

## Review Article

# What a waste! Evidence of consumer food waste prevention and its effectiveness

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## ABSTRACT

Food waste is a great challenge hindering food system sustainability, embodying environmental impacts, economic costs as well as affecting food and nutritional security. Consumers are the most wasteful segment in the food supply chain, and policymakers have recognized the need to tackle consumer food waste by establishing the international reduction target of 50 % by 2030 in SGD 12.3. In order to reach this ambitious target, effective prevention interventions have to be implemented to enable consumers to reduce the amount of food they waste. This review aims to identify which are the different types of interventions conducted as well as their effectiveness in reducing consumer food waste. It does so by performing a systematic literature review according to the PRISMA protocol, through which 49 unique sources were selected for analysis, uncovering great heterogeneity in terms of types of interventions, methodologies and food waste reduction potential but also emphasizing how food waste literature is quickly evolving. Results included mostly examples of nudges, educational programs for school children and to a lesser extent awareness raising. A greater variety of approaches in intervention design and implementation, such as co-creation or the use of digital technologies is detected. The findings of this review help systematize the most recent evidence on food waste reduction efforts at consumer level and expose some gaps which need to be addressed in future research as well as opportunities for further exploitation of results. The food waste reduction potential identified by the actions gathered in the results of this review show that greater effort must be applied, if we are to reach internationally agreed targets. More consistent monitoring and reporting, knowledge sharing and replication of existing interventions are suggested to improve the evidence base on effective interventions. Cost benefit analysis and cost-effectiveness implications should also be included in future analyses and shared with the food waste prevention community in order to support the implementation of suitable policies.

## 1. Introduction

Consumers are estimated to be the most wasteful stage in the food supply chain, especially in high-income countries (United Nations Environmental Program, 2021). In 2019, around 932 million tonnes of food waste were generated globally, 61 % of which came from households. In high income countries, food waste at households accounts yearly about 79 kg of food waste per person (United Nations Environmental Program, 2021). The latest estimates for Europe establish that 59million tonnes of food are wasted yearly, amounting to a value of 130 billion euros (Eurostat, 2022). De Laurentiis et al. (2021) confirm similar food waste levels across the food supply chain, and Caldeira et al. (2019a) support that consumers are the most wasteful step of the food supply chain. The negative impacts associated with food waste concern

the inefficient allocation of resources, the environmental impacts embedded in food production and associated supply chains (Parfitt et al., 2010; Scherhauser et al., 2018), as well as the negative social outcomes in terms of food security (HLPE, 2014).

Waste, and food waste, generation has been acknowledged as an issue as early as the 1970s, with the theorization of waste hierarchies (Reynolds, 2023). However, topical research on food waste specifically has steadily increased since 2011 (Chauhan et al., 2021), when the first estimation of the global food waste levels was established (Gustavsson et al., 2011). The growing body of knowledge on food waste recognises it as a multifaceted issue deserving of analysis from different disciplines and points of view. Policymakers have also put the issue of food waste on their agendas: at a global level, the UN has established SDG 12.3, requiring a 50 % reduction target for retail and consumption level waste,

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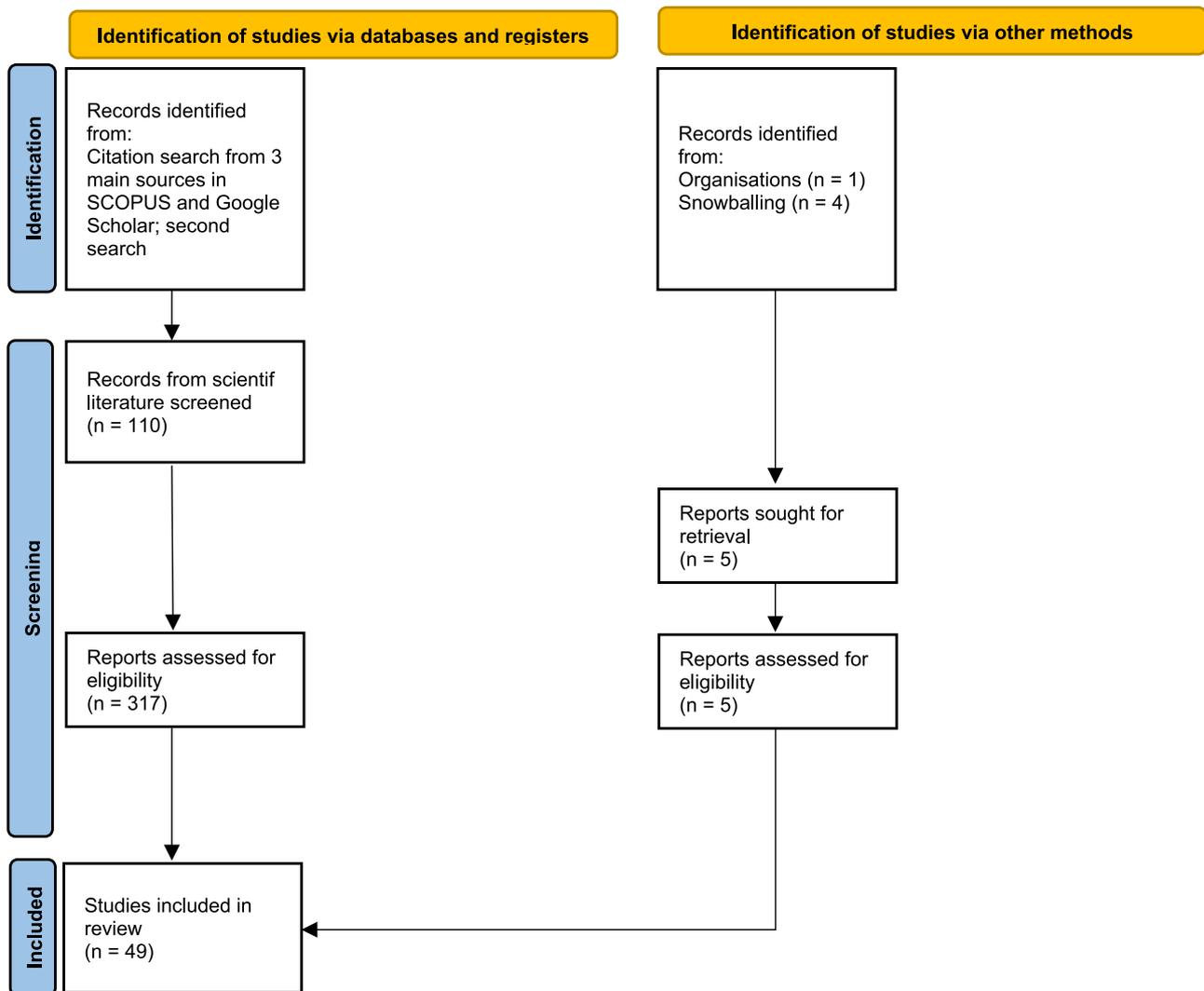


Fig. 1. PRISMA diagram of the review, adapted from Page et al. (2021).

alongside a reduction in food losses from production and other steps by 2030). The European Commission has acknowledged this target within the Farm to Fork strategy (European Commission, 2020), and will subsequently put in place regulation enforcing a commitment, by proposing legally binding targets for food waste at Member States' level (European Commission, 2018). These regulatory attempts are part of the EU commission's policies to establish sustainable production and consumption patterns, as displayed in the European Green Deal, Farm to Fork Strategy and Circular Economy Action Plan. Garske et al. (2020) analyse food waste governance at EU level, uncovering the difficulty in achieving policy cohesion across the different domains legislating over food production (through the Common Agricultural Policy and Common Fisheries Policy), food safety (through Food Law) and waste management (through the Waste Framework Directive), and highlight how this incoherence can hinder substantial reduction of food waste across the supply chain. As the application of effective prevention interventions needs to be widespread, policymakers are in the unique position to establish an enabling environment for food supply chain actors to monitor, report and ultimately reduce food waste levels. With this need, the European Commission established the EU Platform on Food Losses and Food Waste in 2016, which functions as a multi-stakeholder platform with a mandate to collect information and disseminate evidence on best practices for food waste reduction from all Member States. In 2019, the Platform issued Recommendations for Action in Food Waste Prevention (EU Platform for Food Losses and Food Waste, 2019); based on

these recommendations, the European Consumer Food Waste Forum was established in 2021 "to conduct research, issue evidence-based recommendations and to develop tools to help reduce consumer food waste", aiming to research, evaluate and share best practices to facilitate uptake of effective interventions (Candea et al., 2023).

Numerous interventions to prevent, reduce, and manage food waste have been deployed at different stages of the supply chain and at different scales. From improvements in supply chain efficiency in food production (Ludwig-Ohm et al., 2019) and processing (Principato et al., 2019; Stone et al., 2019), and retailers (Dreyer et al., 2019) to national awareness campaigns (*Love Food Hate Waste* from WRAP in the UK and several other countries and *Zu gutt für die Tonne* in Germany are some more prominent examples). However, consumer level food waste presents additional obstacles for quantification and monitoring (van Herpen et al., 2019) as well as being closely linked the complexity of the behavioural antecedents causing it (Vittuari et al., 2023; Schanes et al., 2018; Stancu et al., 2016). Well-designed interventions have to be put in place at scale, coupled with consistent monitoring and knowledge sharing on best practices, to reach the SDG 12.3 target.

In order to understand what is effective and efficient in terms of consumer food waste reduction and why, scholars have highlighted the need for accurate evaluation. Stöckli et al. (2018) have first drawn attention to this research gap in evaluation practices, encouraging researchers to provide further evidence-based evaluations of consumer food waste interventions as well as designing a wider variety of

intervention types, preferably including insights from behavioural sciences. An initial exercise in evaluation was conducted by Reynolds et al. (2019), who provide an overview of existing intervention types and identify some key principles to consider for effective interventions (design, monitoring and measurement, moderation and mediation, reporting, considering systemic effects). To further address the gap in systematic evaluation, Caldeira et al. (2019b) proposed a comprehensive evaluation framework and applied it to a sample of interventions carried out throughout Europe. This evaluation framework includes five criteria: quality of the action design, effectiveness, efficiency, sustainability over time and transferability/scalability. The assessment exercise was based on surveyed interventions taking place in Europe across the supply chain; out of an initial sample of 91 interventions, 15 were considered to be targeting consumer behaviour change (Caldeira et al., 2019b). Wegner et al. (2020) applied a similar evaluation approach to display the results of a three year-long research project, providing an example of the added value of having consistent evaluation efforts and transparent data sharing. A master thesis also provided an application of the evaluation framework for initiatives active in Belgium (Hardy, 2021).

Acknowledging the rapid evolution in of food waste literature, and specifically of interventions aimed at food waste reduction, there is still not enough information to compare results to guide policymakers and practitioners in designing and implementing (cost-) effective interventions (Caldeira et al., 2019b). This work builds from the conclusions discussed by Reynolds et al. (2019) and Stöckli et al. (2018), and the intervention evaluation contained in Caldeira et al. (2019b) and provides a systematic literature review on food waste interventions at the consumer level, assembling evidence of recent efforts in tackling consumer food waste. Setting this scene, the research questions guiding this review are:

- 1) What type of interventions are being deployed and how are they designed?
- 2) How are consumer food waste interventions being evaluated and what are the indicators being used to assess their effectiveness?
- 3) What are the research gaps and policy recommendations?

## 2. Materials and methods

A systematic literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol checklist (Page et al., 2021). The starting point of the work were three main sources: Stöckli et al. (2018), Caldeira et al. (2019b) and Reynolds et al. (2019) for which a citation search was conducted on both Scopus and Google Scholar databases. These databases were chosen for the review because they represent the most widely used interdisciplinary repositories; the citation search was executed also on Google Scholar because the search engine can source grey literature sources, such as theses, dissertations and policy documents. The review was limited to very recent literature, covering the years from 2019 to May 2023 and builds on previous work, as it was assumed that the three principal sources had already assessed the work reported up to 2019 extensively enough to capture relevant trends. The citation search was complemented with a query in SCOPUS, using the search string: “(food AND waste) AND (consum\*) AND (intervention)” (in title, key words and abstracts), considering the same time frame of the first search (from 2019 to 2023).

The review expanded to grey literature to verify the availability of information on interventions published in the same time frame (2019–2022). The aim of this search was the possible inclusion of examples coming from concrete settings rather than from experiments alone. It was assumed that results from this exploration could provide evidence for longer lasting interventions and guide the review towards a more practical perspective.

Key repositories of projects and best practices related to food waste

**Table 1**  
Exclusion and inclusion criteria for the review (authors' elaboration).

Criteria	Inclusion	Exclusion
Boundaries of food waste definition	Food waste occurring at consumption level, both in – home and out-of-home settings are included as long as the objective of the intervention is to affect individuals' waste behaviour (i.e. plate waste reduction in out-of-home settings, even if it occurs as an effect of managerial or training interventions). Interventions in educational settings, in online environments were also included if the objective was to reduce consumer food waste or change related behaviours.	Food waste occurring at primary production, manufacturing, wholesale and logistics, retail if the consumers where not the target
Food waste topic	Prevention intervention, experimental testing of interventions, focus on consumer food waste behaviour, evaluations or assessment of a concluded intervention	Food waste measurement or quantification, descriptive studies, sustainable consumption patterns (plant-based diets, recycling), focus only on behaviour analyses and antecedent factors of food waste, sustainable food consumption patterns, analysis of COVID-19 specific food waste behaviours
Intervention	Experimental tests investigating cause-effect relation of an intervention; evaluation of a running intervention	Not containing intervention as specified by the definition
Effectiveness indicators	Food waste amounts or changes in behaviour as an effect of the intervention are reported	Sources investigating behavioural antecedents alone
Source quality	Scientific journals with peer reviewed articles, known organizations (WRAP, EU Platform for Food losses and Food waste)	Conference proceedings, sources without data and overview of methodology

were a key part of the grey literature, namely:

- The UK based organization WRAP, known to be very active in the field of food waste measurement and prevention.
- EU Food Foss and Food Waste Platform website (Prevention Hub) and other EU commission related websites (EU-funded initiatives and projects such as Life+, Interreg, or Horizon 2020).

Fig. 1 illustrates the review process according to the PRISMA protocol and the following paragraph summarize the main insights arising from the review. The search produced 1110 total records, which were further screened in title and abstract to exclude and include relevant records according to the criteria contained in Table 1.

Inclusion and exclusion criteria for further reading and assessment of sources is presented in Table 1. Searches on databases were conducted in English, results in other languages (German and Swedish) were reached through snowballing.

For the purpose of this review, the following terminology guided the selection of relevant articles and the analysis of the results:

- Food waste reduction intervention (as a synonym of action and initiative): any activity that is designed and implemented to reduce the amounts of food waste generated intended to interfere with and stop or modify a process.

## Food Supply Chain

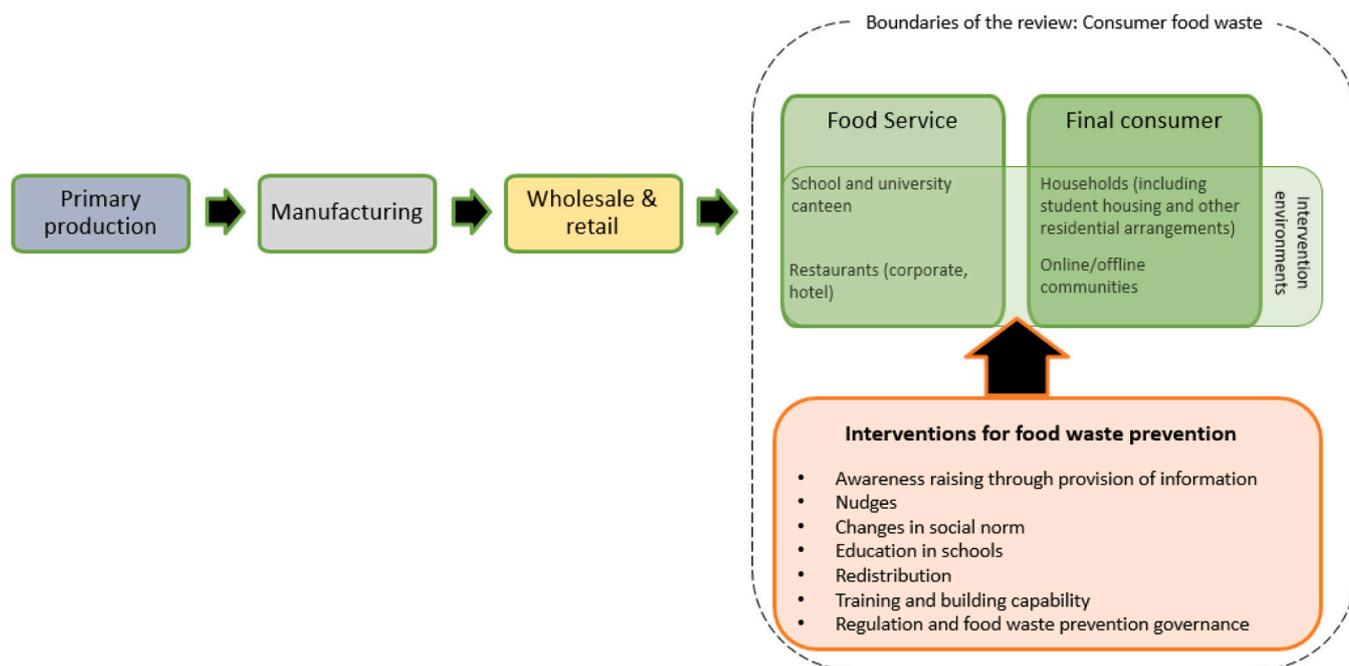


Fig. 2. Boundaries of the review's scope within the food supply chain of where consumer food waste can occur (authors' elaboration).

- Effectiveness: the extent to which the intervention reached its objective as established by Caldeira et al. (2019b). In the scope of this review, a reduction in the amount of food waste or a change in consumer behaviour.

In total, 317 sources were identified from scientific literature and screened entirely to gather the interventions, while 49 were finally selected. The selected sources were further screened and the relevant data was organized in a spreadsheet summarising the type of intervention, geographical location, duration, objectives, study design, methodologies and results in terms of food waste reduction or behaviour change (with special attention to any KPIs and targets set). The results of the analysis elaborated whether the scientific community and food waste practitioners had received and responded to the need to test and evaluate the effectiveness of food waste reduction interventions.

Selected studies concerned only consumer level interventions, therefore both in-home and out-of-home settings were considered. Out of home settings include food services in general, canteens, schools and universities, hotels and restaurants. In-home or household food waste interventions include those targeting specifically food waste occurring in private homes, as schematized in Fig. 2. Consumer level interventions considered in this review include those in which waste happens at final consumption level, both in household and in out of home settings (such as catering, restaurants, schools). Moreover, some interventions included in the review affect indirectly the final consumers by engaging other actors, such as food service staff or teachers (Antón-Peset et al., 2021; Elnakib et al., 2021). This specification is needed to highlight how consumer behaviours can be addressed indirectly by applying a more systemic vision. Some examples of the environments accepted in the selection of the sources are included in Fig. 2.

Table 2 provides a description of the types of interventions identified by this review, the classification was based on previous literature, specifically Caldeira et al. (2019b); Qusted (2019); Barker et al. (2021). Awareness raising interventions were defined by the mere provision of information to participants. Nudges are a non-coercive way to induce a

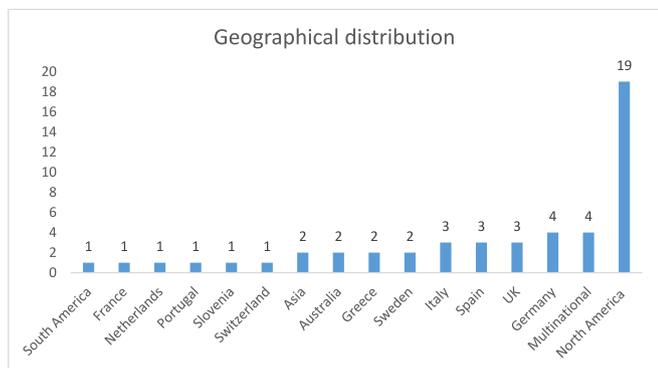
desirable behavioural change, through alterations to the environment in which an individual makes a choice (Thaler and Sunstein, 2008). There is a burgeoning interest in scientific literature on the employment of these methods to encourage sustainable consumption behaviours (Reisch et al., 2021) especially as an alternative to the employment of restrictive regulations and bans. School and educational programs acknowledge the pedagogical component in their design. Training and building capability also involve information sharing and awareness raising but in addition also provide the opportunity to increase practical skills, and are divided from educational interventions as the participants are usually adults, whether in households or at work. Interventions based on social norms are singled out, following recent attention from scientific literature on the importance of social norms in driving consumer behaviour (Blondin and Attwood, 2022).

Redistribution or sharing of surplus is also included as a potential intervention at consumer level, despite traditionally being implemented from retailers. Multi-component interventions are also identified by this review, as a strict categorization is occasionally not possible, as the intervention is composed of multiple intervention elements simultaneously whose single effect cannot be discerned.

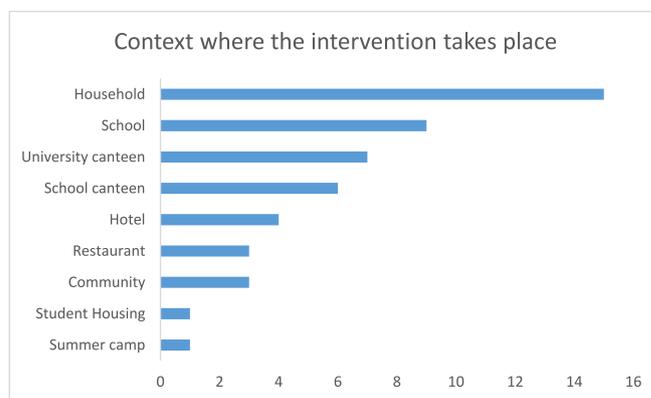
A final analytical step was instrumental in drafting recommendations for policymakers and highlight the research gaps presented in the discussion. To highlight the reported effectiveness of the intervention types, a rough evaluation of the results of each study was performed, assigning a value between '+/–', when the intervention did not achieve reduction of food waste or changes in behaviour, to '++', when the intervention reported a reduction of food waste >30%. This discrimination is of course quite arbitrary and is based only on the effectiveness reported (as outlined in Table 1), not by assessing the quality of the experimental design or other factors. It should be noted that the value of 30% refers the reduction reported in each single study, which might rely on different measurements, units, and variable robustness of intervention design and evaluation methods, therefore it should not be understood as an absolute reference value but a rough indication of the quantitative results found in the literature.

**Table 2**  
Interventions categorization according to literature (Barker et al., 2021; Caldeira et al., 2019b; Quested, 2019).

Type	Description
Awareness raising campaign, provision of information (can be a part of larger national waste prevention programs)	A process that seeks to inform and educate people about food waste with the intention of influencing their attitudes, behaviours and beliefs towards food waste reduction by providing information about the topic on how to adopt less wasteful behaviour (e.g.: through social media campaigns, a newsletter with tips for better food management) (Caldeira et al., 2019b).
School program (education)	Education interventions specifically targeted at students to inform them on food waste, its impacts and strategies to counter it (Caldeira et al., 2019b).
Nudges and changes to consumers' choice architecture	Positive reinforcement and indirect suggestions as ways to influence the behaviour and decision making of groups and individuals. Some examples: Default rules: external meal planning, fee-based strategically portioned food ingredients delivery; Simplification: reducing barriers to target behaviour; Increase in ease and convenience: making low waste food options available; Feedback: informing people of the occurrence and impacts of their own past choices; Commitment: a public pledge to undertake the desired behaviour; prompts: email reminding people to undertake desired behaviour (adapted from Barker et al., 2021).
Social norms based interventions	Interventions that aim to influence social norms, exploiting the tendency of individuals to conform to the majority, shaping behaviour by giving them information about the behaviour or attitudes of the majority of their reference group (e.g.: community focus groups, food sharing practices).
Training and building capability	Programs aiming at increasing consumers/food workers' abilities, skills and confidence necessary to engage in food waste prevention practices (e.g.: teaching cooking classes) (adapted from Quested, 2019).
Redistribution	Redistribution among consumers or food sharing
Multi-component	Interventions comprised of various components where the food waste reduction cannot be attributed to a single component



**Fig. 3.** Geographical distribution of countries where the intervention took place and number of studies (authors' elaboration).



**Fig. 4.** Overview of contexts where the selected interventions took place (authors' elaboration).

### 3. Results

The review identified 49 unique sources describing interventions aimed at reducing consumer food waste or at changing consumer behaviour, further explained in the following sections.

#### 3.1. Geographical distribution and contexts

All the sources identified included studies carried out in high/middle-income countries, as visualized in Fig. 3: 17 from Europe (Germany, Spain, Switzerland, Belgium, France, Greece, Netherlands, UK, Portugal, Sweden, and Italy), 19 North America (USA and Canada), 2 in Asia and Australia and only one from South America; 4 interventions were conducted in multiple countries. There seems to be a lack of evidence of consumer level interventions from middle and low income countries: it could be assumed that in these countries prevention efforts are concentrated in other stages of the supply chain, such as increasing efficiency of primary production and processing phases (FAO, 2019) and consumer food waste research is a budding field. Furthermore, as consumer food waste is closely linked to lifestyle and habits (Aschermann-Witzel et al., 2021; Russell et al., 2017), it can be assumed that high-income countries could have similar patterns of household waste and results could be compared (Fig. 4).

From the analysis, 20 interventions focus on out-of-home eating environments, especially in schools (six) and universities (seven) catered dining settings. Four studies considered specifically hotel restaurants and buffets: these studies could provide some insight for tackling food waste in hedonistic contexts (holidays, leisure) where sustainability issues might not be prioritized by guests (Antonschmidt and Lund-Durlacher, 2021; Cozzio et al., 2021; Dolnicar et al., 2020). The specific dining settings were not extrapolated, but it should be noted that this could be an important variable to consider which could significantly affect food waste generation, as noted by Matzembacher et al. (2020) and Yi-Chi Chang et al. (2022).

15 household level interventions were found through the review, other residential environments such as student housing (Lim et al., 2021) and summer camp (Burg et al., 2021) were also included. Furthermore, community level interventions were also selected, as in the case of Shu et al. (2023), when whole neighbourhoods were targeted by an intervention. The same classification could be assigned to interventions that could be ascribed to a wider context, such as online platforms (Makov et al., 2020) or food systems in general (Ioannou et al., 2022; WRAP, 2020).

Three studies conducted experiments during the COVID-19 pandemic (Cozzio et al., 2021; Malefors et al., 2022; Davison et al., 2022), despite the pandemic and related lockdowns being investigated in regards to food waste quantification and changes in consumer behaviours. Only Davison et al. (2022) openly address the challenges

**Table 3**  
Results of the review in terms of intervention types (author's elaboration).

Type	Examples from literature	Records
Awareness raising campaign, provision of information (can be a part of larger national waste prevention programs)	Ellison et al., 2019b; Lorenz-Walther et al., 2019; van der Werf et al., 2021; Visschers et al., 2020; Wharton et al., 2021; WRAP, 2020; Malefors et al., 2022; Shu et al., 2023; Wang et al. (2022)	9
School program (education)	Antón-Peset et al., 2021; ForskarFredags, 2020; Wegner et al., 2020; Burg et al., 2021; Prescott et al., 2019; Boulet et al., 2022; Costarelli et al., 2022; Hamdi et al., 2020; Sharma et al., 2019; Mariam et al., 2022; Marques et al., 2022; Piras et al., 2023; Serebrennikov et al., 2020	13
Nudges and changes to consumers' choice architecture	Dolnicar et al., 2020; Giaccherini et al., 2021; Lorenz-Walther et al., 2019; Malefors et al., 2022; van Dooren et al., 2020; Vidal-Mones et al., 2022; Visschers et al., 2020; Burg et al., 2021; Eckert Matzembacher et al., 2020; Antonschmidt and Lund-Durlacher, 2021; Turvey et al., 2021; Cooper et al., 2023; Davison et al., 2022; Zhang and Kwon, 2022; Lehn et al., 2023; Schuster et al., 2022; Qi et al., 2022; Kim et al., 2020	18
Social influences and modelling behaviour	Giaccherini et al., 2021; Soma et al., 2021; Pelt et al., 2020; Lim et al., 2021; Piras et al., 2023	5
Training and building capability	Elnakib et al., 2021; Ioannou et al., 2022; Roe et al., 2022; van Dooren et al., 2020; Neff et al., 2021; Wharton et al., 2021; Roe et al., 2022; Leverenz et al., 2019	8
Redistribution/food sharing	Makov et al., 2020	1
Multi-component	Trewern et al., 2022; Wegner et al., 2020; Yi-Chi Chang et al., 2022; Malefors et al., 2022; Kim et al., 2020	5

encountered due to lockdown, whereby the measurement to test the effect of the intervention took place in a dining environment altered to accommodate health and safety requirements. It has been reported that consumption habits and therefore waste were greatly affected by the pandemic, however there is no consensus on whether any changes in consumer behaviour were maintained after the ease in lockdowns (Borghesi and Morone, 2023; Amicarelli and Bux, 2021; Rodgers et al., 2021).

### 3.2. Experimental design and participant samples

Out of the 49 identified sources, 43 were experiments. The remaining six (Elnakib et al., 2021; van Dooren et al., 2020; WRAP, 2020; Makov et al., 2020; Matzembacher et al., 2020; Wegner et al., 2020) refer to evaluations of running national programs and non-experimental interventions. Experimental design varied: the sources reported mostly a quasi-experimental design or field experiments, in few instances randomized control trials. Most of the results provided a pre-post study design of the experiment, by which decreases of food waste levels or changes in behaviour were measured by establishing a baseline before the intervention is run and looking for an effect at a later time. A control group to compare the effects of the intervention was set up only by seven studies. Shu et al. (2023) propose also a new methodology for establishing the effectiveness of an intervention by both providing a local control group and also one based on a national sample. This approach could provide an efficient evaluation method for local-level interventions. Sample sizes varied greatly among the different studies

(Details in the Supplementary Materials).

### 3.3. Intervention types

Multiple sources included more than one manipulation of testing conditions, i.e. the testing the effect of different independent variables on food waste or consumer behaviours, in the same study, therefore the intervention were grouped together based on the intervention type whose effectiveness was being tested in the study. Some studies tested more than one intervention (manipulations within an experimental testing), the number of manipulations ranges between two (Visschers et al., 2020) and seven (Turvey et al., 2021). Despite the nuances in the classification, 21 interventions were identified as nudges (of which five also investigated social norms), 13 were school-based educational programs, six were training programs for adults, five awareness raising alone, and only one was a surplus food sharing intervention. Seven were multicomponent interventions. The interventions were grouped together according to the categories illustrated in Table 2, and are reported in Table 3.

Awareness raising and information based interventions were included in seven sources, usually to test the effectiveness of provision of information alone compared to nudges or other intervention types (Ellison et al., 2019a, 2019b; Soma et al., 2020; Visschers et al., 2020; Lorenz-Walther et al., 2019). Awareness raising, as highlighted by Stöckli et al. (2018), is a widely used strategy in national food waste prevention campaigns and is often a default option, however the effectiveness of awareness raising alone in improving knowledge on the long term and changing consumer behaviour is rarely proven.

18 studies provided evidence related to the implementation of a nudge. Some examples gathered in this review included the different positioning of messages in an environment (Antonschmidt and Lund-Durlacher, 2021; Cozzio et al., 2021), the switch to different shape and size plates in canteens (Lorenz-Walther et al., 2019; Richardson et al., 2021; Visschers et al., 2020; Qi et al., 2022), altering the conditions of the eating environment (Burg et al., 2021; Eckert Matzembacher et al., 2020; Zhang and Kwon, 2022), implementing a reward system (Dolnicar et al., 2020); providing tools for cooking portions control (van Dooren et al., 2020) or easing the preparation of food (Cooper et al., 2023; Schuster et al., 2022). Feedback mechanisms were employed by Lim et al. (2021), Davison et al. (2022) and partly also by the citizen science project (ForskarFredags, 2020). Visual cues and prompts through labels on food packaging were reported by Lehn et al. (2023) and Turvey et al. (2021). The first explored the potential reduction of applying an indicator of the edibility of a product along the date-marking on its packaging; the second tested the effectiveness of different messaging strategies for labelling of date markings. It should be noted that the applicability of these interventions in wider contexts hinges on labelling regulation and for example, as for the case of Lehn et al. (2023) the use of dynamic labelling is not allowed in Europe. However, misunderstanding of date labelling from consumers is acknowledged by scholars and policymakers as an important driver of food waste (European Commission and Directorate-General for Health and Food Safety, 2018).

School programs and education-based interventions have also been reported extensively in literature, as this review collected 13 interventions which had an educational component. The objective of these interventions is generally targeting food-related behaviours of younger generations through pedagogical approaches. In some cases, food waste teachings were embedded, implicitly or explicitly, in other topics, such as sustainable development or environmental protection (Piras et al., 2023; Antón-Peset et al., 2021; Boulet et al., 2022; Malefors et al., 2022; Prescott et al., 2019) or nutrition (Costarelli et al., 2022; Serebrennikov et al., 2020; Sharma et al., 2019; Marques et al., 2022).

Training and building capability interventions for were recorded by Ioannou et al. (2022), Roe et al. (2022), Elnakib et al. (2021), Wegner et al. (2020), Neff et al. (2021), Wharton et al. (2021) and to some extent

by Trewern et al. (2022) providing examples of both trainings for food service workers, but also for households. The main objective of these interventions is to increase practical skills, in parallel to increasing the awareness on food waste.

An example of redistribution among consumers was also included as an intervention type; usually redistribution actions are organized between retailers and charity organization and beneficiaries of donations. Makov et al. (2020) provide an evaluation of the OLIO app, which enables exchanges directly from consumers' surplus food, as well as from food services. As most of the studies aimed specifically at changing consumer behaviour, information regarding any theoretical frameworks tested in experimental settings were extracted. As the review in Reynolds et al. (2019) pointed out how the failure to mention specific theories could lead to misunderstandings in drawing conclusions between cause and effect. The behavioural change theories that were applied included: Theory of Planned Behaviour<sup>1</sup> (Lorenz-Walther et al., 2019; Roe et al., 2022; van der Werf et al., 2021; Visschers et al., 2020; Wharton et al., 2021; Mariam et al., 2022) and Motivation-Opportunity-Ability<sup>2</sup> framework (Soma et al., 2021; van Dooren et al., 2020; Trewern et al., 2022), with a few authors applying different approaches such as utility theory (Dolnicar et al., 2020), cognitive dissonance principles (Pelt et al., 2020) and Attitude – Context – Behaviour<sup>3</sup> framework (Antonschmidt and Lund-Durlacher, 2021). Further application of behavioural sciences included social cognitive theory (Sharma et al., 2019), train the trainer approach (Ioannou et al., 2022), Health Belief Model (Serebrennikov et al., 2020) and Social marketing theory (Kim et al., 2020).

### 3.4. Measures of intervention effectiveness

#### 3.4.1. Food waste quantities

To establish intervention effectiveness, all but nine studies analysed changes in food waste quantities, usually paired with analysis of behavioural changes while just a few focused on solely reporting other variables, such as changes in knowledge (Turvey et al., 2021), distribution of doggy bags (Giaccherini et al., 2021), the number of exchanges happening on online platform (Makov et al., 2020).

In the studies that measured food waste amounts, quantification methods differed and were often adapted to the environment (in-home vs. out-of-home) and to resources constraints (budget, time). Examples of quantification methods included: food diaries (Leverenz et al., 2019; Neff et al., 2021; Mariam et al., 2022), direct weighing of plates or aggregate waste (Antón-Peset et al., 2021; Ellison et al., 2019a, 2019b; Elnakib et al., 2021; Antonschmidt and Lund-Durlacher, 2021; Sharma et al., 2019); waste compositional analysis (van der Werf et al., 2021; Visschers et al., 2020; Shu et al., 2023) and technology assisted quantification (ForskarFredags, 2020; Lim et al., 2021; Roe et al., 2022), or using a large scale survey data (van Dooren et al., 2020; WRAP, 2020; Shu et al., 2023), observation (Cozzio et al., 2021) and photos (Boulet et al., 2022; Lorenz-Walther et al., 2019; Prescott et al., 2019; Serebrennikov et al., 2020). Out of the 40 studies measuring food waste

<sup>1</sup> Theory of planned behaviour explains individual behaviour as a consequence of intention that are based on the interaction among different beliefs described as behavioural, normative and control.

<sup>2</sup> Motivation Opportunity Ability aims to understand the connections between consumers behaviour and their desire, willingness and readiness to perform a specific behaviour (motivation), together with the available and accessible of external resources to support the processing of that behaviour (opportunity) as well as competences to conduct the behaviour (ability). Motivate behaviour changes, create opportunities (e.g. technologies, infrastructure, time) and foster the ability to change (knowledge, skills) from van Geffen et al. (2020).

<sup>3</sup> Comprehensive approach in considering contextual variables. Context includes all influences outside the individual mind that might support or inhibit behaviour, such as economic costs and benefits, incentives, other people's behaviour, and cultural expectations

quantities, seven employed self-reporting methodologies (i.e. through food diaries or surveys).

The methodological variety leads to the reporting of heterogeneous units of food waste quantities: g of plate waste (Antón-Peset et al., 2021; Dolnicar et al., 2020; Matzembacher et al., 2020; Visschers et al., 2020), kg per household (van der Werf et al., 2021), or even reported in single units of breakfast food per person (Cozzio et al., 2021). This inconsistency, combined with the difficulty in establishing a universal rule for what is considered edible or inedible food waste, avoidable or unavoidable, leads to the results being reported in variety of units, hindering comparability (Moreno et al., 2020). It is unfeasible, considering these results, to assess absolute effectiveness of one intervention over another in terms of food waste reduction potential. Some studies report sizeable reductions in waste: some nudging strategies reported by Vidal-Mones et al. (2022) claim a 41 % average reduction in plate waste, (significant for fruits and vegetables), the self-reporting intervention tested by Leverenz et al. (2019) resulted in a 50 % reduction and Soma et al. (2020) obtained a 30 % reduction in household waste for its gamification intervention, however not statistically significant.

#### 3.4.2. Consumer behaviour

As consumers are the focus of the review, many studies investigated changes in their attitudes, behaviour, and knowledge as key indicators of intervention effectiveness. The behavioural variables reported depend on the type of intervention and on the application of a specific theoretical framework. Personal attitudes towards food and food waste were investigated by Visschers et al. (2020), Ellison et al. (2019a, 2019b), Antón-Peset et al. (2021), and specifically financial attitudes were reported by van der Werf et al. (2021), while specific consumption attitudes were explored by Neff et al. (2021). Changes in behavioural antecedents, such as beliefs, habits and knowledge were also investigated to find correlation to food wasting behaviours. Perceived behavioural control and intention were tested when the Theory of Planned Behaviour was applied (van der Werf et al., 2021; Visschers et al., 2020; Wharton et al., 2021). Most of the sources used surveys to monitor the evolution of these indicators, in some cases other approaches such as focus groups (Soma et al., 2021) were applied to detect valuable information that would not have emerged solely through a pre-post intervention survey. Soma et al. (2021) investigated the effect of three tested interventions on Motivation, Opportunity and Ability through a focus group, elaborating on the results of a previous experiment (Soma et al., 2020).

Increase in knowledge and awareness were investigated especially in experiments using provision of information or education as intervention, usually through surveys. Antón-Peset et al. (2021) however also provided a qualitative assessment of the increase in knowledge and awareness through a thematic analysis of children's drawings, showing how qualitative methodologies can be valuable in uncovering intervention effectiveness. Mariam et al. (2022) investigated the changes in food literacy as a result of an educational intervention.

#### 3.4.3. Engagement, participation or enjoyment of intervention

Evaluation of certain interventions was made by reporting numbers of people engaged in a campaign (WRAP, 2020), participation in workshops (Ioannou et al., 2022), numbers of doggy bags redistributed in restaurants (Giaccherini et al., 2021). In some cases, appreciation and enjoyment of the intervention material, especially if it included awareness raising or trainings, was included as part of the evaluation (Dolnicar et al., 2020; Ioannou et al., 2022). In the development of evaluation practices, the quantification of the environmental benefits or trade-offs of a prevention action is also emerging, namely through the application of life cycle assessment. Makov et al. (2020) provide a quantification of the environmental impacts arising from the exchanges occurring on a foodsharing app, by modelling the transportation emissions. As these platforms are gaining popularity (Cane and Parra, 2020; Mullick et al., 2021), evaluations of their actual effectiveness through appropriate

indicators should be devised. An example of a platform where life cycle assessment based environmental benefits of intervention actions are assessed together with costs of the actions, is the prevention actions calculator launched by the European Commission Joint Research Centre (De Laurentiis et al., 2020). Besides, Lehn et al. (2023) assess the environmental and economic savings associated with the application of a novel labelling technology nudging consumers to improve their understanding of expiration dates.

#### 4. Discussion

The main aim of this paper was to analyse the rapid developments in the of consumer food waste interventions and evaluation. It collected 49 unique sources, which tested a wide variety of interventions types, with differing design and specific objectives. By extrapolating the effectiveness of the single interventions to reduce consumer food waste or changing behaviour, it became clear how results are difficult to compare, due to experimental design and diversity of monitoring methods. The review adopted a categorization based on previous research (Caldeira et al., 2019b; Quested, 2019) and adapted it to the results to ease the analysis process. However, multiple elements of the intervention types exist in the same design, which hinders the unconditional assignment of the effect of the intervention to a single element.

Moreover, as the studies collected through this review were heterogeneous in design, sample size, and typology of intervention tested, a comparison of the results is not appropriate. Waste measurements techniques varied, and in some studies the assumptions made were unclear, such as the use of standardized data collection protocol, or the boundaries of the definition of food waste. Furthermore, this review did not assess the quality of the analysis of each study, and many authors were not able to establish strong statistical correlations in their studies. In addition, a limited number of the results, despite being published very recently, related to data gathered almost a decade ago (Leverenz et al., 2019; Soma et al., 2020), and therefore their present applicability might weaken.

Several sources provided experimental approaches: experimental testing provides the initial evidence of effectiveness of different strategies by generating data in a consistent and rigorous manner, providing transparency on methodology and execution and above all establishing cause-effect links in a controlled setting. Very few sources provided the evidence of longer term effects of the interventions, this limits the possibility of drawing conclusions on the longevity, sustainability and replicability, however, as consumer food waste research is a field in its infancy, the rapid proliferation of experiments is positive, providing a variety of approaches which are ready to be replicated.

The next paragraphs provide the discussion according to the established research questions.

##### 4.1. Question 1: what type of interventions are being deployed and how are they designed?

###### 4.1.1. School and education programs

Schools and other educational settings (such as summer camps) emerge from this review as a key environment to target food waste behaviour, especially in a wider context of a transition to a sustainable food systems. Educational interventions and school programs aimed at increasing knowledge on nutrition, food literacy or sustainability issues can reap multiple benefits, including food waste reduction. Boulet et al. (2022) provide an example of how targeting interactions between different levels (i.e. schools, workplaces) can affect food waste generation in households as well. Antón-Peset et al. (2021) and Prescott et al. (2019) provide an example of education interventions for schools, with the latter specifically testing an education strategy based on food system sustainability. The citizen science experiment conducted by the Swedish organization ForskarFredags (2020) also shows how engaging students through citizen science methods could be an innovative opportunity

both for data gathering and awareness raising (Pateman et al., 2020). Educational interventions however do not show consistent results in achieving reductions of food waste, behaviour changes or knowledge increase in school pupils. Some authors suggest different reasons for this variability: Mariam et al. (2022) cannot confirm the effect of their “Food Waste Lab” in improving food literacy or students’ practical skills, but state that such educational interventions can “positively shape cognitive attitudes and ideologies regarding the role of food waste in climate change”. A few studies implemented in the US investigated the effects of educational intervention on nutrition on children’s intake of fruits and vegetables (Hamdi et al., 2020; Serebrennikov et al., 2020; Sharma et al., 2019), highlighting how food waste can be also interpreted through its mirror, i.e. increased consumption of key nutrients.

###### 4.1.2. Awareness raising and provision of information

The results from this review reiterate the notion elaborated in previous literature (National Academies of Science, 2020; Stöckli et al., 2018), that provision of information and awareness raising alone might be less effective than other types of interventions in reducing food waste. Visschers et al. (2020), Pelt et al. (2020), Soma et al. (2020) provided evidence of this, showing how in the same setting, information interventions performed unfavourably compared to different strategies. The only source contradicting this notion was Malefors et al. (2022), which evidenced a greater success of an awareness-based intervention opposed to plate waste trackers, tasting spoons and better forecasting in a school canteen setting. Information-based and awareness campaigns are often the default intervention option because they require low investment and effort, however, whether these strategies have effect on a target population should be assessed prior to large scale implementation. Other examples analysed in this review provide some insights regarding the use of different messaging strategies (van der Werf et al., 2021: focusing on economic impact), better targeting the intervention audience (Ellison et al., 2019a, 2019b: crafting message as appeal to personal responsibility after focus group with target audience), including an environmental appeal (Dolnicar et al., 2020: testing different manipulations with environmental messaging) or egoistic vs. altruistic messaging (Cozzio et al., 2021). Wang et al. (2022) used anthropomorphic cues and environmental framing. Lastly, the evaluation of the TRIFOCAL project (WRAP, 2020) proposes also clearer brand image and recognisability as a way to increase effectiveness of awareness campaigns. For future interventions based on provision of information and awareness raising, these elements in designing an effective message should be reflected.

Nisa et al. (2022) also evaluated the different effects of a variety of messages on consumer’s responses on their food waste behaviour, evidencing how including too many messages and information in a single awareness campaign might lead to confusion and counter the intended effect of an awareness campaign. Khalil et al. (2021) investigated how numerical precision in messages promoting food waste reduction can be influential in increasing consumer awareness. Neubig et al. (2020) assert that providing action-related information on specific solutions and their impacts helps consumers increase their intentions in reducing food waste. Interestingly, the evaluation of awareness raising interventions detected through this review did not rely on self-reported quantification methods to assess their effectiveness, but employed direct weighing, waste audits or technology assisted measurements.

###### 4.1.3. Nudges

Stöckli et al. (2018) had encouraged the development of testing of behavioural approaches to counter food waste and there has been an uptake of these approaches in food waste research, as evidenced by this review. Nudges and changes to choice organization show a good potential for food waste reduction. In food service settings, interventions changing the shape and size of plates (Richardson et al., 2021; Visschers et al., 2020) or altering the eating environment (Burg et al., 2021; Eckert Matzembacher et al., 2020), have shown promise in reducing food

waste. The review also highlighted the example of using visual cues on food labelling to nudge consumers to reduce their food waste: [Turvey et al. \(2021\)](#) test the effectiveness of different messaging strategies for communication of expiration dates. Similarly, [Lehn et al. \(2023\)](#) investigate the theoretical reduction of food waste deriving from the application of dynamic labelling on fish. Simplification, as trialled by [van Dooren et al. \(2020\)](#) and [Schuster et al. \(2022\)](#), is also an approach that is garnering more attention. This evidence further highlights the policy relevance of these approaches, as also evidenced by [Barker et al. \(2021\)](#) in a study reviewing nudge examples for sustainable food choices. Going forward however, the effectiveness of these strategies should be further tested and evaluated to provide a comparison and to substantiate the effectiveness of these approaches.

#### 4.1.4. Using social norms

Leveraging social influences and modelling behaviour can be considered a form of nudge, but was highlighted as a different category because it is a form of intervention which is gaining attention from scholars ([Blondin and Attwood, 2022](#)). [Giaccherini et al. \(2021\)](#) specifically tested the different effects of providing a doggy bag at restaurants as a default option and affecting social norms to understand the effect that shame has on restaurant guests. [Lim et al. \(2021\)](#) included a social comparison showing the amount of food wasted between corridors in student housing. As [Blondin and Attwood \(2022\)](#) have emphasised, there is promise in targeting specifically social norms – “rules and standards understood by members of a group that guide or constrain social behaviours without the force of law - however there is still a lack of widespread evidence on the design and application of this mechanism in food waste literature, while more examples can be found in nutrition and health scholarship.

#### 4.1.5. Training and building capability

Interventions focusing training and development of knowledge and skills can be particularly useful in improving ability of consumers. [Ioannou et al. \(2022\)](#) propose a training kit based on participatory workshops to communicate anti-waste behaviours and a replicable methodology to use the training kit in different contexts and also in another steps of the supply chain. [Roe et al. \(2022\)](#) tested a technology-aided tailored sustainability intervention based on the interactions between trained counsellors and individuals, like a personal training for food waste behaviour. [Elnakib et al. \(2021\)](#) tested the effectiveness on consumer food waste reduction of training aimed at food service workers – showing how intervention can influence multiple levels of the food system ([Boulet et al., 2021](#)).

#### 4.1.6. Emerging trends

Novel interventions, including the use of ICT and new technologies, also provided evidence of effectiveness in reducing food waste. Developments in the use of AI and image recognition, could simplify the quantification of household food waste with the recognition of waste components ([ForskarFredags, 2020](#); [Roe et al., 2022](#)). As photo coding can be a time consuming activity ([van Herpen et al., 2019](#)), automating the recognition of food waste quantities or creating more engaging user interfaces could advance efforts in household waste quantification ([Jones-Garcia et al., 2022](#)). The development of these technologies is time and capital intensive, however there are many examples of their use being mainstreamed in the food service industry by start-ups ([Martin-Rios et al., 2020](#)) and more established companies ([Leanpath, 2023](#); [Winnow, 2023](#)). Furthermore, the possibility to include immediate feedback from a human-computer interaction at the time when waste occurs could lead consumers to alter their wasteful behaviours ([ForskarFredags, 2020](#); [Lim et al., 2021](#)). [Makov et al. \(2020\)](#) also provide an example of how to evaluate the effect of a foodsharing app, highlighting the environmental benefits that can be gained by connecting consumers' surplus in a localized networks. As these platforms are gaining popularity ([Cane and Parra, 2020](#); [Mullick et al., 2021](#)), evaluations of their

actual effectiveness through appropriate indicators should be devised.

Regarding the design process of the interventions analysed in this review, it is worth pointing out how many interventions were based on a theoretical underpinning (i.e. consumer behaviour studies), however, this was not always the case. Furthermore, [Vidal-Mones et al. \(2022\)](#) and [Ellison et al. \(2019a, 2019b\)](#) provide interesting examples of co-creation in the intervention design process, including researchers and food service workers or final consumers.

#### 4.2. Question 2: how are consumer food waste interventions being evaluated and what are the indicators being used to assess their effectiveness?

Greater standardization of food waste quantification is encouraged to enable a comparison. In recent years, guidance and protocols for data collection have been issued to assist practitioners and researchers in following a standardized quantification process ([Hanson et al., 2016](#)). The increase of attention from the research community ([Tian et al., 2022](#)) in the food waste topic provides some example of experimental interventions, however it is apparent that widespread monitoring, evaluation and dissemination is not practiced, even for large-scale national programs. In addition, the relatively low number of studies (seven) relying on self-reported measurements of food waste quantities for the evaluation shows a great step forward in the field. The application of direct and robust quantification methodologies, such as waste compositional analysis or direct weighing, helps constructs a more reliable evidence base. Departing from previous literature for this review proved to be useful and showed the rapid expansion of this field, as only 17 sources were found in 2019 ([Reynolds et al., 2019](#)) and almost three times as many were published over the short time span that this review considered. The variety of nudges and educational interventions gathered in the review also show an increased diversity of approaches compared with previous literature.

#### 4.3. Question 3: what are the research gaps and policy recommendations?

##### 4.3.1. Food system approach and behavioural interventions

As recent literature highlighted, antecedents of food waste behaviours are manifold. Applying a systemic approach in intervention design, as well as monitoring, could unearth possible trade-offs or co-benefits of implementing an intervention. This consideration builds on the multidimensionality of food waste reduction interventions. Multidimensional in this context is understood as an intervention that achieves synergies beyond food waste reduction alone, encompassing other challenges as well; as exemplified by [Mariam et al. \(2022\)](#), [Burg et al. \(2021\)](#), [Hamdi et al. \(2020\)](#), [Sharma et al. \(2019\)](#). In these interventions, food waste was evaluated in parallel to increased consumption, especially of key food groups for nutritional value (fruits and vegetables, milk). The TRIFOCAL project also considered a multidimensional approach by targeting sustainable consumption patterns in a general sense, from shifting to increasingly plant-based diets to waste reduction and appropriate recycling. Finally, [Trewern et al. \(2022\)](#) apply a more systematic approach in testing a multi-component intervention targeting multiple food-related behaviours at once: decreased meat consumption, food waste reduction and cooking from scratch. Accounting for this multidimensionality in intervention design, pairing the food waste narrative with other compatible issues, could prove more efficient especially in terms of resource used and return on investment ([National Academies of Science, 2020](#)).

Furthermore, as suggested in literature ([National Academies of Science, 2020](#); [Reynolds et al., 2019](#)), applying sound theoretical bases in intervention design could help in clarifying interventions' effectiveness. By providing evidence on how to frame behaviours in order to induce desired one, could lead to designing successful interventions. There is growing evidence of behavioural approaches applied to sustainable food consumption patterns, including food waste reduction ([Reisch et al.,](#)

**Table 4**  
Recommendations on consumer food waste interventions based on review results.

Type of intervention	Recommendations for policy-makers	Recommendations for practitioners	Needs for further research
Information based interventions (awareness raising)	National and transnational campaigns should: <ul style="list-style-type: none"> <li>- Craft appropriate messages that trigger change in consumers</li> <li>- Set appropriate KPIs, monitor and evaluate</li> <li>- Share knowledge on success factors, to enable replication</li> </ul>	<ul style="list-style-type: none"> <li>- Develop different, targeted messages based on the type of awareness campaign (not all types of information will be suitable for the whole population);</li> <li>- Bundle information and awareness with other types of intervention, such as nudges or leveraging social norms;</li> <li>- Explore the possibilities given by social media (Jenkins et al., 2022)</li> <li>- Brand recognisability and curated image might improve attention and the possibility to link any registered effect to the intervention being evaluated (WRAP, 2020) for national campaign</li> <li>- Altruistic messaging might be more effective than egoistic ones (Cozzio et al., 2021)</li> <li>- Do not bundle too much information in the same message (Nisa et al., 2022)</li> </ul>	<ul style="list-style-type: none"> <li>- Aid practitioners in designing and targeting appropriate messages and information for more effective interventions;</li> <li>- Develop methodologies for evaluating large scale national campaigns</li> </ul>
Nudges	Incorporate behavioural insights in the policy-making process	<ul style="list-style-type: none"> <li>- Replicate existing nudge interventions in different contexts and evaluate;</li> <li>- Generate information on cost-effectiveness of these interventions (Explore cost/benefits of nudge implementation (for example: for an intervention requiring the change of the plates in food services, quantify the costs deriving from the implementation vs. the benefits)); Provide evidence of long-term effect of the nudges implemented</li> <li>- For approaches such as the ones proposed by Eckert-Matzembacher et al. (2020), it could be worth studying what are the management implications for reorganizing a business to nudge sustainable consumer behaviour</li> <li>- Investigate optimal placement of visual prompts informing consumers of food waste reduction (Antonschmidt and Lund-Durlacher, 2021)</li> </ul>	<ul style="list-style-type: none"> <li>- Expand evidence base of nudge effectiveness, different methodologies, comparison with different segments of the population and;</li> <li>- Continue exploring effectiveness with thorough experimental testing, consolidate the evidence base of the effectiveness of these approaches</li> </ul>
Social norms based interventions		Include social norm messaging in interventions, in combination with other types of intervention	Examine social norm based approaches in experimental tasting to establish causality of these approaches on food waste behaviours; test messages from other fields (pro-environmental behaviour and health intervention)
School programs	Fund school education for sustainable development, including food waste; might have the largest public costs but long term benefits; include clauses for public procurement of canteens that require food waste monitoring in public canteens	Incorporate different pedagogical approaches in education and classes; target multiple levels for interventions; create scalable and transferable interventions (curricula) as to lower costs of implementation	Exploit qualitative methodologies for evaluation of interventions; explore further multi-level effects of school-based interventions
Trainings and building capabilities	<ul style="list-style-type: none"> <li>- Require institutional food service managers and staff to undergo food waste prevention training in the same way it requires HACCP knowledge</li> <li>- Apply Green public procurement criteria for food catering tenderers that include food waste training for staff</li> </ul>	<ul style="list-style-type: none"> <li>- Routine trainings of food service staff regarding different strategies can be a cost-effective intervention to curb plate waste</li> <li>- Empowering the target audience of the trainings to find the solutions to food waste generation in specific contexts through co-creation/co-design could be further explored (Vidal-Mones et al., 2022)</li> <li>- Apply personalized coaching if resources allow (Roe et al., 2022)</li> </ul>	
Food waste prevention governance	Evaluate options for clearer labelling and date marking in information to consumer legislation; target overconsumption as a driver of food waste; Have institutional food service (such as hospitals and schools) actively commit to food waste reduction targets	Participate in governance at multiple levels (local, national and EU) and in stakeholders dialogues	
New approaches		Leverage the use of technology to engage directly with intervention participants, as in the tailored coaching propose in the technology assisted intervention in Roe et al. (2022)	Explore accuracy of photo recognition through artificial intelligence as a way to increase quantification in households
Redistribution	Explore opportunities for enhancing redistribution without compromising food safety standards and consumer health	Disclose information on food redistributed; investigate if food redistributed gets consumed consistently through	Develop methodologies to evaluate app-based redistribution actions
Cross-cutting recommendations	Provide funding for research activities and initial investments; provide support and facilitate exchanges of success stories in the form of	Practice monitoring and evaluation/Knowledge sharing about effectiveness	Strengthen theoretical understanding of causality of interventions; create experimental protocols that are easy to follow and replicate;

(continued on next page)

Table 4 (continued)

Type of intervention	Recommendations for policy-makers	Recommendations for practitioners	Needs for further research
	platforms and networks; enable monitoring and evaluation; engage citizens in active participation in food system governance		incorporate system thinking to analyse beyond the linear supply chain in food waste narrative and set a research agenda on rebounds effect from consumer level interventions

2021). Massari et al. (2022) also propose the application of design thinking methodologies to the food waste issue, highlighting how intervention implementation can further leverage synergies between different disciplines and knowledge fields. In addition, quantitative KPIs such as food waste reduction and behaviour change should be complemented by qualitative insights gathered through interviews or focus groups to gather insights on the barriers and opportunities for behavioural change (Antón-Peset et al., 2021; Ioannou et al., 2022; Soma et al., 2021; WRAP, 2020).

In addition, as pointed out by Ellison et al. (2019a, 2019b), information on cost-effectiveness or cost-benefit analysis should also be disclosed along with food waste related data. Among the results of this review, only Dolnicar et al. (2020) and Wegner et al. (2020) provided some information on the economic input of running the intervention tested. The other 47 sources did not provide any information on costs or monetization of benefits accrued thanks to the intervention. Muth et al. (2019) highlight how including economic analyses for food waste interventions can help prioritize investments, and as consumer food waste interventions analysed in this review are mostly run by public or not-for-profit organizations (Universities, Municipalities) which often have budget constraints, knowing how to allocate resources to maximise benefits will help in running efficient interventions.

Regarding spill-overs and rebound effects, one study selected in the this review analysed undesired effects of interventions: Malefors et al. (2022) measured both plate waste and serving waste to monitor effectiveness and could assess that an intervention concerning tasting spoons for canteen attendees resulted in an increase of serving waste. This is an interesting insight, as the study of rebound effects and unintended consequences is a persistent research gap in food waste literature and especially in evaluation practices (Qi and Roe, 2017). Lastly, an interesting feature emerging from some of the results is that the environments in which consumer food waste occurs are more nuanced than for other steps in the supply chain (Lim et al., 2021; Makov et al., 2020; WRAP, 2020), and considering wider contexts such as communities and systems could provide greater insight in the food waste phenomenon. Fattibene et al. (2020) provide an observation of this by analysing food waste within urban settings and propose a framework for urban food policies targeting waste. These instances could provide some inspiration for a conceptual expansion in the design of interventions, beyond the linearity of the food supply chain as it is commonly rationalized in food waste research, and more towards a systemic vision.

The main insights gathered through the literature review are presented in Table 4 by rationalizing the outcomes of the evidence on consumer level interventions.

#### 4.4. Recommendations and further research

This review highlights advancements in tested interventions that have proven effectiveness, albeit variable, in reducing consumer food waste. Practitioners could find the results useful in designing and deploying new actions, as well as evaluating or upscaling existing ones. Furthermore, replication of existing studies and methodologies in different contexts might corroborate the registered effects of the different interventions and provide valuable insights for tailoring interventions to specific consumer groups. Improvements in knowledge sharing and transfer are advised to ensure that successful interventions will be upscaled beyond experimental settings. The investigation of long-term effects of interventions, in terms of sustainability (Caldeira

et al., 2019b) and longevity (Quested, 2019) is also a substantial research gap which needs to be addressed in future evaluation efforts.

It is acknowledged that interventions implemented in other steps of the supply chain, as well as regulation of the wider food environment, could impact consumer food waste. This review has not uncovered concrete examples of such interventions and this could be further analysed, especially as retail spaces, both physical and online, could provide opportunities to influence consumers' wasteful behaviours. Furthermore, adequately identifying and targeting the audience of the intervention can be a success factor. Further research should focus on leveraging audience segmentation for a more effective intervention design, following the recent increase in on the topic (Aschemann-Witzel et al., 2021; Bilska et al., 2019; Borg et al., 2022). Finally, as Simões et al. (2022) and Vittuari et al. (2023) identification of drivers and barriers of consumer behaviour can also improve intervention design.

More consistency and transparency in data collection is also advised to ensure future comparability of food waste reduction outcomes. A balance should be sought between producing more data on many different interventions and having enough data to guarantee comparability.

In Table 5, a synthesis of available interventions is proposed with the aim of providing practitioners with an accessible information to aid intervention choice and design. The intervention types were chosen based on availability of sources.

## 5. Conclusion

The aim of this review was to investigate food waste reduction interventions at consumer level and relay their reported effectiveness in reaching a decrease in food waste or a change in behaviour. The results show high variability, heterogeneity of interventions types and their specific objectives as well as monitoring methods, specifically regarding waste measurement. Most interventions resulted in a detectable decrease in food waste, when it was quantified, or changes in behaviour towards food waste reduction, but the robustness of the results is also variable. The review provides a solid collection of possible approaches for food waste prevention interventions. As consumer level food waste remains a topical issue, well-designed interventions have to be deployed and monitoring and evaluation needs to be widespread practice in the food waste community. Replication and scale up of the interventions indicated in this review is advisable to solidify the evidence of their effectiveness, also accounting for contextual differences.

The main limitations of this work concern the restriction of sources to mostly academic works in English and the lack of comparison between interventions. The lack of data availability from more grassroots interventions and the focus on outputs in one language might have restricted the pool of sources. In the future, as the research community will produce more evidence of food waste interventions, a meta-analysis could be conducted to compare different interventions and establish a common ground to evaluate effectiveness.

#### Research data statement

All information and data used for this study were retrieved from literature and are publicly available.

**Table 5**  
Guide for intervention choice and implementation.

Intervention type	Intervention mechanism	Features to be included in design	Effectiveness reported	Resources	Skills needed	Experimental setting
Awareness raising/provision of information	National food waste prevention campaign	Recognizability of campaign; appropriate outreach KPIs need to be set	+/-	++	+++	No
	Posters and visual reminders/generic awareness campaigns	Content and mean should be adapted to target audience;	+	+	+++	No
Capacity building & training	Training for staff of restaurants and canteen to induce	Creating an eating environment that enables waste reduction; collaboration of serving staff to serve less/more often	+	++	+	No
	Increase of skills in food management for consumers	Personalized coaching/community workshops/monitoring as awareness raising	++	+++	+	Yes
School programs	Education based interventions	Integrating food waste narrative in educational programs for pupils; long term impact; multidimensionality	++	+	+++	No
Nudges	Default rules; Simplification; Feedback; Changes in configuration	Variety of approaches due to flexibility of category; examples with changes in physical configuration have a stronger evidence base (i.e. smaller plates)	++	+	++	Yes

## Legend.

**Effectiveness reported:** +/- (yellow): information unavailable on food waste reduction (other KPIs available usually); + (light green): information available on food waste reduction but according to literature evidence reduction is low, i.e. <30 %; ++ (dark green): information available on food waste reduction but based on experimental settings, replication and further testing is needed.

**Resources needed for implementation (time and financial investment):** +: resource need is presumed to be low, the intervention is not experimental and requires limited resources (e.g. printing informational material, changing plates or food serving configuration); ++: more investment required, it might not be a one-off intervention but needs to be repeated in time, reskilling of workers or is a large scale intervention; +++: investment is higher because intervention is experimental and requires research/development and evaluation; continuous and labour intensive.

**Skills needed:** +: there is not a robust evidence base available which will entail conducting additional research or the intervention includes the ability to teach or train others; ++: there are already some examples but in specific contexts, further implementation might require adaptation to the precise situation; +++: there are many examples of successful interventions from which to draw inspiration, there is no need for additional experimental research for the design or implementation.

## Declaration of competing interest

None.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.spc.2023.08.002>.

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