European Commission

JRC TECHNICAL REPORTS

Suggestions to improve data coverage and comparability in food waste accounting studies across the EU

Carla Caldeira, Valeria De Laurentiis, Serenella Sala

2019

Joint Research Centre

EUR 30024 EN

Contact information
Name: Serenella Sala
Address: Joint Research Centre, Via E. Fermi, 2749, 21027 Ispra (VA) Italy
Email: serenella.sala@ec.europa.eu
Tel.: 0332/786417

EU Science Hub
https://ec.europa.eu/jrc

JRC118985

EUR 30024 EN

PDF	ISBN 978-92-76-14272-0	ISSN 1831-9424	doi:10.2760/850030
Print	ISBN 978-92-76-14271-3	ISSN 1018-5593	doi:10.2760/99859

Luxembourg: Publications Office of the European Union, 2019

How to cite this report: Caldeira, C., De Laurentiis, V., Sala, S. *Suggestions to improve data coverage and comparability in food waste accounting studies across the EU*, EUR 30024 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-14272-0, doi:10.2760/850030, JRC118985

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Acknowledgements

This report is a deliverable of the Administrative Arrangements between European Commission Joint Research Centre and DG Sante, contract n° 2018 SI2.776026.

Abstract

Member States are now obliged to monitor the generation of food waste along the food supply chain and to take measures to limit it. To contribute to the harmonization of food waste quantification in the EU, the European Commission has published a delegated act establishing a common methodology and minimum quality requirements for the uniform measurement of food waste generated in Member States. A review of studies quantifying food waste at Member State level carried out by the European Commission Joint Research Centre (EC-JRC) unveils big discrepancies in the state-of-play in food waste accounting across Member States. Only a few countries have quantified food waste along the entire food supply chain. Moreover, the studies reviewed were developed following different quantification approaches, including the adoption of different food waste definitions, which limits their comparability. Based on the review conducted, this report summarizes the main limitations and data gaps encountered that hinder comparability of the results, in light of what is required by the delegated act. Issues identified include: the food waste definition used, the assessment of edible and inedible food waste, the geographical and temporal scope and system boundaries, the quantification of food waste drained as/with wastewater, the choice of the measurement method, the use of primary and/or secondary data, the adoption of sampling and upscaling procedures, and the assessment of the results uncertainty. Additionally, suggestions are provided to support Member States in addressing the limitations and data gaps encountered. The harmonization of food waste quantification across the Member States is essential to ensure the comparability of the results and to assess the performance of the EU towards target 12.3 defined under the Sustainable Development Goal (SDG) 12 – Responsible Consumption and Production.

1 Introduction

The amendment to Directive 2008/98/EC on Waste (European Commission, 2018) obliges European Union (EU) Member States (MSs) to monitor the generation of food waste along the food supply chain (FSC) and to take measures to limit its generation. A review of studies quantifying food waste at MS level carried out by the European Commission Joint Research Centre (EC-JRC) (Caldeira et al., 2019a) unveils a big discrepancy in the state of-play in food waste accounting in MSs. Only a few countries have quantified food waste along the entire FSC. Moreover, the studies reviewed were developed following different quantification approaches, including different food waste definitions, which limits their comparability.

Guidelines for food waste quantification exist, such as:
a) the *Food Losses and Waste Standard* (FLW Standard) (FLW Protocol, 2016a) that was published by the Food Losses and Waste Protocol[1] in 2016 and was developed to support countries, cities, companies, and other entities in the development of inventories of food waste generated and its destinations. The standard provides requirements and guidance for quantifying (what to measure and how to measure it) and reporting on the weight of food and/or associated inedible parts removed from the FSC. It was developed to encourage consistency and transparency of the reported data, enabling the consistent quantification of baselines and tracking of progress towards target 12.3 as well as other targets (FLW Protocol, 2016a).
b) the *Food waste quantification manual to monitor food waste amounts and progression* that was published in 2016 in the FUSIONS[2] project (FUSIONS, 2016a). This quantification manual is consistent with the principles of the FLW Standard, but with a particular focus on the quantification of food waste in the MSs. The main objective of this manual is to support EU MSs in monitoring and reporting national food waste data in each sector of the FSC.
However, only few of the food waste quantification studies reviewed in Caldeira et al. (2019a) referred to the above-mentioned guidelines.

To contribute to the harmonization of food waste quantification in the EU, the European Commission (EC) has published a delegated act establishing a common methodology and minimum quality requirements for the uniform measurement of food waste generated in MSs (European Commission, 2019). The delegated act is expected to contribute to reduce the discrepancy in the state of play on food waste quantification among the different MSs by providing a common approach for MSs to develop their studies. Moreover, the harmonization of food waste quantification in the MSs is essential to assess the performance of the EU towards target 12.3 defined under the Sustainable Development Goal (SDG) 12 – Responsible Consumption and Production. This target aims at halving per capita global food waste at the retail and consumer levels, and reducing food losses along production and supply chains including post-harvest losses by 2030. The EC has committed in the European Circular Economy Action Plan to achieve the SDG target 12.3 (European Commission, 2015). To this end, it established in 2016 the EU Platform on Food Losses and Food Waste (FLW), which brings together EU institutions, experts from the EU countries and relevant stakeholders. The Platform aims to support all actors in: defining measures needed to prevent food waste; sharing best practices; and evaluating progress made over time (European Commission, 2017).

Based on the aforementioned review of studies on food waste quantification in EU MSs, and in support to the activities of the subgroup 'Food waste Measurement' of the EU Platform on FLW, the EC-JRC have identified the main limitations and data gaps encountered in the studies analysed, relatively to what is required in the established methodology. This report summarizes such findings and provides suggestions to support MSs in addressing the limitations and data gaps encountered, to improve data coverage and comparability across the EU in light of what is required by the delegated act.

[1] FLW Protocol is a multi-stakeholder partnership (e.g. WRI, FAO, WRAP, UNEP, and WBCSD), which has developed the FLW standard to report on food loss and waste and associated reporting tools.
[2] FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) was an EU-funded project carried out from 2007 to 2012 that developed recommendations for the measurement of food waste at MS level and estimated of food waste generation in the EU.

2 Suggestions to improve comparability of food waste quantification in Member States

The review carried out by the EC-JRC on food waste quantification in the MSs (Caldeira et al. 2019a) pointed out several methodological aspects that constrain significantly the comparability of the results of the different studies.

The methodological aspects are the following:

- Food waste definition;
- Assessment of edible and inedible food waste;
- Geographical and temporal scope and system boundaries;
- Inclusion of food waste drained 'as' or 'with' wastewater;
- Selection of the measurement method;
- Use of primary and/or secondary data;
- Adoption of sampling and upscaling procedures;
- Uncertainty assessment.

In the next sections, these aspects are discussed and possible ways forward are identified, by providing suggestions on how to address them (consistently with the requirements of the delegated act) in order to ensure comparability of the results of future studies on food waste quantification at national level.

2.1 Adopting a common food waste definition

The EC-JRC review study showed that different food waste definitions are used in studies quantifying food waste at MS level, which limits significantly the comparability of the results. For example, in some studies, food diverted to animal feed was not considered food waste, whilst in others it was (Caldeira et al., 2019a). Therefore, to ensure the comparability of future food waste accounting studies, **the definition of food waste adopted should be the one provided in the amendment to Directive 2008/98/EC on Waste** (European Commission, 2018). In this document, food waste is defined as:

"all food as defined in Article 2 of Regulation (EC) No 178/2002 of the European Parliament and of the Council (European Parliament and Council, 2002) that has become waste. The definition of 'food' laid down in Regulation (EC) No 178/2002 encompasses food as a whole, along the entire food supply chain from production until consumption. Food also includes inedible parts, where those were not separated from the edible parts when the food was produced, such as bones attached to meat destined for human consumption. Hence, food waste can comprise items that include parts of food intended to be ingested and parts of food not intended to be ingested. 'Waste' means any substance or object which the holder discards or intends or is required to discard" (European Parliament and Council, 2008).

The EC definition is in line with the one reported in FUSIONS which defines food waste as: *fractions of 'food and inedible parts of food removed from the food supply chain' to be recovered or disposed (including: composted, crops ploughed in/not harvested, anaerobic digestion, bioenergy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)* (FUSIONS, 2014). However, the EU definition of food waste does not include losses at stages of the food supply chain where certain products have not yet become food as defined in Article 2 of Regulation (EC) No 178/2002, such as edible plants, which have not been harvested, excluding crops ploughed in/not harvested which are instead included in the FUSIONS definition.

2.2 Considering both edible and inedible food waste

Another aspect that may hinder the comparability of different studies, and that is closely related to the food waste definition used in a study, is the distinction and quantification (or not) of edible and inedible parts of food. Among the 48 studies analysed by EC-JRC, most studies quantified both edible and inedible parts of food. 6 provided disaggregated results i.e. results for edible and inedible food waste separately, whilst 9 studies focused only on the edible parts of food.

According to the delegated act (European Commission, 2019), **MSs are obliged to report the total amount of food waste i.e. the sum of the edible and inedible parts of food. The breakdown between edible and inedible streams is voluntary. In case the study accounts for these streams separately, it is recommended to clearly identify what was accounted as edible and inedible components**. Although EU Regulation No 178-2002 specifies that 'food means any substance or product, […] intended to be, or reasonably expected to be consumed by humans,' this distinction is not always straightforward and is highly influenced by cultural and behavioural factors. For example, for some people, according to the recipe, vegetable and potato peelings are considered edible, whilst for others they never are. Similarly, in some cultures, parts of the fifth quarter of animals such as offal are traditionally eaten, but in others they are usually discarded (Nicholes et al., 2019; Roodhuyzen et al., 2017). For this reason, a clear identification of what is considered as edible and inedible parts of food (if the study makes this distinction) would be relevant for comprehensiveness of the study results and comparability. A good example of such approach are the studies carried out by the Flemish Food Supply Chain Platform for Food Loss (2017) and WRAP (2018).

2.3 Clearly defining the geographical and temporal scope, and system boundaries of the study

Another important aspect to ensure comparability across studies is to provide a clear identification of the geographical and temporal scope and of the system boundaries of the study, which was not always the case in the studies analysed by EC-JRC. **Therefore, studies should explicitly state:**

- **i) the geographical scope within which food waste occurs. In the context of the delegated act, the geographical scope should cover the entire country (adopting a territorial approach)[3];**
- **ii) the timeframe considered in the study, which in the context of the delegated act should be a full calendar year, and**
- **iii) the stages of the FSC included in the assessment (which in the context of the delegated act should be: primary production, processing and manufacturing, retail and other distribution of food, restaurants and food services, and households).**

For comprehensiveness, details should be provided on the individual activities considered at each stage of the supply chain. For example, at primary production these could include: harvesting, sorting, storing, and transport. The FUSIONS food waste quantification manual provides recommendations to quantify food waste at each stage of the food supply chain, illustrating the individual activities that can be considered within each stage (FUSIONS, 2016a). The manual has a sector-wise approach and presents sector-specific aspects for each stage of the FSC. For example, at primary production, it recommends which individual activities should be included in the food waste quantification for the following sectors: plant products, meat and farmed fish, wild fish and hunted, and products from animals (e.g. milk or eggs). Although MSs are not obliged to follow the approach suggested in the FUSIONS manual (i.e. sector-wise), this document is very useful to guide MSs in food waste

[3] This means including all the food waste generated within the borders of country A. This includes the quantities linked to the production of food taking place in country A to be exported to country B, and excludes the food waste generated in country C to produce commodities that are then imported and consumed within country A.

quantification and its use in the development of food waste quantification studies is suggested.

2.4 Accounting for food waste drained 'as' or 'with' wastewater

A stream that was barely accounted for in the food waste quantification studies analysed by EC-JRC was the food waste drained 'as' or 'with' wastewater. Some studies (e.g. Kaal et al. (2017); Van Dooren (2017); WRAP (2018)) accounted for liquid food waste separately, attributing the liquid food waste to specific food categories, such as milk or beverages in general. **According to the delegated act, the quantification of the share of food waste disposed 'as' or 'with' wastewater is not mandatory. However, MSs can provide such data on a voluntary basis, which would give a more complete picture on the food waste situation.** Additionally, the quantification of this stream would avoid that food waste is sent to sewer to 'reduce' the amounts of food waste reported. The methods used to quantify this stream were either surveys or kitchen diaries. However, such methods may provide inaccurate information as people tend to provide socially acceptable answers, underestimating the amounts of food waste they generate (Caldeira et al. 2019a). Current methods do not allow measuring this stream of food waste with a sufficient level of confidence ensuring the comparability of the data reported, highlighting the need for further research in this area. A promising approach has been recently presented by van Dooren et al. (2019) making use of a phone app to engage consumers in recording liquid food waste throughout the day. Recently, WRAP published guidelines to support business in the quantification of food waste discharged to the sewer/wastewater treatment as part of sludge generated from on-site treatment of effluent (WRAP, 2019).

2.5 Selecting the most adequate measurement method

The measurement method used to quantify food waste might influence significantly the results obtained. A list (and short description) of methods typically used to quantify food waste is presented in Annex 1. The methods are categorized in two groups:
1) *Direct methods*, quantifying directly the amount of food waste by: weighing, waste composition analysis (WCA), surveys, diaries, records, and observation;
2) *Indirect methods*, where food waste is estimated from various secondary data sources: modelling, mass balance, proxy data, and literature data.
The studies assessed in the EC-JRC review were conducted using a wide range of measurement methods and, in most cases, more than one method was used within the same study. The most used methods were surveys, literature data, and proxy data, which are the least accurate (Xue et al., 2017). Caution should be taken when using surveys to quantify food waste, as they might lead to an underestimation of the results due to social desirability bias (Xue et al. 2017). As highlighted by van Herpen et al. (2019), this risk is particularly high when surveys use 'general survey questions' (i.e. questions asking about the amount, frequency, or proportion of food waste generated on average and not referring to e.g. the past week). However, literature data and proxy data tend to provide less accurate results compared to surveys (FLW Protocol, 2016b).

To increase the robustness of food waste results, **the most accurate methods should be used in the quantification of food waste.** Additionally, more than one direct method can be used on the same sample to assess the robustness of the results as done by Giordano et al. (2018), who triangulated results obtained through WCA, surveys, and diaries.

The available resources (budget and time) will influence significantly the selection of the method to use. Methods more accurate such as WCA or weighing are more expensive and time costly than less accurate methods such as surveys.

Figure 1 and Figure 2 illustrate how direct and indirect methods, respectively, perform in terms of accuracy, objectivity, reliability, time, and cost based on the research published by Xue et al. (2017).

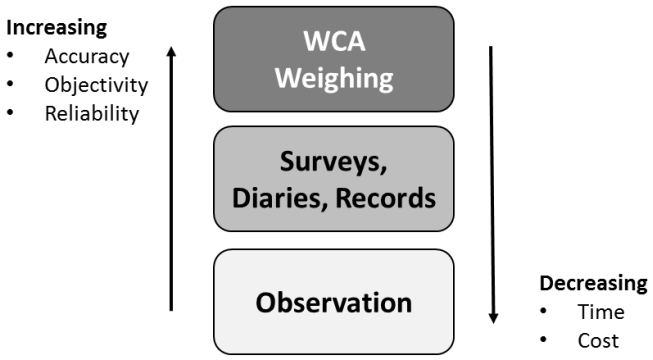

Figure 1. Direct measurement methods hierarchy in terms of time, cost, accuracy, objectivity, and reliability. Adapted from Xue et al. (2017). WCA: Waste Composition Analysis.

	Time	Cost	Accuracy	Objectivity	Reliability
High				Mass balance Proxy data Literature data	
Medium	Modelling		Mass balance Proxy data Literature data		Mass balance Proxy data
Low	Mass balance Proxy data Literature data	Mass balance Proxy data Literature data Modelling	Modelling		Literature data Modeling

Figure 2. Indirect measurement methods performance in terms of time, cost, accuracy, objectivity, and reliability. Adapted from Xue et al. (2017).

The FLW Protocol developed a tool to support entities carrying out food waste quantification studies in the selection of the most suitable measurement method, based on the resources and information available: the FLW Quantification Method Ranking Tool (FLW Protocol, 2016c), to be used as a complement to the FLW standard. The tool helps guide decisions regarding the most appropriate methods, based on a set of questions related to the circumstances (e.g. desired level of accuracy and access to the physical food waste being quantified) under which the entity is quantifying food waste. The methods available in this tool represent those commonly used to quantify food losses and waste (including those suggested in the delegated act) and are described in a guidance document which complements the FLW standard (FLW Protocol, 2016b). This document provides guidance on 10 quantification methods providing for each an overview, advantages and disadvantages, the level of expertise required, information over the costs, and guidance on implementing the different methods.

Annex III of the delegated act suggests which methods of measurement should ideally be used in the quantification of food waste at each stage of the FSC, as illustrated in Figure 3. Direct methods are reported in the green-shaded cells whilst indirect methods, in the blue-shaded cells. Cells with blue and green stripes include both direct and indirect methods. According to the delegated act, studies can make use of any other method equivalent in terms of relevance, representativeness, and reliability. Adopting the classification used in Xue et al. (2017), the majority of the methods suggested in the delegated act present medium to high level of accuracy and reliability.

<table>
<tr><th>Stage of the FCS</th><th colspan="6">Methods for food waste measurement</th></tr>
<tr><td>Primary Production</td><td rowspan="5">Direct measurement (Weighting or volumetric)***</td><td rowspan="3">Mass Balance**</td><td></td><td colspan="2" rowspan="2">Questionnaires and interviews**
Coefficients and production statistics**</td></tr>
<tr><td>Processing and manufacturing</td></tr>
<tr><td>Retail and distribution of food</td><td rowspan="3">Waste Composition Analysis***</td><td rowspan="2">Counting/ Scanning**</td><td></td></tr>
<tr><td>Restaurants and food services</td><td></td><td rowspan="2">Diaries**</td></tr>
<tr><td>Households</td><td></td><td></td></tr>
</table>

Figure 3. Accuracy and reliability of the methods suggested in the Delegated Act (Xue et al., 2017) (***high, **medium, *low).

2.6 Ensuring food waste quantification studies are based as much as possible on primary data

There is a significant lack of food waste data based on direct measurements at all stages of the food supply chain. Literature and proxy data combined were the main sources of data adopted in the studies analysed by EC-JRC. This was also identified by Xue et al. (2017) that examined 202 publications which reported food loss and waste data for 84 countries. According to the authors, only 20% of the studies were based on first-hand primary data, which signals high uncertainties in the existing global food losses and waste inventories. **Therefore, more field work and primary data collection should be promoted to fill data gaps and help verifying existing estimations, contributing to a more accurate and reliable picture on food waste generation.**

Although the lack of data is a crosscutting issue for all sectors of the food supply chain, it is more prominent at the primary production and at the processing and manufacturing stages. Among the 48 studies analysed in the EC-JRC review, 7 quantified food waste generated at primary production using direct measurement methods. Of these, six studies used surveys (Roels et al. 2017, Franke et al. 2016, Värnik et al., 2018, Ministerio de Agricultura, Pesca y Alimentación, 2018, Vernier et al., 2016, Baptista et al., 2012) and one used a combination of weighing and records (Flemish Food Supply Chain Platform for Food Loss, 2017). Some of the studies reporting food waste at primary production (e.g. Hartikainen et al. 2018) had used the FUSIONS food waste definition, which includes food that is left on field. As mentioned previously, crops left on field are not considered food waste according to the definition considered in the delegated act ('Food waste does not include losses at stages of the food supply chain where certain products have not yet become food as defined in Article 2 of Regulation (EC) No 178/2002, such as edible plants which have not been harvested' (European Commission, 2019). Therefore, such studies cannot be used to assess food waste at primary production as defined in the delegated act.

Although not covered by the delegated act, this stream – which is designated in this report as food losses - should ideally be captured as it is representative of the inefficiencies of the food system. Major causes for leaving crops on fields are market conditions such as for example cosmetic specifications or supply and demand contractual conditions. According to Porter et al. (2018) over a third of total farm production is lost for aesthetic reasons. Other causes of food losses are adverse climate conditions, pests and diseases. Better agricultural practices might contribute to the reduction of such losses, as well as to reduce the amount of produce left on field due to losses during harvesting (also not included in the scope of the delegated act). Figure 4 represents in the white boxes the streams that are not included in the scope of the delegated act (here defined as food losses) and, in the grey boxes, the flows considered food waste in light of the delegated act. The quantification of food losses is important so that action can be taken towards their minimization, consequently increasing the efficiency of the food supply chain.

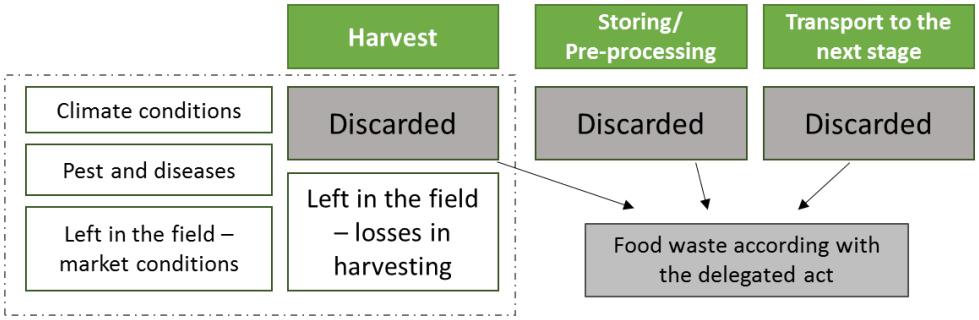

Figure 4. Representation of the food waste (grey boxes) and food losses (white boxes) streams in individual stages in primary production (e.g. plant products).

More data on food waste at primary production needs to be collected. Besides the food that is being discarded, it is also relevant that MSs capture the streams that are instead lost due to market conditions. Such information is relevant to identify actions that will allow reducing such losses (e.g. the creation of new business models or the improvement of management practices).

Johnson et al. (2018) reported that, so far, the majority of studies estimating food waste (and/or food losses) at primary production have based their data collection on interviews and surveys, highlighting the potential inaccuracy of these estimates. This might be due to a 'reluctance to disclose' data (Milepost Consulting, 2012), or due to wide variability and impossibility in confirming the estimates (Berkenkamp & Nennich, 2015; Rogers, 2013; Snow & Dean, 2016; WRAP, 2011; Hartikainen et al., 2018). To overcome the risk of underestimation limitations, field sampling techniques have been used in recent studies to provide a more robust estimation in comparison to a grower's visual or perceived estimate of what remains in the field (Schneider et al., 2019; Johnson et al., 2018). Estimates derived from interviews could be made more reliable with corroboration through field sampling. These types of studies would also allow overcoming an existing limitation of using statistics that are compiled by MSs in line with European and FAO guidelines (FAO, 2019); the primary agricultural production data in those statistics refer to harvested crops, slaughtered animals, and captured fish, and do not include loss of production ready to be harvested (slaughtered, captured). According to Johnson et al. (2018) and Hartikainen et al. (2018), the engagement of farmers and key stakeholders is a key factor for the success of studies using either surveys or field measurement to quantify food losses and food waste at primary production.

Regarding the processing and manufacturing stage, a major obstacle to food waste quantification is the confidentiality of business data (Redlingshöfer et al., 2017). Other factors causing scarcity of data at this stage are the inexistence of mandatory reporting requirements on food waste data (Kranert et al., 2012) and a lack of incentives for manufacturers to respond to surveys (Värnik et al., 2018). To overcome such limitations, it is necessary that businesses understand the advantages of quantifying food waste. The quantification of food waste in industries will allow identifying hotspots where the processing processes can be optimized to increase their efficiency, either by reducing directly the amounts of food waste or by allowing the identification of streams the can be valorised by other industries (e.g. pharmaceutical, cosmetic).

The scarcity of data on food waste generated at retail and distribution and by food services, makes it challenging to conclude about the overall food waste generation from these sectors (Beyer et al., 2012; Lebersorger & Schneider, 2014). Several authors have highlighted the need to conduct research on food waste in the retail sector at national level, stressing the importance of collecting data from a large sample size and for long periods of time (Bilska et al., 2018; Kranert et al., 2012; Beyer & Winter, 2016).

More data is available on food waste generated at the household consumption stage compared to the other stages of the FSC. Nevertheless, the quality of the data may be questionable. There could be an underestimation of food waste amounts due to biases in the measurement method, as it is the case of results obtained using surveys. Additionally, the household sector is very diverse and the food waste generation depends on several factors

such as the household structure, eating and consumption habits, the variability of the seasons and special holidays (Abeliotis et al., 2015; Szabó-Bódi e al., 2018). Therefore, as discussed in the next section, ensuring the representativeness of the sample is also a key factor to ensure the quality of the data.

2.7 Adopting robust and transparent sampling and upscaling procedures

The quantification of food waste at national level will very likely involve sampling[4] and upscaling[5] data as it is unfeasible to collect data that cover the whole food waste generation sites and/or timeframe. The results of the studies presented in the EC-JRC review were obtained through sampling and upscaling. However, information on the sampling procedure adopted and upscaling approach was barely provided. Exceptions are studies Stensgård & Hanssen (2018), WRAP (2018) and Syversen et al., (2018) where the upscaling procedure adopted to obtain results at national level is explained in detail. As an example, Stensgård & Hanssen (2018) collected data on food waste generation from food manufacturing companies, covering approximately one quarter of total sales at national level. This information was then used to upscale the results obtained by multiplying the production volume by the percentage of waste recorded by the reporting companies by product group and year. Data for the annual production volume of each product group at national level were taken from Statistics Norway's Table 10455 'Sold Production of Goods for Large Industrial Companies, by 8-digit PRODCOM Code'.

The representativeness of the sample and the adequacy of the upscaling factor are two key elements to ensure the reliability and accuracy of the results. For this reason, studies should clearly provide information on the sampling procedure adopted. The lack of such information precludes the assessment of the accuracy of the results as well as the comparison between different studies. To be compared, results should be obtained through representative samples. **Therefore, studies quantifying food waste should report clearly which sampling and upscaling procedures were adopted, ensuring that the procedures followed are adequate.**

The FLW Standard (FLW Protocol, 2016a) provides in Appendix 2 a general guidance on sampling, including considerations important for (i) selecting the sampling approach, (ii) obtaining a sample that represents food waste production over time, and (iii) determining the appropriate sample size. It also provides guidance on upscaling approaches, which is required when the sample data do not cover the whole population and/or timeframe of the food waste inventory (FLW Protocol, 2016a). The FUSIONS quantification manual provides some indicative upscaling factors for each stage of the FSC. Those factors were used in the quantification exercise carried out by the project (FUSIONS, 2016b).

The delegated act suggests a set of indicators to be used to estimate the food waste generated in those years where 'in-depth measurement' is not used (i.e. following the methods suggested in Annex III of the delegated act and reported in Figure 3 of this report). This is based on the principle that these indicators are likely to be correlated with food waste generation and can therefore be used to upscale or downscale food waste amounts from one year to another. MSs can use other indicators if they are better correlated with the generation of food waste within a given stage of the food supply chain (EC, 2019).

It is interesting to note that, although the use of these two sets of indicators (the one provided in FUSIONS, and the one provided in the delegated act) is different, the indicators suggested for each stage of the FSC are very similar. Table 1 presents the upscaling factors used in FUSIONS and the indicators suggested in the delegated act for each stage of the FSC.

[4] the process of choosing to measure or approximate, over a given period of time, the amount of food waste from a subset of FLW-producing units within a population, or from a fraction of the physical food waste produced.

[5] the adaptation of the sample data to cover the entire scope of a sector or of a segment of sector of which it is deemed representative.

Table 1. Upscaling factors used in the FUSIONS food waste quantification (FUSIONS, 2016a) and indicators suggested in the delegated act to be used when 'in depth measurement' are not possible (European Commission, 2019).

Stage of the FSC	Scaling factors used in FUSIONS (FUSIONS, 2016a)	Indicators suggested in the Delegated act (European Commission, 2019)	NACE Codes
Primary production	Produced food amounts	Food production in agriculture, fishery, and hunting	01-03
Processing and manufacturing	Produced food amounts	Production of processed food (based on Prodcom data*)	10-11
Retail and other distribution of food	Population (but turnover would be preferred)	• Turnover of food products • Population	46-47
Restaurants and food services	Turnover number	• Turnover • Employment	55-56
Households	Population	• Population • Households disposable income**	Not applicable

*Commission Regulation (EC) No 912/2004 of 29 April 2004 implementing Council Regulation (EEC) No 3924/91 on the establishment of a Community survey of industrial production (OJ L 163, 30.4.2004, p. 71).
**As reported by Eurostat.

2.8 Performing the uncertainty assessment of the results

Food waste quantification studies entail several sources of uncertainty that should be analysed. However, this aspect was barely addressed in the existing studies quantifying food waste in the MSs. The assessment of the uncertainty associated with food waste figures is important because such uncertainty will affect both the results and the conclusions drawn from them (FLW Protocol, 2016a). Therefore, **studies quantifying food waste should provide an assessment of the uncertainty (if not quantitative, at least qualitative) associated with the results presented.** The FLW Standard (FLW Protocol, 2016a) provides a list of potential sources of uncertainty that include for example, systematic, methodological, and data-processing errors. The standard provides as well approaches to perform quantitative and qualitative uncertainty assessment. A qualitative description of uncertainty should list and describe the various sources of uncertainty assessed during the course of the study. A discussion of the potential impact of uncertainty on the results should also be provided (if an estimate is not provided). A more robust uncertainty assessment is done through a quantitative approach, which allows presenting the results with a confidence interval. Many researchers use the 95% confidence interval that describes the range in which the results of 95 percent of the hypothetical calculations would be found if the study were to be repeated in the same way (FLW Protocol, 2016a). Guidance on how to perform such assessments is provided in the Chapter 9 of the FLW Standard (FLW Protocol, 2016a).

2.9 Summary of suggestions to improve data coverage and comparability of food waste studies

Table 2 presents a summary of the key methodological aspects that may hinder the comparability of results of food waste quantification studies identified based on the EC-JRC review study (Caldeira et al. 2019a). It also provides suggestions on how to address such issues, in order to improve data coverage and comparability of studies carried out by MSs in light of what is required by the delegated act (EC, 2019). Moreover, it refers to studies that have addresses such issues that can be used as an example. The suggestions herein provided should be taken upon by those developing food waste quantification studies but also highlight the areas in which the EC and the scientific community can develop further work towards the harmonization of food waste quantification and the increase of its robustness.

In order to address some of the methodological aspects reported in Table 2, further guidance could be provided by the EC based on existing research. The EC could for example provide guidance on what should be accounted for as edible or inedible parts of food, in order to minimise discrepancies due to different cultural and behavioural conditions. Furthermore, it could be more prescriptive on the choice of measurement method to be used in food waste quantification studies. The delegated act provides a list of methods that could be used and it also states that studies can make use of any other method that is equivalent in terms of relevance, representativeness, and reliability. However, no guidance is provided on how such equivalence can be assessed. Therefore, additional research and guidance should be developed on this matter. This can be done by capitalizing on existing tools such as the FLW Quantification Method Ranking Tool (FLW Protocol, 2016c), to be used as a complement to the FLW standard (FLW Protocol, 2016b). The FLW standard can also be a very useful source for the development of guidance on 'sampling and upscaling' or in 'uncertainty assessment'.

However, other methodological aspects have been barely addressed by the scientific community so far, and further research is therefore needed before guidance can be provided. This is the case of the quantification of food waste drained 'as' or 'with' wastewater, for which current methods do not allow measuring this stream of food waste with a sufficient level of confidence.

The collection of primary data on food waste generation is without doubt a key area in which more studies need to be developed. This would require the collaboration between the scientific community in supporting the development of such studies, the MSs that would be responsible for coordinating them, and the EC that should verify and assess the quality of the procedures followed and of the results. Due to the high cost of this type of studies the EC could consider to provide funding for the development of adequate primary data collection, in order to increase the robustness and coverage of the primary data used to quantify food waste in the MSs.

Table 2. Suggestions to improve data coverage and comparability of food waste studies and related examples from the literature.

Key methodological aspects	Suggestion to improve data coverage and comparability of food waste studies	Examples from the literature
Food waste definition	A crucial aspect to be considered in studies carried out to quantify food waste in the MS is the use of the same food waste definition, which should be the one defined in the amendment to Directive 2008/98/EC on Waste	
Quantification of edible and inedible parts of food	According to the delegated act, MSs are obliged to report the total amount of food waste i.e. the sum of the edible and inedible parts of food. The breakdown in edible and inedible streams is voluntary. In case a study accounts for these streams separately, it should clearly state what is considered edible/inedible.	Flemish Food Supply Chain Platform for Food Loss (2017) WRAP (2018)
Geographical and temporal scope, and system boundaries of the study	Studies should explicitly state: i) the geographical borders considered in the study, which in the context of the delegated act should cover the entire country; ii) the timeframe considered in the study, which in the context of the delegated act should be yearly; and iii) the stages of the FSC included in the assessment (which in the context of the delegated act should be primary production, processing and manufacturing, retail and other distribution of food, restaurants and food services, and households).	Flemish Food Supply Chain Platform for Food Loss (2017)
Food waste drained 'as' or 'with' wastewater	According to the delegated act, the quantification of the share of food waste disposed as or with wastewater is not mandatory. However, MSs can provide such data on a volunteer basis, which would provide a more complete picture of the food waste situation. This stream of food waste can be measured using kitchen diaries and specific phone apps, taking care in minimising the risk of underestimating the results.	Kaal et al. (2017) Van Dooren (2017) WRAP (2018)
Measurement method	To increase the robustness of food waste results, the most accurate methods should be used in the quantification of food waste. Additionally, more than one direct method can be used on the same sample to assess the robustness of the results. The FLW standard provides guidance on the selection of the most adequate method for each stage of the FSC depending on the resources available.	Flemish Food Supply Chain Platform for Food Loss (2017) WRAP (2018) Van Dooren (2017) Giordano et al. (2018)
Use of primary data	More field work and primary data collection should be promoted to fill data gaps and help verifying existing data, contributing to a more accurate and reliable picture on food waste quantification.	Schneider et al. (2019) Eriksson et al. (2012)
Sampling and upscaling	Studies quantifying food waste should report clearly on the sampling and upscaling procedures adopted, ensuring that the procedures followed are adequate. The FLW standard provides guidance on sampling and upscaling.	Stensgård & Hanssen (2018) WRAP (2018) Syversen et al. (2018)
Uncertainty Assessment	Studies quantifying food waste should provide an assessment of the uncertainty (if not quantitative, at least qualitative) associated with the figures presented. The FLW standard provides guidance on how to perform such assessment.	Caldeira et al. (2019b) Beretta et al. (2013)

3 Conclusions

The review of studies quantifying food waste at MS level carried out by EC-JRC showed a considerable discrepancy in the state of-play in the food waste assessments performed so far by the MSs. Only a few countries have quantified food waste along the entire FSC and, among those that did, different quantification approaches were followed, including the adoption of different food waste definitions. This limits significantly the comparability of the results obtained. In order to improve the comparability of food waste quantification in MSs, this report analyses the main points of discrepancy (relatively to what is required in the delegated act (EC, 2019)) in the studies reviewed and provides suggestions to address such issues.

It is essential that studies use a common food waste definition, which is now defined in the amendment to Directive 2008/98/EC on Waste. Such definition implies the quantification of both edible and inedible food waste. Since the distinction between edible and inedible is not always straightforward and is highly influenced by cultural and behavioural factors, to ensure the comprehensiveness of a study and the comparability of its findings with similar studies, it is important to clearly specify which components are considered edible/inedible, when such distinction is made. Although the quantification of the share of food waste disposed 'as' or 'with' wastewater is not mandatory in the delegated act (MSs can do it on a voluntary basis), the quantification of this waste stream would be relevant to ensure the comprehensiveness of the study. Critical aspects for the robustness of the results are the choice of the most accurate measurement method, and the collection of primary data, ensuring that such data is collected from representative samples and that the adequate upscaling approach is adopted. Additionally, it is also important to perform the assessment of the uncertainty associated with the food waste figures because such uncertainty will affect both the results and the conclusions drawn from them.

The suggestions herein provided should be taken upon by those developing food waste quantification studies but also highlight the areas in which the EC and the scientific community should develop further work towards the harmonization of food waste quantification in MSs. For some of the aspects identified the EC could provide additional guidance. This is the case of food waste measurement methods, sampling and upscaling procedures, and uncertainty assessment of the results. For other aspects, further research is needed before guidance can be provided. For instance little evidence is available on which approach should be adopted to quantify food waste drained 'as' or 'with' wastewater with a sufficient level of confidence. A crucial aspect that needs to be addressed to increase the robustness of food waste accounting in the MSs is the collection of primary data. As MS will start collecting data from 2020 the situation is expected to improve. However, due to the high economic burden that this type of studies may represent, the EC might consider providing specific funding to further support the development of measurement methods and quantification studies.

The harmonization of food waste quantification across MSs is essential to ensure comparability of results and to assess the performance of the EU towards target 12.3 defined under the Sustainable Development Goal (SDG) 12 – Responsible Consumption and Production. The suggestions herein presented intend to support MSs in identifying essential aspects that need to be taken into consideration when developing food waste quantification studies.

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List of abbreviations

DG Directorate General

EC European Commission

EU European Union

FAO Food and Agriculture Organization

FLW Food Losses and Waste

FSC Food supply chain

FUSIONS Food Use for Social Innovation by Optimising Waste Prevention Strategies

FSC Food supply chain

GHG Greenhouse Gas

HaFS Hospitality and food service sector

JRC Joint Research Centre

MS Members State

SDG Sustainable Development Goal

WRAP Waste and Resources Action Programme

WCA Waste Composition Analysis

WDCSD World Business Council for Sustainable Development

WRI World Resources Institute

UNEP United Nations Environmental Programme

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Annexes

Annex 1. List and short description of methods for food waste quantification

Description of the type of methods for food waste quantification obtained from Caldeira et al. (2017):

Direct methods

Weighing - Use of weighting scales to measure the weight of food waste. It may or may not include waste composition analysis.

Waste Composition Analysis (WCA) - Physically separate, weight and categorise food waste. This method may be used to separate food waste from a 'waste' stream that includes other material, which is not food waste. It may also be used to understand the different materials that make up food waste (e.g. types of food categories, or amount of food waste that is food versus associated inedible parts).

Surveys - Collect information regarding individuals or entities on attitudes, beliefs and self-reported behaviours on food waste through questionnaires.

Diaries - Collect data from daily records on amount and type of food waste for a period of time.

Records - Determine the amount of food waste based on information collected that is not initially used for food waste record (e.g. warehouse record books).

Observation - Assess the volume of food waste by counting or using scales with several points to evaluate food leftover by visual method.

Indirect methods

Modelling – Calculate the amount of food waste using mathematical models based on factors that are related to its generation, using for example waste coefficients.

Mass balance - Infer food waste by measuring inputs (e.g. ingredients at a factory site) and outputs (e.g. products made) alongside changes in levels of stock and changes to the weight of food during processing (e.g. evaporation of water during cooking).

Proxy data - Infer food waste using data from companies or statistical agencies (often used for upscaling data to produce aggregated food waste estimates).

Literature data - Use data directly from literature or calculate the amount of food waste based on data reported in other publications.

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KJ-NA-30024-EN-N

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doi:10.2760/850030

ISBN 978-92-76-14272-0