021). Therefore, food waste includes in this definition both edible and non-edible parts such as bones, rinds and pits/stones. The novelty trend of considering non-edible fractions has also been identified in recent policies such as a law project on FLW prevention law in Spain (Spanish Government, 2021).

A controversial issue detected is the fact that a Food Loss Index was previously presented in 2018. However, its content and development seems to have gained less attention by policy-makers and scientists (English et al., 2018). In contrast, the Food Waste Index Report, which is much more detailed, seems to connect with the apparently greater interest in food waste reduction targets of SDG12.3 (UN, 2015). Moreover, as explained by UNEP (2021) in contrast to the Food Loss Index which is focused only on the so-called "key commodity losses", the Food Waste Index measures total food waste (rather than loss or waste associated with specific commodities). To include only few "key commodity losses" could be a source of high uncertainty when calculating food loss. In this line, English et al. (2018) highlighted the fact that since underlying data is a critical component in terms of calculating food loss indices as well as the complexities of these supply chains in measuring and monitoring post-harvest losses, strategies for food loss data collection are needed. In this line, initiatives such as the HESTIA database, providing a standardized and structured format to represent agri-environmental data, may be promising paths.

3.4.2. Analyzing food production models: towards qualitative assessment in FLW policy

Beyond a merely quantitative analysis of the problem, there are critical voices in the scientific literature that highlight the need to approach the problem from a qualitative perspective. In this framework, Gascón (2018) highlighted the need to assess how and why FLW is generated, and who is responsible for it. In fact, it has been suggested that the hegemonic and most widespread paradigm identifies logistical and technical shortcomings in different stages of the life cycle, such as production, transport, and processing, to deficient food management by end consumers, as the main carriers of FLW. Thus, FLW generation is a result of system dysfunctions and can be mitigated with the application of technological solutions and awareness-campaigns. In contrast, there are dissenting voices stating that large agri-food processing and distribution companies have an important role in FLW generation (Devin and Richards, 2018), highlighting that the ultimate cause of this phenomenon does not lie in logistical and technological factors, nor in the lack of citizen engagement. Instead, they argue that it is the predominant agro-industrial model and its unbalanced power relationships that is responsible for the current dysfunctions (OBrien, 2012). Additionally, although these topics are out of the scope of the current review, it is important to mention other critical approaches such as the one presented by Bowman (2020), highlighting that the mainstream conception of the FLW generation problematic also eclipses vital power relations not only in the present, but also in the past, across the FSC, and through colonial and post-colonial exploitation between countries. Thereby, this author analyzed how structural features of capitalism create drivers for waste (including FLW), food poverty, overproduction, colonialism and ecological degradation.

Other important points to be highlighted based on the analysis are that, according to Xue et al. (2017), only a small bunch of industrialized countries, such as United States and the United Kingdom, are linked to most of the existing publications, and the use of secondary data is reported in over half of these studies, despite the inherent uncertainties. Moreover, Kafa and Jaegler (2021) claimed that downstream FSCs are studied to a greater extent than upstream FSCs, with a clear emphasis on consumer waste. In fact, they state that a majority of articles on FLW focus on only one supply chain activity, and on the fact that the main metric to quantify FLW is weight. All these critical points have been confirmed in the present review. Moreover, concerning the ambiguity and lack of studies regarding the calculation of food loss (upstream FSC), it could be again linked to the nature of SDG 12.3 itself, which focuses on specific targets for food waste quantification (i.e., to *halve* per capita food waste by 2030), but leaves tangible objectives for food loss quantification very much in the air ("*to reduce food loss by 2030*").

Following the above mentioned points of view, Gascón (2018) stated that the main problem and the solution are, above all, essentially political. According to Gascón (2018), the existence of an asymmetric productive and commercial structure, where large distribution accumulates oligopolistic power, allows the establishment of conditions for food producers, which urge the farmer or producer to generate FLW. In fact, due to the low prices of food products, agricultural producers have recurrently encountered problems to collect crops, redirecting their unsold or surplus products for secondary products such as juices or sauces (with much lower price). In some cases, they are even forced to destroy the products to maintain competitive prices (Thorsen et al., 2022). Moreover, a study by Fernández-Zamudio et al. (2020) underlined that there are important causes of FLW generation related to commercial criteria, in which agricultural producers often feel powerless and cannot sell the so-called "ugly food". Consequently, it forces producers to intensify their crops, because they need to produce many kilograms of "perfect" fruit in aesthetic terms (van Giesen and Hooge, 2019). As an example, Porter et al. (2018) estimated, based on visual appearance standards in Europe and the UK, the amount of wasted fresh fruit and vegetables, and its link to greenhouse gas (GHG) emissions. They estimated FLW amounts of up to 4,500 kt year^{-1} (970 kt CO_2eq) in the UK and 51,500 kt year^{-1} (22,500 kt CO_2eq) in Europe (Porter et al., 2018). As a response, it is remarkable that efforts are being made to reincorporate these so-called ugly food products consumption chains through maximizing marketing strategies (Qi et al., 2022). In this line Van Giesen and De Hooge (2019) stated that a sustainability positioning can increase consumer choices for ugly food. These findings extended a path of evidences suggesting that providing consumers with information on the FLW problematic (Quested et al., 2011; Del Giudice et al., 2016) and its environmental impacts, can influence consumer behavior and choices (Van Giesen and Hooge, 2019).

Gascón (2018) claimed that the increasing requirements on the quality of the product, either due to appearance or linked to strict hygienic and/or sanitary regulations, prevent producers from introducing perfectly edible fruits or vegetables into the commercial circuit. In order to deal with these external pressures, producers seek inefficient strategies, such as productive specialization or overproduction (Herzberg et al., 2022). More concretely, the requirements of hygienic-sanitary conditions greatly harm small producer compared to the larger agro-industrial sector, since they focus a lot on limiting the sales of natural products and very little on limiting the use of agrochemicals (Gascón, 2018). Similarly, Bustos and Moors (2018) developed a study detailing the structural inefficiencies that lead to postharvest losses and which of them can be identified in global FSCs. In this line, Gascón (2018) stated that the globalized large-scale FSC, combined with the ongoing increase of food mass retail and related dietary transitions (e.g., eating fresh products out of season), have contributed to additional FLW generation and overconsumption.

According to Messner et al. (2020), most of the initiatives that address the phenomenon of FLW generation do not delve into the roots of the problem, which would allow the establishment of prevention strategies, but rather deal with the problem when it already exists. The authors named it "The Prevention Paradox", i.e., the risk of viewing FLW as an opportunity is that it makes it a phenomenon to be managed, rather than a problem to be minimized as much as possible (Messner et al., 2020). Thus, it is common to find researchers, public institutions and social entities that perceive FLW as an opportunity to face the scourge of poverty, allocating these foods to the population groups that suffer from it (Gascón and Montagut, 2015; Contreras and Verthein, 2018). Similarly, multiple studies have suggested energy recovery through FLW management as a partial solution to energy limitations, by generating biogas, hydrogen or electricity (Guo et al., 2010; Nayak and Bhushan, 2019; Hoehn et al., 2019). Other studies, instead, have highlighted the possibilities of improving the structure of overexploited soil, when destined to compost (Sullivan et al., 2002; Awasthi et al., 2020). Moreover, different studies highlight the possibilities of re-using FLW as animal feed sources (WRAP, 2016). In contrast, possible conflicts of interest between FLW prevention and existing economic norms and practices (Gascón, 2018) or the lack of sufficient innovative ideas to be fully implemented on a global scale could be seen.

Consequently, by introducing a qualitative approach for assessing the FLW generation problem, the processes of FLW generation that will never be consumed will be revealed, allowing to identify the responsibilities and power relations more clearly behind the phenomenon: it is a political problem linked to the hegemonic agro-industrial food production model, which will not be solved by modernizing logistical and technological structures (Gascón, 2018). Hence, in a framework of increasing social acceptance of the "limits to growth", the response to problems such as FLW generation, and its associated environmental (e.g., climate change) and social (e.g. food poverty) impacts, which will potentially need to address future inevitable crises, requires us to look beyond 'reformism' to more radical 'transformist' solutions that distribute wealth and resources more equitably (Bowman, 2020). All these critical approaches are inevitably linked to the need of following a sustainable degrowth path, i.e., satisfying human requirements while reducing resources use and minimizing environmental (Latouche, 2006; Infante-Amate and González de Molina, 2017). Thereby, sustainable degrowth, similarly to other sectors of our economies and daily lives such as energy consumption for transport or in industrial uses, should also be implemented throughout the FSC (Hoehn et al., 2021). All it in order to implement strategies to mitigate FLW, towards circular bioeconomy systems (Georgescu-Roegen and Bonaiuti, 2011).

3.5. *Challenges for FLW quantification*

Throughout this critical review, the existing discussions regarding the suitability of some FLW quantification methodologies over others have been reflected, highlighting in all cases the limitations that exist for the quantification process, either due to the subjectivity of more direct methods (such as surveys, kitchen diaries or weighing), as well as the limitations of the representativeness of indirect methods (among which FAO's Food Balance Sheets stand out). In terms of the limitations derived from the definition of what FLW is, although there is still a long way to go, it seems that recent progress is being made towards the inclusion of non-edible FLW (i.e., food that is not harvested due to multiple reasons) in the quantification process, which are also losses with nutritional value of food fractions that could be edible, or else have environmental and social impacts derived from their production process. Hence, some clear gaps in the methodologies have been detected in the current review when quantifying FLW. As a response to all those gaps, or critical points of discussion, at least three important challenges, related to quantification of FLW, need to be tackled in upcoming years (as shown in Fig. 5):

- Challenge 1: To quantify and mitigate FLW linked to planned overproduction to meet contract specifications with retail chains (Priefer et al., 2016).
- Challenge 2: To quantify and reduce FLW related to excessively low prices for food commodities, with a special focus on the FLW generated at agricultural production, where market prices do not justify the expense of harvesting (Priefer et al., 2016). More specifically, non-collected crops, destroyed crops and low rates of redistributed products to secondary uses (such as sauces or juices), should be considered (Gascón et al., 2022).
- Challenge 3: To quantify and eradicate losses linked to uneven standardization protocols for food production and consumption, as the currently conditions promote restrictions in processes linked to organic or local products (e.g., direct sale of products at the farm), while there are lower restrictions concerning the use of agrochemical products. This has led to a situation in which hygienic-sanitary conditions limit small producers compared to larger agribusiness companies (Montagut and Gascón, 2014).

4. Conclusions and challenges

The descriptive assessment provided in the current review highlighted that the available methodologies that quantify FLW without using the loss factors of the FAO Food Balance Sheets on a global scale

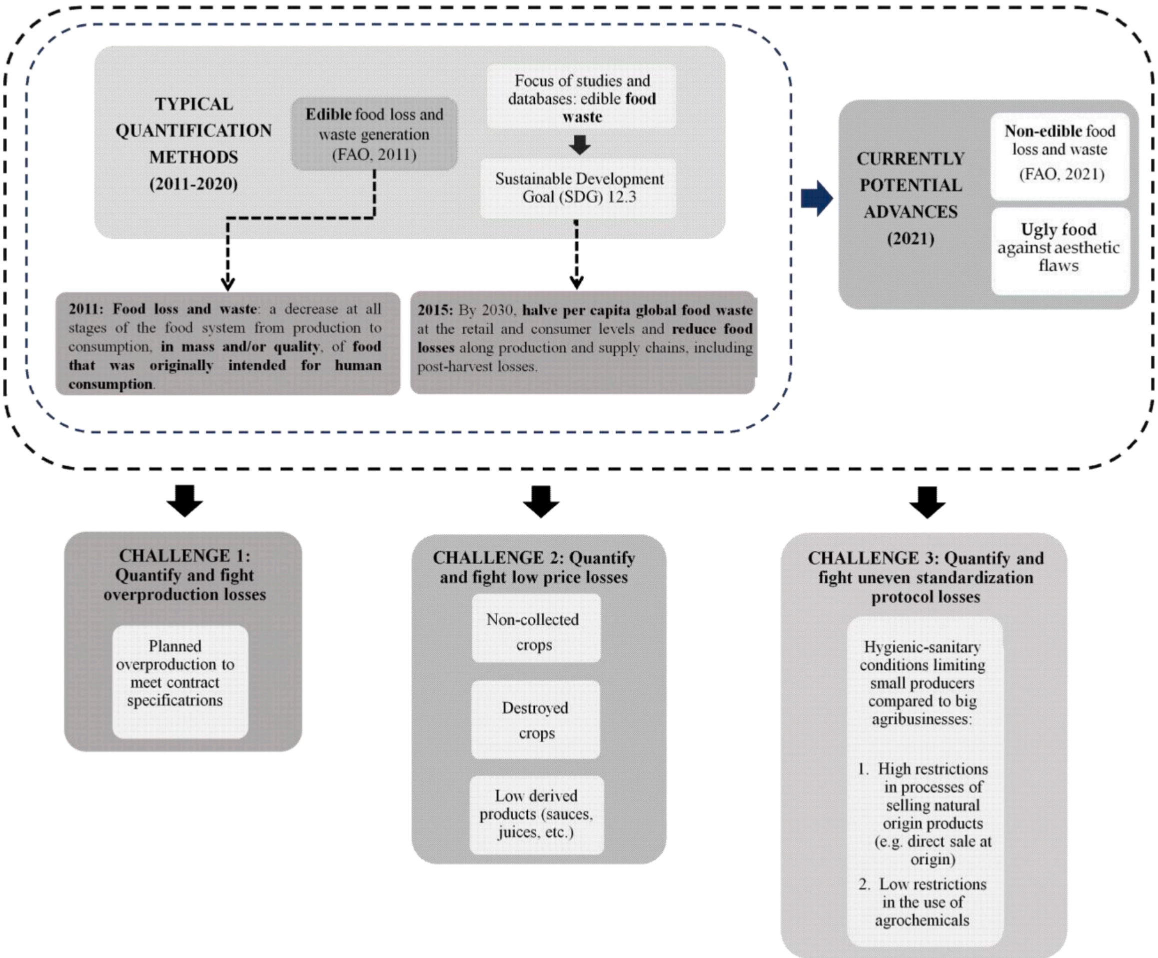

Fig. 5. Overview of the current food loss and waste (FLW) quantification approaches (top left), and potential advances existing in recent reports and policies (top right). The bottom part of the graph represent the three main challenges to be considered for future strategies related to FLW quantification.

are scarce, whereas it is the small-scale studies, including national and regional, but mostly local approaches, those that have shown to be more innovative in providing new metrics for FLW estimation. This has led to a situation in which existing studies on FLW quantification on a global scale are mainly based on FAO's estimates (and few other similar secondary databases such as the LAFA data series), which leads to important levels of uncertainty when reporting the results. Consequently, based on this review, it is considered imperative that the definitions applied to FLW should be revisited in terms of what is quantified and what unit of measure is used, in order to generate more sophisticated, holistic and close-to-reality methods to quantify the complex flows of FLW generation on a global scale. Moreover, from the 237 studies included in the scope of this review, a geographical lock-in has been detected, with most studies concentrated in developed nations, mainly in Europe and North-America, which skew the representativeness of the available data. This implies an important challenge in terms of understanding the real picture in the so-called emerging and developing nations, where food consumption and, therefore, food production and FLW generation, are expected to grow most in upcoming years.

The critical review provided in this study aimed to answer the second research question: *Is there a need of developing alternative paths beyond the currently widespread methodologies of FLW quantification and approaches of assessment?* According to the literature assessed, it appears that the global and continental loss factors reported by FAO seem to be conservative and with relatively high levels of uncertainty. This seems especially true when related to the FLW generated in the early stages of the FSC and, more specifically, in agricultural production or fishing operations. In fact, there is increasing evidence that FLW generation levels could be substantially higher than those reported by the scientific literature, due to a series of factors, that include: i) the exclusion of non-edible fractions from quantification metrics; ii) quantifying FLW only in terms of mass, omitting nutritional or other perspectives that can highlight other properties and benefits of food consumption; iii) FLW generation due to aesthetic reasons promoted by commercial criteria; iv) overproduction due to sales requirements by the big agribusinesses and distribution companies; v) excessively low prices of some food items; vi) contradictory hygienic-sanitary restrictions; vii) high distances involved in food freight and related logistics (especially concerning fresh food consumption out of season, with higher risk of spoilage); among others.

The FAO Food Balance Sheets in 2011 and 2013 responded to a context in which this problem had hardly begun to be investigated. However, both because of the criticisms received and knowledge advances in recent years, in addition to the directions in which certain public policies point towards, it is clear that there are still many elements that must be improved and/or included when quantifying and tackling the FLW generation problem. In this context, the need to maintain the focus on consumer behavior and responsibility is important. However, it is essential for policy to delve into the role played by large agricultural and distribution companies when generating FLW throughout the FSC. In other words, FLW generated in the early stages of the FSC is a phenomenon that is receiving less attention than consumer behavior, hindering efficient responses to mitigate FLW.

As an overall conclusion, it seems clear that there is a need to improve FLW metrics worldwide in order to obtain a clear picture of

FLW generation, especially at a global level. For this, many criteria related to the way of functioning of the agro-industrial food system, for FLW quantification, must be considered. Regarding the assessment presented in this study, a potentially interesting pathway could be to standardize some of the more local direct ways of quantification presented in the literature (e.g., surveys, diaries, weighing or a mix of all of them), and to scale them from local to national and global levels. Nevertheless, this path also presents limitations due to subjectivity and lack of geographical or temporal representativeness. Moreover, it could be very difficult, or even unrealistic, to standardize and extensively implement a single common path to quantify national or regional levels due to multiple technical, economic and political reasons. Additionally, especially the use of surveys and diaries may underreport the level of FLW generation, presenting a problem due to the importance of accuracy. Finally, the extent to which underreporting is dependent on, for instance, awareness of food waste issues, is unknown, and this represents an ever bigger issue when comparing food waste levels over time.

Alternatively, this study has highlighted the presence of different critical voices suggesting the need to introduce a qualitative approach for assessing the FLW generation problem. More specifically, they suggest avoiding a focus on the numerical quantification, but on revealing the processes of food accumulation that will never be consumed. This perspective may allow identifying the responsibilities and power relations more clearly behind the FLW phenomenon, as well as creating a clear pathway towards the creation of circular bio-economy systems.

Declaration of competing interest

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

Data Availability

The data used (reviewed articles and some of their characteristics) are available in the Supplementary Material

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.resconrec.2022.106671.

References

Abbade, E.B., 2020. Estimating the nutritional loss and the feeding potential derived from food losses worldwide. World Dev. 134, 105038.
Abiad, M.G., Meho, L.I., 2018. Food loss and food waste research in the Arab world: a systematic review. Food Secur. 10, 311–322.
Aldaco, R., Hoehn, D., Laso, J., Margallo, M., Ruiz-Salmón, I., Cristóbal, J., Kahhat, R., Villanueva-Rey, P., Bala, A., Batlle-Bayer, L., Fullana-i-Palmer, P., Irabien, A., Vázquez-Rowe, I., 2020. Food waste management during the COVID-19 outbreak: a holistic climate, economic and nutritional approach. Sci. Total Environ. 742, 140524.
Awasthi, S.K., Sarsaiya, S., Awasthi, M.K., Liu, T., Zhao, J., Kumar, S., Zhang, Z., 2020. Changes in global trends in food waste composting: Research challenges and opportunities. Bioresour. Technol. 299, 122555.
Bhattacharya, A., Nand, A., Prajogo, D., 2021. Taxonomy of antecedents of food waste – a literature review. J. Clean. Prod. 291, 125910.
Bellemare, M.F., Çakir, M., Hanawa-Peterson, H., Novak, L., Rudi, J., 2017. On the measurement of food waste. Am. J. Agric. Econ. 99 (5), 1148–1158.
Beretta, C., Stoessel, F., Baier, U., Hellweg, S., 2013. Quantifying food losses and the potential for reduction in Switzerland. Waste Manage. 33 (3), 764–773.
Bovay, J., Zhang, W., 2020. A century of profligacy? The measurement and evolution of food waste. *Agric.* Resour. Econ. Rev. 49 (3), 475–489.
Bowman, M., et al., 2020. Challenging hegemonic conceptions of food waste: critical reflections from a food waste activist. In: Reynolds, C., et al. (Eds.), Routledge Handbook of Food Waste. Routledge, London and New York.
Bräutigam, K.R., Jörissen, J., Priefer, C., 2014. The extent of food waste generation across EU-27: different calculation methods and the reliability of their results. Waste Manag. 32 (8), 683–694.
Bustos, A.C., Moors, E.H., 2018. Reducing post-harvestr food losses through innovative collaboration: insights from the Colombian and Mexican avocado supply chains. J. Clean. Prod. 199, 1020–1034.
Buzby, J.C., Farah-Wells, H., Hyman, J., 2014. The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States. US Department of Agriculture - Economic Research Service. USDA-ERS Economic Information Bulletin, Washington, p. 121.
Cahyana, A.S., Vanany, I., Arvitrida, N.I., 2019. Food waste in supply chains: a literature review. In: Proceesings of the International Conference on Industrial Engineering and Operations Management, (MAR), pp. 1646–1655.
Canali, M., Amani, P., Aramyan, L., Gheoldus, M., Moates, G., Östergren, K., Silvennoinen, K., Waldron, K., Vittuari, M., 2017. Food waste drivers in Europe, from identification to possible interventions. Sustainability 9 (1), 37.
Chaboud, G., Daviron, B., 2017. Food losses and waste: navigation the inconsistencies. Glob. Food Sec. 12, 1–7.
Chauhan, C., Dhir, A., Akram, M.U., Salo, J., 2021. Food loss and waste in food supply chains. A systematic literature review and framework developed approach. J. Clean. Prod. 295, 126438.
Contreras, J., Verthein, U., 2018. Hambre en la abundancia. In: ODELA, En (Ed.), Polisemias de la alimentación. Universitat de Barcelona, Barcelona, pp. 17–32.
Corrado, S., Sala, S., 2018. Food waste accounting along global and European food supply chains: state of the art and outlook. Waste Manag. 79, 120–131.
Cuéllar, A.D., Webber, M.E., 2010. Wasted food, wasted energy: the embedded energy in food waste in the United States. Environ. Sci. Technol. 44 (16), 6464–6469.
Del Giudice, T., La Barbera, F., Vecchio, R., Verneay, F., 2016. Anti-waste labelling and consumer willingness to pay. *J.* Int. Food Agribus. Mark. 28 (2), 149–163.
Delley, M., Brunner, T.A., 2018. Household food waste quantification: comparison of two methods. Br. Food J. 120 (7), 1504–1515.
Devin, B., Richards, C., 2018. Food waste, power, and corporate social responsibility in the Australian food supply chain. J. Bus. Ethics 50 (1), 199–210.
Dhir, A., Talwar, S., Kaur, P., Malibari, A., 2020. Food waste in hospitality and food services: a systematic literature review and framework development approach. J. Clean. Prod. 270, 122861.
Díaz-Ruiz, R., Costa, M., López, F., Gil, J.M., 2018. A sum of incidentals or a structural problem? The true nature of food waste in the metropolitan region of Barcelona. Sustainability 10 (10), 3730.
Do, Q., Ramudhin, A., Colicchia, C., Crazza, A., Li, D., 2021. A systematic review of research on food loss and waste prevention and management for the circular economy. Int. J. Prod. Econ. 239, 108209.
Dou, Z., Toth, J.D., 2021. Global primary data on consumer food waste: Rate and characteristics – a review. Resour. Conserv. Recycl. 168, 105332.
English, A., Ahmad, T., Biswas, A., 2018. Pilot Testing the Food Loss Index. Food and Agriculture Organization of the United Nations.
EC, 2020. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. Farm to fork strategy. For a fair, healthy and environmentally-friendly food system. COM(2020) 381. Final.
FAO, 2011. Global Food Losses and Food Waste – Extent, Causes and Prevention. Food Agric. Org. United Nations (FAO), Rome.
FAO, 2013. The Methodology of the FAO Study: "Global Food Losses and Food Waste – Extent, Causes and Prevention" – FAO, 2011. The Swedish Institute for Food and Biotechnology (SIK), Göteborg, Sweden.
FAO (2014). Definitional framework of food loss, Working paper (27th of February 2014), Rome.
FAO, 2019. The State of Food and Agriculture 2019, Moving Forward on Food Loss and Waste Reduction. Food and Agriculture Organization, Rome, Italy.
Fernández-Zamudio, M.A., Barco, H., Schneider, F., 2020. Direct measurement of mass and economic harvest and post-harvest losses in Spanish persimmon primary production. Agriculture 10 (12), 581, 1-20.
García-Herrero, I., Hoehn, D., Margallo, M., Laso, J., Bala, A., Batlle-Bayer, L., Fullana, P., Vázquez-Rowe, I., González, M.J., Durá, M.J., Sarabia, C., Abajas, R., Amo-Setién, F.J., Quiñones, A., Irabien, A., Aldaco, R., 2018. On the estimation of potential food waste reduction to support sustainable production and consumption policies. Food Policy 80, 24–38.
Gascón, J., Montagut, X. (2015). Banco de alimentos: ¿Combatir el hambre con las sobras?, Barcelona, Icaria.
Gascón, J., 2019. Comida no comida: Un análisis del desperdicio de alimentos desde la agroecología. In: ODELA, en (Ed.), Polisemias de la alimentación. Universitat de Barcelona, Barcelona, pp. 33–52.
Gascón, J., 2018. Food waste: a political ecology approach. Jl Political Ecol 25 (1), 587–601.
Gascón, J., Solà, C., Larrea, C., 2021. No es negociable: Desperdicio alimentario y relaciones de poder en la cadena agroalimentaria. Icaria, Barcelona.

Gascón, J., Solá, C., Larrea-Killinger, C., 2022. A qualitative approach to food loss. The case of the production of fruit in Lleida (Catalonia, Spain). Agroecol. Sustain. Food Syst. 42, 5.
Georgescu-Roegen, N., Bonaiuti, M., 2011. From economics to degrowth. ISBN 9781138802964.
Göbel, C., Langen, N., Blumenthal, A., Teitscheid, P., Ritter, G., 2015. Cutting food waste through cooperation along the food supply chain. Sustainability 7 (2), 1429–1445.
Griffin, M., Sobal, J., Lyson, T.A., 2009. An analysis of a community food waste stream. Agric. Hum. Values 26 (1/2), 67–81.
Guo, X.M., Trably, E., Latrille, E., Carrère, H., Steyer, J.P., 2010. Hydrogen production from agricultural waste by dark fermentation: a review. Int. J. Hydrog. Energy 35 (19), 10660–10673.
Hall, K.D., Guo, J., Dore, M., Chow, C.C., 2009. The progressive increase of food waste in America and its environmental impact. PLoS One 4 (811), e7940.
Harvey, J., Nica-Avram, G., Smith, M., Hibbert, S., Muthuri, J., 2021. Mapping the landscape of consumer food waste. Appetite 168 (1), 105702.
Hasset, A. F., Klippel, R. W., Bernstein, Sheldon, Homnick, Douglas, N., Mercer, Walter, A. (1973). Food processing waste management.
Hebrok, M., Boks, C., 2017. Household food waste: Drivers and potential interventions points for design – an extensive review. J. Clean. Prod. 151, 380–392.
Herzberg, R., Schmidt, T., Keck, M., 2022. Market power and food loss at the producer-retailer interface of fruit and vegetable supply chains in Germany. Sustain. Sci.
HESTIA database. Available at: https://www.hestia.earth/. Accessed on 2nd May 2022.
Hoehn, D., Margallo, M., Laso, J., García-Herrero, I., Bala, A., Fullana-i-Palmer, P., Irabien, A., Aldaco, R., 2019. Energy embedded in food loss management and in the production of uneaten food: seeking a sustainable pathway. Energies 12, 767.
Hoehn, D., Laso, J., Cristóbal, J., Ruiz-Salmón, I., Butnar, I., Borrion, A., Bala, A., Fullana-i-Palmer, P., Vázquez-Rowe, I., Aldaco, R., Margallo, M., 2020. Regionalized strategies for food loss and waste management in Spain under a life cycle thinking approach. Foods 9, 1765.
Hoehn, D., Laso, J., Margallo, M., Ruiz-Salmón, I., Amo-Setién, F.J., Abajas-Bustillo, R., Sarabia, C., Quiñones, A., Vázquez-Rowe, I., Bala, A., Batlle-Bayer, L., Fullana-i-Palmer, P., Aldaco, R., 2021. Introducing a degrowth approach to the circular economy policies of food production, and food loss and waste management: towards a circular bioeconomy. Sustainability 13, 3379.
Infante-Amate, J., González de Molina, M., 2017. Sustainable de-growth" in agriculture and food: An agro-ecological perspective on Spain's agri-food system (year 2000). J. Clean. Prod. 155.
Kafa, N., Jaegler, A., 2021. Food losses and waste quantification in supply chains: a systematic literature review. Brit. Food J. 123 (11), 3502–3521.
Kling, W., 1943. Food waste in distribution and use. Am. J. Agric. Econ. 25 (4), 848–859.
Koester, U., 2013. Total and per capita value of food loss in the United States, comments. Food Policy 41, 63–64.
Kummu, M., de Moel, H., Porkka, M., Siebert, S., Varis, O., Ward, P.J., 2012. Lost food, wasted resources: global food supply chain losses and their impacts on freshwater cropland, and fertiliser use. Sci. Total Environ. 438, 477–489.
Latouche, S., 2006. Le pari de la Décroissance. Fayard, Paris, France.
Lipinski, B., Hanson, C., Waite, R., Searchinger, T., Lomax J. (2013). Reducing food loss and waste, world resources Institute Working Paper, Jne.
Luo, N., Olsen, T.L., Liu, Y., 2021. A conceptual framework to analyze food loss and waste within food suuply chains: An operations management perspective. Sustainability 13 (2), 927, 1-21.
McLaren, S., Berardy, A., Henderson, A., Holden, N., Huppertz, T., Jolliet, O., De Camillis, C., Renouf, M., Rugani, B., Saarinen, M., Van Der Pols, J., Vázquez-Rowe, I., Antón Vallejo, A., Bianchi, M., Chaudhary, A., Chen, C., Cooreman-Algoed, M., Dong, H., Grant, T., Green, A., Hallström, E., Hoang, H., Leip, A., Lynch, J., McAuliffe, G., Ridoutt, B., Saget, S., Scherer, L., Tuomisto, H., Tyedmers, P., van Zanten, H., 2021. Integration of Environment and Nutrition in Life Cycle Assessment of Food Items: Opportunities and Challenges. FAO, Rome, Italy.
Messner, R., Richards, C., Johnson, H., 2020. The "Prevention Paradox": food waste prevention and the quandary of systemic surplus production. Agric. Hum. Values 1–13.
Mladenova, R, Shtereva, D., 2009. Pesticide residues in apples grown under a conventional and integrated pest management system. Food Addit. Contam Part A Chem. Anal Control Expo. Risk Assess, 26 (6), 854–858.
Monier, V., Mudgal, S., Escalon, V., O'Connor, C., Gibon, T., Anderson, G., Montoux, H., Reisinger, H., Dolley, P., Ogilvie, S., Morton, G., 2010. Final report – Preparatory study on Food Waste Across EU 27; European Commission [DG ENV-Directorate C]. BIO Intelligence Service, Paris.
Montagut, X., Gascón, J., 2014. Alimentos desperdiciados: Un análisis del derroche desde la soberanía alimentaria. Icaria, Barcelona.
Muriana, C., 2017. A focus on the state of the art of food waste/losses issue and suggestions for future researches. Waste Manag. 68, 557–570.
Nahman, A., Lange, W., 2013. Costs of food waste along the value chain: evidence from South Africa. Waste Manag. 33 (11), 2493–2500.
Nayak, A., Bhushan, B., 2019. An overview of the recent trends on the waste valorization techniques for food wastes. J. Environ. Manage. 233, 352–370.
OBrien, M., 2012. A "lasting transformation" of capitalist surplus: from food stocks to feedstocks. Sociol. Rev. 60 (2), 192–211.
OECD, 2017. Improving Energy Efficiency in the Agro-Food Chain, OECD Green Growth Studies. OECD Publishing, Paris, France.
Oliveira, M.M.D., Lago, A., Dal´Magro, G.P., 2021. Food loss and waste in the context of the circular economy: a systematic review. J. Clean. Prod. 294, 126284.
Östergren, K., et al., 2014. FUSIONS Definitional Framework of Food Waste: Full Report. Goteborg: SIK, UE, FUSIONS.
Parfitt, J., Barthel, M., Macnaughton, S., 2010. Food waste within food supply chains: quantification and potential for change to 2050. Philos. Trans. R. Soc. Lond. B 365, 30065–33081.
Porter, S.D., Reay, D.S., Bomberg, E., Higgins, P., 2018. Avoidable food losses and associated production-phase greenhouse gas emissions arising from application of cosmetic standards to fresh fruit and vegetables in Europe and the UK. J. Clean. Prod. 201, 869–878.
Priefer, C., Jörissen, J., Bräutigam, K.R., 2016. Food waste prevention in Europe – a cause driven approach to identify the most relevant leverage points for action. Resour. Conserv. Recycl. 109, 155–165.
Qi, D., Penn, K., Li, R., Roe, B.E., 2022. Winning ugly: Profit maximizing marketing strategies for ugly foods. J. Retail. Consum. Serv. 64, 102834.
Quested, T.E., Parry, A.D, Easteal, S., Swannel, R., 2011. Food and drink waste from households in the UK. Nutr. Bull. 36, 460–467.
Quested, T.E., Palmer, G., Moreno, L.C., McDermott, C., Schumacher, K., 2020. Comparing diaries and waste compositional analysis for measuring food waste in the home. J. Clean. Prod. 262, 121263.
Raak, N., Symmank, C., Zahn, S., Aschemann-Witzel, J., Rohm, H., 2017. Processing and product-related causes for food waste and implications for the food supply chain. Waste Manag. 61, 461–472.
Redlingshöfer, B., Coudurier, B., Georget, M., 2017. Quantifying food loss during primary production and processing in France. J. Clean. Prod. 164, 793–814.
Reynolds, C., Mirosa, J.M., Clothier, B., 2016. New Zealand's food waste: estimating the tonnes, value, calories and resources wasted. Agriculture 6 (1), 9.
Ristaino, J.B., Anderson, P.K., Bebber, D.P., Wei, Q., 2021. The persistent threat of emerging plant disease pandemics to global food security. AS 118 (23), e2022239118.
Roe, B.E., Van der Lans, I.A., Holthuysen, N., Nijenhuis-de Vries, M., Quested, T.E., 2020. The validity, time burden, and user satisfaction of the FoodImageTM smarthphone app for food waste measurement versus diaries: a randomized crossvertrial. Resour. Conserv. Recycl. 160, 104858.
Schanes, K., Dobernig, K., Gözet, B., 2018. Food waste matters- A systematic review of household food waste practices and their policy implications. J. Clean. Prod. 182, 978–991.
Sheahan, M., Barrett, C.B., 2017. Food loss and waste in Sub-Saharan Africa: a critical review. Food Policy 70, 1–12.
Spanish Government (2021). Anteproyecto de ley de prevención de las pérdidas y el desperdicio alimentario. Madrid, 21st October 2021. Available at: La Moncloa. 11/10/2021. Anteproyecto de Ley para combatir el desperdicio de alimentos en España [Consejo de Ministros].
Sullivan, D.M., Bary, A.I., Thomas, D.R., Fransen, S.C., Cogger, C.G., 2002. Food waste compost effects on fertilizer nitrogen efficiency, available Nitrogen, and tall Fescue yield. Soil. Sci. Soc. Am. J. 66 (1), 154–161.
Santos, P.H.A., Martins, R.A., 2021. Food waste and performance measurement systems: a systematic review of the literature. RAE. Revista de Administraçao de Empresas 61 (5), 1–24.
Soysal, M., Bloemhof-Ruwaard, J.M., Meuwissen, M.P., Van der Vorst, J.G., 2012. A review on quantitative models for sustainable food logistics management. Int. J. Food. Syst. Dyn. 3 (2), 136–155.
Spang, E.S., Moreno, L.C., Pace, S.A., Achmon, Y., Donis-González, I., Gosliner, W.A., Jablonski-Sheffiled, M.P., Momin, M.A., Quested, T.E., Winans, K.S., Tomic, T.P., 2019. Food loss and waste: measurement, drivers, and solutions. Annu. Rev. Environ. Resour. 44, 117–156.
Stenmarck, A., Jensen, C., Quested, T., Moates, G., Buksti, M., Cseh, B., Juul, S.L., Parry, A., Politano, A., Redlingshofer, B., Scherhauder, S., Silvennoinen, K., Soethoudt, H., Zübert, C., Östergren, K., 2016. Estimates of European Food Waste Levels, FUSIONS project. IVL Swedish Environmental Research Institute. ISBN 978-91-88319-01-2.
Stuart, T., 2009. Waste: Uncovering the Global Food Scandal. WW Norton & Company, New York.
Thorsen, M., Mirosa, M., Skeaff, S., 2022. A quantitative and qualitative study of food loss in glasshouse-frown tomatoes. Horticulturae 8 (1), 39.
Thyberg, K.L., Tonjes, D.J., Gurevitch, J., 2015. Quantification of food waste disposal in the United States: a Meta-analysis. Environ. Sci.Technol. 49 (24), 13946–13953.
United Nations (2015). Resolution adopted by the General Assembly on 25th of September 2015. Transforming our world: the 2030 Agenda for Sustainable Development. A/RES/70/1.
United Nations Environment Programme (2021), Food Waste Index Report 2021. Kenya, Nairobi.
Van der Werf, P., Gilliland, J.A., 2017. A systematic review of food losses and food waste generation in developed countries. Waste Resour. Manag. 170 (2), 66–77.
Van Giesen, R.I., De Hooge, I.E., 2019. Too ugly, but I love its shape: Reducing food waste of suboptimal products with authenticity (and sustainability) positioning. Food Qual. Prefer. 75, 249–259.
Van Herpen, E., Van der Lans, I.A., Holthuysen, N., Nijenhuis-de Vries, M., Quested, T.E., 2019. Comparing wasted apples and oranges: An assessment of methods to measure household food waste. Waste Manage. 88, 71–84.
Vázquez-Rowe, I., Laso, J., Margallo, M., García-Herrero, I., Hoehn, D., Amo-Setién, F., Bala, A., Abajas, R., Sarabia, C., Durá, M.J., Fullana-i-Palmer, P., Aldaco, R., 2020. Food loss and waste metrics: a proposed nutritional cost footprint linking linear programming and life cycle assessment. Int. J. Life Cycle Assess. 25 (7), 1197–1209.

Withanage, S.V., Dias, G.M., Habib, K., 2021. Review of household food waste quantification methods: Focus on composition analysis. J. Clean. Prod. 279, 123722.
WRAP (2016). Guidance for food and drink manufacturers and retailers on the use of food surplus as animal feed. Project code: CSC101-003.
Xue, L., Lui, G., Parfitt, J., Liu, X., Van Herpen, E., Stenmarck, A., OConnor, C., Östergren, K., Cheng, S., 2017. Missing food, missing data? A critical review of global food losses and food waste data. Environ. Sci. Technol. 51, 6618–6633.