

Review Article

A systematic literature review of impactful food waste interventions at the consumer level

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ABSTRACT

As consumers contribute largely to the global food waste quantity, many efforts have been made to reduce food waste through interventions. However, knowledge of the impact of the interventions is required to reduce consumers' food waste. We systematically reviewed 49 studies that evaluated 54 interventions to reduce food waste at the consumer level. The studies were assessed according to three criteria: the type of intervention (single- or multi-component), the study design (randomised experiments, non-randomised [quasi] experiments, non-experimental studies), and the impact on food waste reduction (significant reduction, non-significant reduction, no reduction). The majority of interventions were single-component ($n = 45$), with only a small percentage being multi-component ($n = 9$). Most interventions resulted in a significant reduction in food waste ($n = 36$). Furthermore, the majority of the studies used non-randomised (quasi) experiments ($n = 35$). Multi-component interventions with nudges showed promise for reducing food waste among consumers, with most having a significant impact and leading to the highest food waste reductions (up to 84.3 %). This review synthesises the current state of knowledge regarding the impact of food waste reduction interventions, which can help identify and implement effective interventions in the future.

1. Introduction

In 2022, around 1.05 billion tons of food were wasted globally in households, food services, and retail (United Nations Environment Programme, 2024). Consumers—positioned at the final stage of the food supply chain—contribute a significant 88 % to the amount of food wasted (Stenmarck et al., 2016; United Nations Environment Programme, 2024), despite the fact that food waste is preventable. High-, middle-, and low-income countries are similarly responsible for this high quantity of food waste (United Nations Environment Programme, 2024). In addition to negative environmental impacts, food waste has negative social and economic impacts (McGuire, 2015; Seberini, 2020). Furthermore, reducing food waste is a highly relevant strategy to feed the growing population and alleviate hunger crises in many countries (Hamilton and Richards, 2019).

Therefore, it is crucial to implement effective measures to tackle food waste at the consumer level and to shift consumers towards a more sustainable behaviour by reducing food waste. Studies have shown that behavioural interventions targeting consumers are effective in reducing food waste and have become increasingly popular in recent years

(Caldeira et al., 2019a, 2019b; Jagau and Vyrastekova, 2017; Reynolds et al., 2019). Therefore, behavioural interventions are seen as relevant leverage to promote and strengthen evidence-based food waste prevention measures (Kallbekken and Sælen, 2013).

However, previous research has shown that studies evaluating and comparing food waste interventions face several challenges. For example, due to the difficulty and expense of measuring food waste, the quantification or measurement of food waste has not been consistent among the available studies. Instead, the effectiveness of the intervention has often been evaluated based on the intention to reduce food waste (Aschemann-Witzel et al., 2017; Nikravech, 2023). Furthermore, the evaluation of the intervention methodology and the study design is often lacking (Casonato et al., 2023; Tian et al., 2022). This is surprising, as the choice of study design has a significant impact on the success and effectiveness of interventions (Steinmetz et al., 2016). Lastly, comparing the impact of interventions on food waste reduction is challenging due to the heterogeneity of food waste measurement (e.g. direct via weighing or indirect via recall, the functional units such as food waste per plate, per person, per kitchen, the different settings, such as households or restaurants) (Caldeira et al., 2019b; Reynolds et al., 2019;

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Vittuari et al., 2023) Thus, several researchers have highlighted the lack of systematic evaluations of experimental food waste interventions aimed at reducing food waste at the consumer level (Reynolds et al., 2019; Stöckli et al., 2018; Wunder et al., 2019).

We contribute to narrowing this gap by conducting a systematic review to provide an overview of the current state of knowledge on the impact of empirical interventions aimed at reducing food waste at the consumer level. The included studies are assessed according to three defined criteria from the literature: the type of intervention (single- and multi-component), the study design (randomised experiments, non-randomised [quasi] experiments, or non-experimental studies), and the impact on food waste reduction (significant reduction, non-significant reduction, or no reduction).

We use a holistic approach by including all types of interventions, study designs, and consumer settings without imposing any temporal or geographical restrictions, a comprehensive approach lacking in recent reviews (Casonato et al., 2023; Jobson et al., 2024; Rolker et al., 2022). To assess the impact of highly heterogeneous interventions, we adopt a non-arbitrary approach (we do not define a cut-off reduction level for efficient or inefficient interventions), as the data are not directly comparable. Further, we focus on interventions that measured behavioural change through quantified reductions in food waste, excluding those that focused solely on willingness or intention to reduce food waste. Thus, this contributes to enhanced data reliability, which is currently lacking in the food waste domain.

This review synthesises the current state of knowledge regarding the impact of interventions to reduce food waste. This will help identify and implement effective interventions in the future. In addition, we have provided recommendations and identified research gaps to strengthen the evidence for potentially effective interventions to reduce food waste. Thus, we believe that our manuscript is highly relevant to the field of food waste reduction at the consumer level and could strengthen the legislative basis for setting more binding food waste reduction targets.

2. Methods

2.1. Systematic literature review

In September 2023, we conducted a systematic literature review (hereafter referred to as a review) of studies assessing the effectiveness of food waste interventions at the consumer level. In particular, we assessed the impact on food waste reduction by taking into account the study design. We followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, as outlined by Page et al. (2021). Prior to the review process, we defined the relevant search terms, search databases, and inclusion and exclusion criteria below.

We used the search terms “food waste” and “food loss” to limit our search to all research related to wasted food. We used both terms because “food loss” and “food waste” are often used synonymously (Beretta et al., 2013; Galanakis, 2020). The terms “reduction” and “prevention” were added to focus on quantifiable outcomes. To assess the impact of interventions, we added the term “intervention”, along with synonyms such as “interventional”, “experiment”, “experimental”, and “trial”, which were generated through online translators and author discussions. We focused on the most relevant terms to limit the search restrictions. Hence, our search string was the following Boolean operation:

“food waste” OR “food loss”) AND (reduction OR prevention) AND (intervention OR interventional OR experiment OR experimental OR trial)

For this review, we searched two major databases: ScienceDirect and Scopus. These databases were chosen because of their extensive use in scientific research and their coverage of a wide range of scientific topics. In addition to the databases of ScienceDirect and Scopus, we also included conference abstracts as grey literature. Only peer-reviewed scientific literature available in English was considered. No start date

was specified, and no geographical region was excluded from the search to ensure that the widest possible range of scientific literature was obtained.

The initial search yielded 862 academic studies (Fig. 1). After removing duplicates ($n = 210$), we screened 652 studies for titles and abstracts. A total of 605 studies were excluded due to the exclusion criteria (Supplementary Table 1). Most of the excluded studies focused either on the utilisation of wasted food (e.g. processing, composting, digestion, and animal feed) (Exclusion Criterion 3) or on studies with no intervention (Exclusion Criterion 4) with 31 % each. More information on the excluded studies can be found in Supplementary Fig. 1. After the screening process and manually adding two more relevant studies, this review identified 49 scientific studies describing interventions to reduce food waste at the consumer level.

2.2. Relevant study criteria

Following the aforementioned review process, the papers that met the inclusion criteria were finally included in the study. As illustrated in Fig. 2, all included papers were then assessed according to three defined criteria from the literature: (1) intervention type, (2) study design, and (3) impact of the intervention on food waste reduction.

2.2.1. Criterion 1: Intervention type

Table 1 provides an overview of the most relevant types of single-component interventions based on previous literature. We also considered multi-component interventions that combined at least two different types of single-component interventions. The interventions identified in this review were then categorised according to the types in Table 1. For this review, both in-home and out-of-home (e.g. restaurants, schools, universities) consumer intervention settings were considered. See Fig. 2 Criterion 1.

2.2.2. Criterion 2: Study design

In this study, we distinguished between three frequently applied study designs: randomised experiments, non-randomised (quasi) experiments, or so-called before–after studies, and non-experimental studies (Qusted, 2019; The Maryland Scientific Methods Scale (SMS), 2015; Thiese, 2014) (see Fig. 2 Criterion 2). In randomised experiments, participants or homogeneous groups of participants are randomly assigned to a treatment group (with intervention) or a control group (without intervention). Such a study design allows for the assessment of the power of the intervention on the outcome (Aggarwal and Ranganathan, 2019; Thiese, 2014). The chance of being assigned to the treatment or to the control group is the same for all participants. Further, randomisation allows the creation of comparable groups and reduces selection bias. Due to the comparability of the groups created, differences in the outcome between the two groups can be explained as an effect of the intervention (Bruns and Nohlen, 2023; Price and Lovell, 2018). Thus, randomised experiments are considered robust study designs (Nikravech, 2023; Qusted, 2019; The Maryland Scientific Methods Scale (SMS), 2015). In particular, randomised controlled trials (RCTs) are considered to be highly robust studies for assessing the cause–effect relationship between an intervention and the outcome (Aggarwal and Ranganathan, 2019; Bruns and Nohlen, 2023; Price and Lovell, 2018), as they reduce selection bias and help minimise confounding variables that affect the impact assessment.

Non-randomised (quasi) experiments are often pre-post or before–after studies that, in this context, measure consumer food waste before (baseline measurement) and after the intervention (Aggarwal and Ranganathan, 2019; Thiese, 2014). Such experiments can show a relationship between the intervention and the outcome. Other non-randomised experiments compare, for example, different conditions (e.g. different plate sizes) or time points (start–end point) with each other, without a baseline measurement before the intervention. Non-experimental studies are mainly based on observations, such as

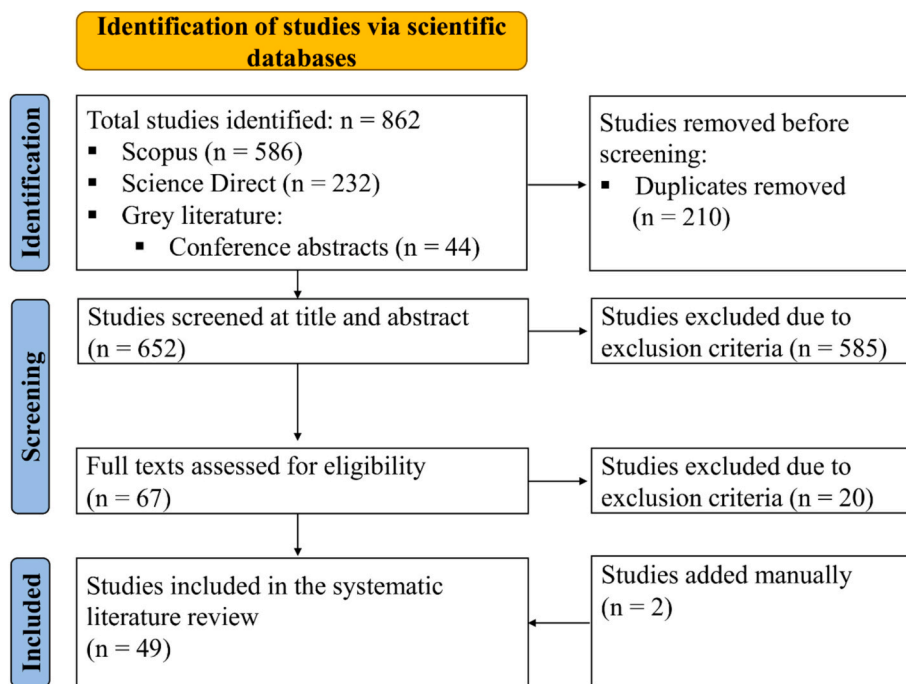


Fig. 1. PRISMA flowchart diagram of this systematic literature review, adapted from Page et al. (2021). A total of 652 studies were screened for titles and abstracts, and 49 studies were included in this systematic literature review.

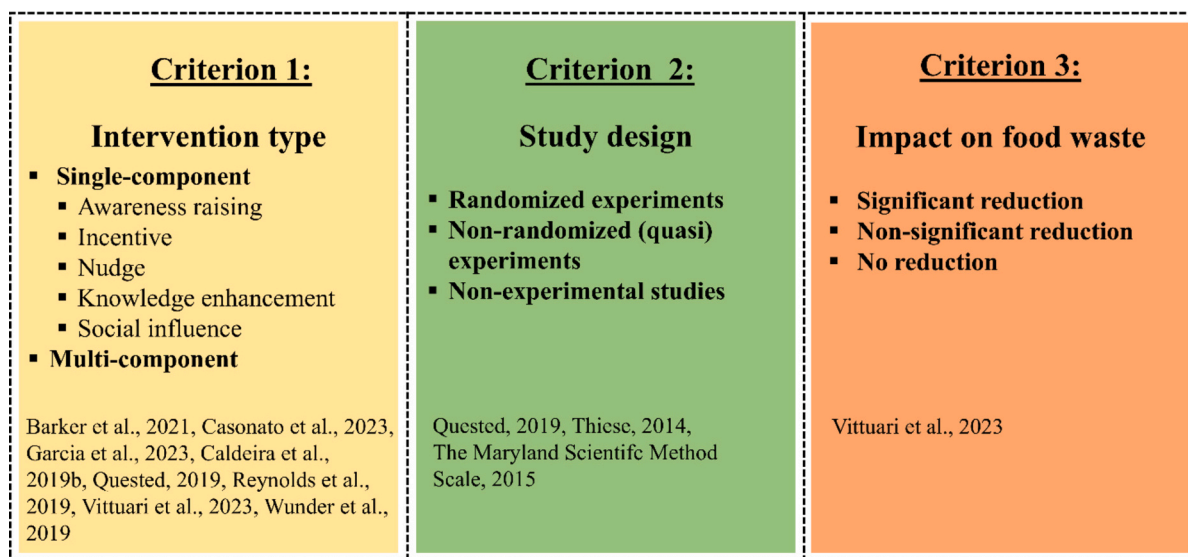


Fig. 2. The studies included in this systematic literature review were assessed based on criterion 1 (intervention type), criterion 2 (study design), and criterion 3 (impact on food waste reduction).

national programmes or cross-sectional studies (Aggarwal and Ranganathan, 2019; Quested, 2019; The Maryland Scientific Methods Scale (SMS), 2015). Thus, there is no active manipulation (experiment) being tested by the researcher.

2.2.3. Criterion 3: Impact

We measured the impact of food waste interventions using the food waste reduction schema from Vittuari et al. (2023) (see Fig. 2: Criterion 3). This schema represents a holistic and non-arbitrary approach to provide an overview of the outcomes of food waste interventions. The reported amounts of food waste were therefore used as a proxy to assess the performance of the interventions, as follows: (1) significant reduction—when the intervention resulted in a statistically significant

reduction in the amount of food waste; (2) non-significant reduction—when the intervention resulted in a non-significant reduction in the amount of food waste; and (3) no reduction—when the intervention did not have the desired effect of reducing food waste or even increasing the amount of food waste.

3. Results

This review included 49 studies. This sample came from 26 journals between January 1, 2013 and September 20, 2023. We considered the incidence of published articles on food waste interventions and observed a steady increase from 2019 to 2022 (see Supplementary Fig. 2). However, in 2023, there was a decrease in the incidence of publications.

Table 1

An overview of the types of interventions considered in this review (Barker et al., 2021; Caldeira et al., 2019b; Casonato et al., 2023; Garcia et al., 2023; Qusted, 2019; Reynolds et al., 2019; Vittuari et al., 2023; Wunder et al., 2019).

Intervention type	Description	Examples
Awareness raising	A process that seeks to inform and educate people about food waste and its social, economic and environmental impacts. The intention is to influence peoples' attitudes, behaviours, and beliefs towards food waste reduction by providing information about the topic on how to adopt less wasteful behaviour.	Display of informative posters, table cards, messages, using different, communication tools, campaigns, self-reporting food waste, etc.
Incentives	Economic and non-economic incentives for citizens to reduce food waste.	Economic incentives (e.g. different pricing models, discount, gift-cards), non-economic incentives (level of interaction, game) etc.
Nudge	Positive reinforcement and indirect suggestions as ways to influence the behaviour and decision making of groups and individuals, changing of the choice architecture.	Prompts (email reminding people to undertake desired behaviour), feedback (informing people of the occurrence and impacts of their own past choices), commitment (a public pledge to undertake the desired behaviour), changes in diet/menus (reduced portion etc.), technological aids (plate size, shape, and colour, etc.), food waste reduction tools (providing storage bags), etc.
Knowledge enhancement	Programmes aiming at increasing consumers' abilities, skills, and confidence necessary to engage in food waste prevention practices.	School programmes (education interventions specifically targeted at students to inform them on food waste, its impacts and strategies to counter it), education, training, instructions (introduction of meal planning and food storage methods, cooking skills, and food waste reduction tips), etc.
Social influence	Interventions that aim to influence social norms or shape behaviour by giving consumers information about the behaviour or attitudes of the majority of their reference group.	Use of various communication channels, food sharing, community workshop and engagement, etc.
Multi-component	Interventions that combined at least two of the above-mentioned intervention types.	For example, nudges combined with awareness-raising strategies.

Interestingly, regarding the study design, randomised experiments, which are known for their high robustness of results, showed a consistent increase from 2019 to 2023.

The dominant journal source was *Resources, Conservation and Recycling*, followed by *Sustainability*, *Journal of Cleaner Production*, and *Waste Management* (see Supplementary Table 2 for more information). Further, we identified 22 different countries of publication among the 49 articles, with the USA and the UK dominating. Further, 41 % of all studies were conducted in EU regions, while 28 % were conducted in EU member states (see Supplementary Fig. 3 for more information).

3.1. Criterion 1: Intervention type

We identified 54 interventions in the 49 studies included in this review. Of the 54 interventions included in the review, we found predominantly single-component interventions (83 %), while multi-component interventions (17 %) were applied less often. As shown in

Fig. 3, most single-component interventions tested nudging (42 %) or knowledge enhancement (24 %) strategies. Interventions involving awareness raising, social influence, and incentives were less frequently used. Further, the multi-component interventions mainly used nudges in combination with other types of interventions. Only one multi-component intervention combined awareness raising with knowledge enhancement. Four studies tested different types of single-component interventions in parallel (Malefors et al., 2022; Pelt et al., 2020; Soma et al., 2020; Visschers et al., 2020); therefore, the nine single-component interventions from these four studies were categorised according to intervention type.

The majority of interventions were conducted in households (35 %), followed by universities (24 %), schools (18 %), hotels (9 %), retail with spillover in households (unintended behaviour of an intervention, for example, providing hampers and stickers with sustainable products or giving a live in-store cooking demonstration, could lead to reduced food waste at home) (6 %), hospitals/nursing homes (4 %), restaurants (2 %), and camping (2 %). The target population varied according to the setting, with household members (33 %), students (26 %), and children and adolescents (18 %) being the most frequent study participants. Other target groups included staff at work (7 %), customers/employees (6 %), hotel/restaurant guests (6 %), residents (2 %), and patients (2 %).

3.2. Criterion 2: Study design

The study designs of the 54 interventions were categorised as randomised experiments, non-randomised (quasi) experiments, and non-experimental studies. Most of the studies (65 %) conducted non-randomised (quasi) experiments, of which 58 % were before-after studies. Experimental studies comparing different interventions/conditions (trays versus no trays, food sharing versus no food sharing, different plate colours) or time points (evaluation over time) were less frequently presented, at 7 % (Chawla et al., 2020; Hansen and Derdowski, 2020; Kim and Morawski, 2012; Morone et al., 2018). Randomised experiments accounted for 26 %, of which 9 % were RCTs (Cooper et al., 2023; Gimenez et al., 2023; Roe et al., 2022; Thorsen et al., 2015; van der Werf et al., 2019) and 17 % were other types of randomised experiments (Liu et al., 2022; Pelt et al., 2020; Qi et al., 2022; Qi and Roe, 2017; Ramos et al., 2023; Shaw et al., 2018; van Herpen et al., 2023). Non-experimental studies accounted for 9 % and included national programmes and cross-sectional studies (Chen et al., 2022; Dooren et al., 2020; Eckert Matzembacher et al., 2020; Elnakib et al., 2021; Lee and Jung, 2017).

Multi-component interventions more often applied randomised experiments (44 %) compared to single-component interventions (22 %) (Fig. 4). There were no studies with a non-experimental design among the multi-component interventions. Further analysis of the study design of the publications by setting revealed that randomised experiments were only present in household studies (53 %), universities (23 %), and schools (10 %).

Furthermore, we found large heterogeneity in the number of participants in the studies (12–25,522), the definition of food waste (e.g. edible vs. inedible waste), and the measurement of food waste (82 % direct measurement via weighing vs. 18 % indirect measurement via images or estimations via recalls, 75.5 % non-self-reported data vs. 24.5 % self-reported data). In total, six studies applied food waste composition analysis, in which food waste was measured directly via weighing by researchers (non-self-reported) (Dooren et al., 2020; Morone et al., 2018; Pelt et al., 2020; Shaw et al., 2018; Soma et al., 2020; van der Werf et al., 2019). Within the studies that used RCTs, we also observed methodological differences (e.g. food waste measurement, food waste reduction units, food categories). An overview of the methods used in the RCT studies is provided in Supplementary Table 3. Furthermore, almost all RCT studies measured food waste indirectly via self-reporting (recall or photo) (Cooper et al., 2023; Gimenez et al., 2023; Roe et al., 2022), while one study measured food waste directly via waste

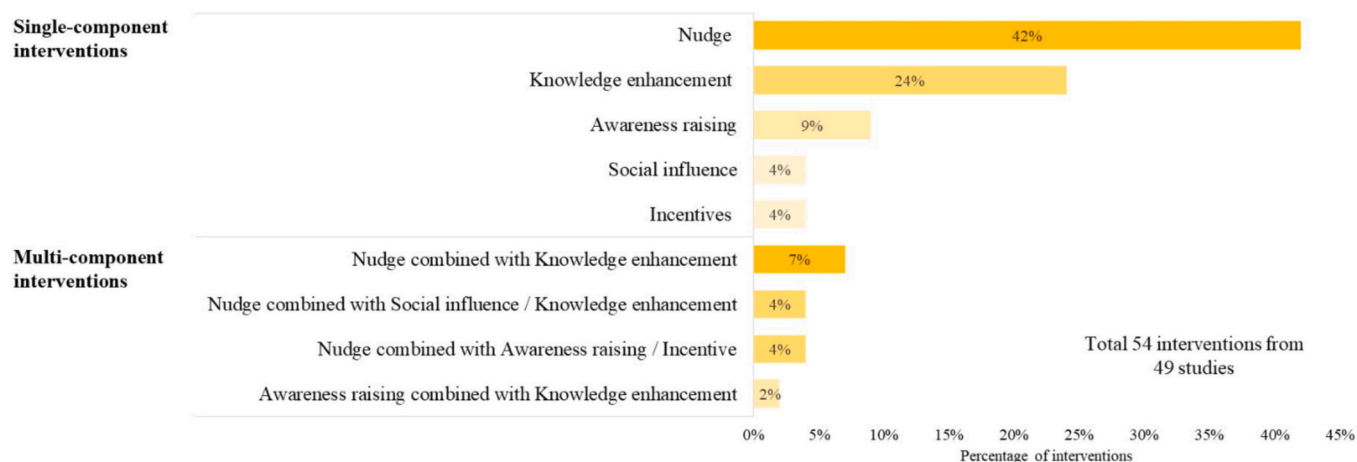


Fig. 3. An overview of the types of interventions identified in this systematic literature review in the proportion (%) of the total number of interventions (n = 54) from 49 studies. The interventions are divided into five intervention types: nudge, knowledge enhancement, awareness raising, social influence and incentive. Further, we distinguished between single-component interventions, that is, using only one type of intervention, and multi-component interventions, that is, using more than one type of intervention).

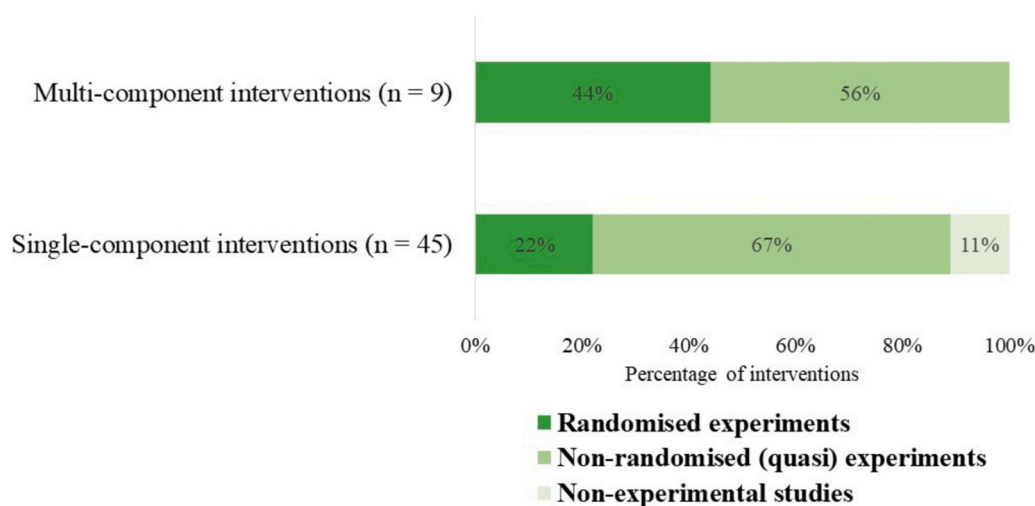


Fig. 4. An overview of the study designs (n = 54 interventions from a total of 49 studies) in this systematic literature review. The interventions were categorised into randomised experiments, non-randomised (quasi) experiments and non-experimental studies.

composition analysis (van der Werf et al., 2019).

3.3. Criterion 3: Impact

We evaluated 54 interventions to determine whether they led to a statistically significant reduction, a non-significant reduction, or no reduction in food waste. An overview of all the studies included in this review (with their impact on food waste reduction, study design, and intervention type) is given in Table 2. The study design and the methods used to measure food waste are heterogeneous. Therefore, it is often difficult to compare the percentage reduction in food waste between studies. Nonetheless, in this section, in addition to the results for the three impact categories, we also report the percentage reduction in food waste. This provides a plausible estimate of the potential for quantitative reductions in food waste.

We found that the majority of the interventions led to a significant reduction in food waste (67%), whereas less than a third showed a non-significant reduction (26%). We classified a few interventions as having no reduction or even an increase (7%) in food waste. Eight studies reported a positive effect on long-term food waste reduction when food waste was measured sometime after the intervention (Cooper et al.,

2023; Dooren et al., 2020; Leverenz et al., 2021; Pelt et al., 2020; Trewnern et al., 2022; Wang et al., 2022; Wharton et al., 2021; Young et al., 2018).

A comparison of the impact of single- and multi-component interventions (Fig. 5) showed that multi-component interventions were more likely to have a significant impact on food waste reduction (89%) compared to single-component interventions (62%). Furthermore, there were no multi-component interventions without a reduction in food waste.

3.3.1. Intervention with significant food waste reduction

Eight out of nine multi-component interventions (e.g. nudges combined with knowledge enhancement and social influence and awareness raising combined with knowledge enhancement) resulted in a significant reduction in food waste (Fig. 6). Similarly, among the single-component interventions tested, the majority of nudges (70%) and awareness raising (60%) reported significant reductions in food waste. However, only about half of the interventions that tested knowledge enhancement (54%), social influence (50%), incentives (50%), or nudges combined with awareness raising and incentives (50%) reported a significant reduction in food waste. Furthermore, the percentage

Table 2

A summary of the 49 studies (a total of 54 interventions) included in this systematic literature review. Information provided on the authors with year, the intervention type, the applied instruments, the study design, the study setting and the indication whether the intervention achieved a significant food waste reduction.

Authors with year	Intervention type	Instruments	Study design	Study setting	Significant food waste reduction?
1. Ahmed et al. (2018)	Nudge	Reduced portion size, smaller serving utensils, educational messages	Non-randomised (quasi) experiment	University	No
2. Alattar and Morse (2021)	Knowledge enhancement	School food waste diversion program	Non-randomised (quasi) experiment	University	Yes
3. Antón-Peset et al. (2021)	Knowledge enhancement	Didactic interventions for pupils and teachers	Non-randomised (quasi) experiment	School	No
4. Antonschmidt and Lund-Durlacher (2021)	Nudge	Environmental communication tools, graphic and written messages, context manipulation	Non-randomised (quasi) experiment	Hotel	Yes
5. Boulet et al. (2022)	Knowledge enhancement	Mix of educational, skills-based, and whole-of-school-events	Non-randomised (quasi) experiment	School	No
6. Chawla et al. (2020)	Nudge	Different portion size, calibration, transparency and location of waste bins	Non-randomised (quasi) experiment	Hotel	No
7. Chen et al. (2022)	Knowledge enhancement	School program with educational curriculum	Non-experimental study	Camping	No
8. Cooper et al. (2023)	M: Nudge/Knowledge enhancement	Identifying foods that are at risk of being thrown away, using flexible recipes, prompts, follow-up reminders	Randomised experiments (RCT)	Household	Yes
9. Cozzio et al. (2021)	Nudge	Functional and experiential appeal message	Non-randomised (quasi) experiment	Hotel	Yes
10. Davison et al. (2022)	Nudge	Informative place cards, salient signs, and poster prompts, posters providing group feedback.	Non-randomised (quasi) experiment	University	No
11. Souza et al. (2019)	Nudge	Adjusting quality and quantity of meals	Non-randomised (quasi) experiment	School	Yes
12. Eckert Matzembacher et al. (2020)	Incentives	Monetary incentives and different levels of interactions	Non-experimental Study	Restaurant	No
13. Elnakib et al. (2021)	Knowledge enhancement	School program smarter lunch room movements, 29 strategies	Non-experimental Study	School	Yes
14. Gimenez et al. (2023)	M: Awareness raising /Knowledge enhancement	Self-reporting food waste, reading a text about food waste and completing a task	Randomised experiments (RCT)	Household	Yes
15. Barba-Gutiérrez and Ortega-Rubio (2013)	Knowledge enhancement	Educational workshops	Non-randomised (quasi) experiment	Household	Yes
16. Hansen and Derdowski (2020)	Nudge	Different plate colours	Non-randomised (quasi) experiment	Nursing home	No
17. Ramos et al. (2023)	Knowledge enhancement	Instructions for purchase and planning, cooking and planning	Randomised experiment	Household	Yes
18. Kim and Morawski (2012)	Nudge	Using no trays	Non-randomised (quasi) experiment	University	Yes
19. Lee and Jung (2017)	Incentives	Different pricing systems	Non-experimental Study	Household	Yes
20. Leverenz et al. (2019)	Awareness raising	Self-reporting food waste	Non-randomised (quasi) experiment	Household	Yes
21. Leverenz et al. (2021)	M: Nudge/Awareness raising	Self-reporting food waste, just-in time preparation, smaller serving dishes, reduced buffet quantity	Non-randomised (quasi) experiment	Hotel	No
22. Lim et al. (2021)	Nudge	Waste bin E-COMate captures and visualise domestic food waste data in waste bin	Non-randomised (quasi) experiment	University	Yes
23. Liu et al. (2022)	Nudge	Different display size for ordering meals, narrow (small portion) vs. broad menus (larger portion)	Randomised experiment	University	Yes
24a. Malefors et al. (2022)	Awareness raising	Awareness campaign	Non-randomised (quasi) experiment	School	Yes
24b. Malefors et al. (2022)	Nudge	Tasting spoon, plate waste tracker, forecasting tool	Non-randomised (quasi) experiment	School	Yes
25. Marques et al. (2022)	Knowledge enhancement	School program with educational curriculum	Non-randomised (quasi) experiment	School	Yes
26. Morone et al. (2018)	Social influence	Food sharing	Non-randomised (quasi) experiment	Household	No
27. Mariam et al. (2022)	Knowledge enhancement	Educational workshop “Food Waste Lab”	Non-randomised (quasi) experiment	School	Yes
28a. Pelt et al. (2020)	Nudge	Implementation plan based on cognitive dissonance (commitment)	Randomised (quasi) experiment	Households	Yes
28b. Pelt et al. (2020)	Knowledge enhancement	Leaflets with food waste information	Randomised (quasi) experiment	Households	No
28c. Pelt et al. (2020)	Awareness raising	Self-reporting food waste	Randomised (quasi) experiment	Households	No
29. Qi and Roe (2017)	Awareness raising	Information cards with negative environmental outcomes	Randomised (quasi) experiment	University	Yes
30. Qi et al. (2022)	Nudge	Meals on a larger and smaller plate; meals with more or less vegetables, meals on a compostable or plastic plate	Randomised (quasi) experiment	University	Yes
31. Rathnayake and Dalpatadu (2020)	Nudge	New diet order form based on dietary preferences	Non-randomised (quasi) experiment	Hospital	Yes
32. Richardson et al. (2021)	Nudge	Changing plate shape and size	Non-randomised (quasi) experiment	University	Yes

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Table 2 (continued)

Authors with year	Intervention type	Instruments	Study design	Study setting	Significant food waste reduction?
33. Roe et al. (2022)	M: Nudge/Knowledge enhancement	Individual training and tailoring with coach, prompts as tips via text, email or call	Randomised experiment (RCT)	Household	Yes
34. Shaw et al. (2018)	Awareness raising	Messages via leaflets showing negative impact of food waste on environment	Randomised (quasi) experiment	Household	No
35. Shu et al. (2023)	M: Nudge/Awareness raising and incentive	Communication channels, prompts (tips), tool to reduce food waste in household and incentive (discount)	Non-randomised (quasi) experiment	Household	Yes
36a. Soma et al. (2020)	Nudge	Gamification approach with points and rewards	Non-randomised (quasi) experiment	Households	Yes
36b. Soma et al. (2020)	Knowledge enhancement	Passive handouts with information about food waste and tips	Non-randomised (quasi) experiment	Households	No
37. Thorsen et al. (2015)	Nudge	New Nordic diet vs. packed lunch as usual	Randomised experiment (RCT)	School	No
38. Trewern et al. (2022)	M: Nudge/social influence/knowledge enhancement	Live expert webinars, cook-alongs, Facebook groups, product hampers, tailored advice, tips and hacks	Non-randomised (quasi) experiment	Retail	Yes
39. van der Werf et al. (2019)	M: Nudge/Knowledge enhancement	Food literacy messaging, save money by reducing food waste, food waste reduction tools (e.g. grocery list)	Randomised experiment (RCT)	Household	Yes
40. Dooren et al. (2020)	Nudge	Tool to reduce food waste in household: "Eetmaatje" measuring cup for pasta and rice.	Non-experimental Study	Household	No
41. van Herpen et al. (2023)	Nudge	Experiment 1: tool package (measuring cup etc.) vs. motivational messages; Experiment 2: only messages	Randomised (quasi) experiment	Household	Yes
42. Vidal-Mones et al. (2022)	Nudge	Different nudges via posters: (1) visual (e.g. the menu of the day) (2) participative (e.g. how to eat fruits), (3) educative (e.g. food waste talks)	Non-randomised (quasi) experiment	School	Yes
43a. Visschers et al. (2020)	M: Nudge/Knowledge enhancement	Smaller servings, information about food waste	Non-randomised (quasi) experiment	University	Yes
43b. Visschers et al. (2020)	Knowledge enhancement	Information about food waste	Non-randomised (quasi) experiment	University	No
44. Wang et al. (2022)	Nudge	(1) environmental framing and (2) environmental framing with anthropomorphic cues	Non-randomised (quasi) experiment	Hotel	Yes
45. Wharton et al. (2021)	Knowledge enhancement	Online education: virtual online websites, podcasts, infographics, videos	Non-randomised (quasi) experiment	Household	Yes
46. Whitehair et al. (2013)	Nudge	(1) Prompt-type message (e.g. do not waste food), (2) Feedback based message (e.g. average waste students)	Non-randomised (quasi) experiment	University	Yes
47. Young et al. (2017)	Social influence	Social media communication channels (Facebook), information (e-news-letters, magazine)	Non-randomised (quasi) experiment	Retail	Yes
48. Young et al. (2018)	M: Nudge/Social influence /Knowledge enhancement	In-store magazine, in-store demonstrations etc., prompts, food waste reduction messages	Non-randomised (quasi) experiment	Retail	Yes
49 Zhang and Kwon (2022)	Nudge	Using no trays	Non-randomised (quasi) experiment	University	No

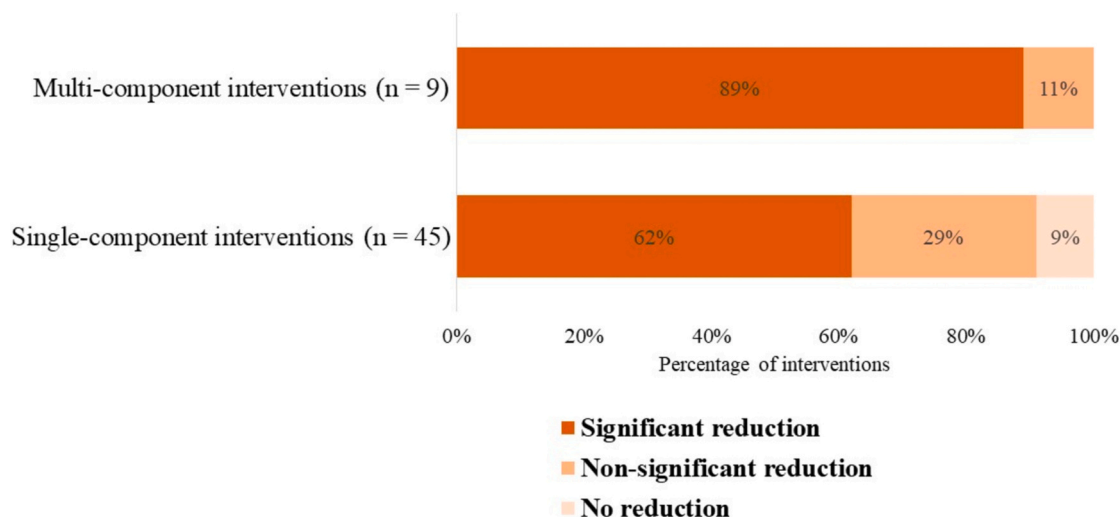


Fig. 5. Impact of interventions on food waste of single- and multi-component interventions (a total of 54 interventions from 49 studies) in this systematic literature review. With significant reduction, non-significant reduction, and no reduction in food waste.

reduction in food waste ranged from 7 % ($p < 0.001$, knowledge enhancement) (Elnakib et al., 2021) to 79 % ($p < 0.001$, multi-component nudge combined with knowledge enhancement) (Roe et al., 2022).

Regarding multi-component interventions with significant reductions in food waste, we found that a nudge combined with knowledge enhancement led to the highest level of reduction among the 49 studies. The use of individualised training and tailoring with a coach,

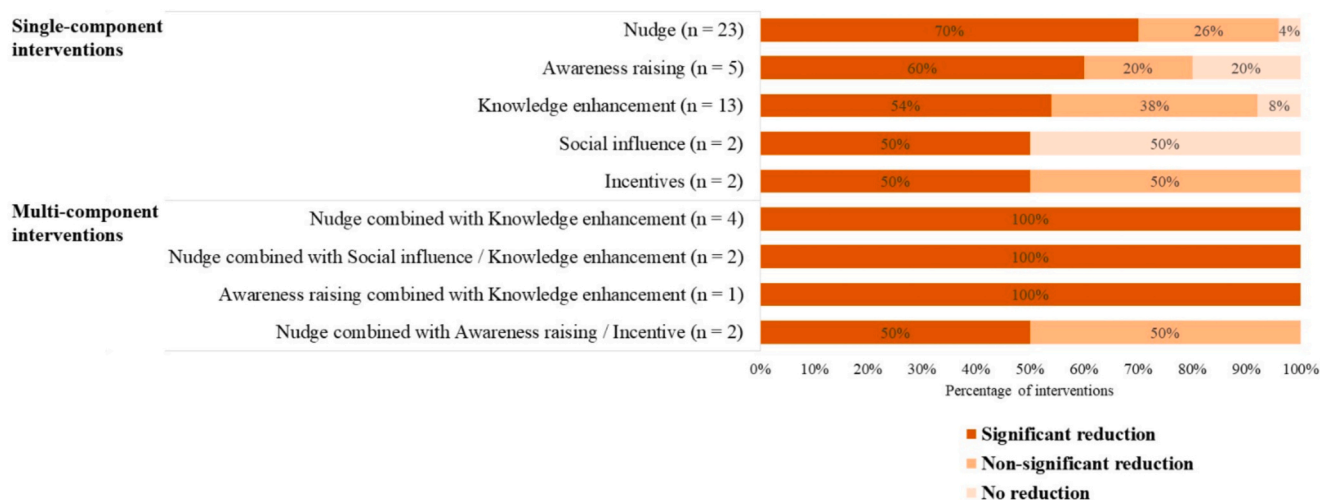


Fig. 6. Impact of interventions on food waste ($n = 54$ interventions from 49 studies), with significant reduction, non-significant reduction, and no reduction. Interventions are divided into single-component (nudge, awareness raising, knowledge enhancement, social influence, incentive) and multi-component interventions.

including prompts such as tips via text, email, or calls (household, randomised experiments), led to a significant reduction in avoidable food waste in the treatment group of up to 79 % ($p = 0.001$) (Roe et al., 2022). Furthermore, the combination of nudges with social influence and knowledge enhancement (retail with spillover to households, non-randomised [quasi] experiment) achieved a significant food waste reduction of 40 % ($p < 0.01$) (Trewern et al., 2022). This multi-component intervention conducted in retail used tools such as information, training, live expert webinars, cook-along, private Facebook groups, and tailored advice. Another multi-component strategy was the combination of a nudge with awareness raising and incentives (households, non-randomised [quasi] experiment), which led to a significant reduction in food waste of 23 % ($p < 0.01$) among volunteer participants (Shu et al., 2023). The intervention included a community-based campaign that provided information through communication channels to prevent food waste via prompts, tips, and tools to reduce food waste at home, and an incentive, such as a discount for buying a composter. Finally, an intervention combined awareness raising and knowledge enhancement (households, randomised experiment) to achieve a significant reduction in food waste of 16 % per capita ($p = 0.038$) through self-reported food waste and reading a text on food waste and answering questions afterwards (Gimenez et al., 2023).

Among the multi-component interventions, we identified a total of four studies using RCTs that showed a significant reduction in food waste (Cooper et al., 2023; Gimenez et al., 2023; Roe et al., 2022; van der Werf et al., 2019) (Supplementary Table 3). They used multi-component interventions, in particular nudges combined with training and knowledge enhancement or awareness raising combined with knowledge enhancement. Food waste reductions ranged from 15.8 % ($p = 0.038$) (Gimenez et al., 2023) to 79 % ($p = 0.001$) (Roe et al., 2022).

Among the single-component interventions with a significant reduction, we found that nudging children to eat healthier by improving sensory qualities of food (school, non-randomised [quasi] experiment) achieved a 78 % reduction in leftovers per child ($p < 0.001$), based on pre- and post-interventional data (Souza et al., 2019). Further, an awareness-raising intervention using cards informing participants about the negative environmental impact of food waste (university, randomised experiment) resulted in a 77 % reduction in food waste ($p < 0.001$) (Qi and Roe, 2017). Among the studies that applied knowledge enhancement, a maximum food waste reduction of 56 % ($p < 0.01$) was reported (school, non-randomised [quasi] experiment) by implementing a school programme with an educational workshop (Mariam et al., 2022). Regarding the social influence intervention, social media channels and information dissemination were used. Specifically, this

intervention was conducted in school settings via a non-randomised (quasi) experiment and led to a 19 % reduction ($p < 0.05$) in food waste (Young et al., 2017). An incentive intervention with different pricing schemes resulted in a significant reduction in food waste ($p < 0.01$), but the reduction could not be quantified (household, non-randomised (quasi) experiment) (Lee and Jung, 2017).

We also found that experiments with randomisation reported the highest percentage (72 %) of significant reductions in food waste. Our analysis of food waste reductions based on the study setting revealed that interventions conducted in retailers with spillovers to homes (100 %), schools (70 %), universities (69 %), and households (68 %) were most effective. Interestingly, all studies conducted in retailers showed significant impacts, with food waste reductions ranging from 9 % ($p \leq 0.05$) (Young et al., 2017) to 40 % ($p < 0.01$) (Trewern et al., 2022). These studies tested social influence in combination with nudges (Trewern et al., 2022; Young et al., 2018) or without nudges (Young et al., 2017). All retailer studies were conducted in the UK and used different communication channels via social media, e-newsletters, magazines, in-store magazines, product stickers, in-store demonstrations, prompts (food waste reduction messages, tips and hacks, sustainable product hampers), training, webinars from nutritionists, cook-along, or tailored advice.

3.3.2. Interventions with a non-significant food waste reduction

We found a non-significant reduction in food waste for about half of the incentives tested and for half of the combinations of nudge and awareness raising. Of the interventions tested, 38 % of the knowledge-enhancement interventions, 26 % of the nudge interventions, and 20 % of the awareness-raising interventions showed a non-significant reduction in food waste (Fig. 6). The percentage reduction in food waste of these interventions ranged from 6.2 % (nudge) (Zhang and Kwon, 2022) to 84.3 % (multi-component intervention with nudge combined with awareness raising) (Leverenz et al., 2021).

A multi-component intervention that combined nudges and awareness-raising strategies (hotel, non-randomised [quasi] experiment) reported 84.3 % effectiveness, the highest reduction in food waste among all 49 studies. The study used a self-reporting approach, just-in-time preparation, smaller portion sizes, and a reduction in the amount of food on the buffet to reduce breakfast buffet leftovers (Leverenz et al., 2021). Considering the average food waste reduction of all four included hotels, the breakfast buffet leftovers were reduced by >64 %. This intervention demonstrated that a self-reporting food waste approach is promising for reducing food waste in hotel kitchens and buffets.

Among single-component interventions, studies testing nudge

interventions demonstrated that using technological aids, such as waste bins of different sizes, calibration, transparency, and location, led to a non-significant reduction in food waste of 73 % (hotel, non-randomised [quasi] experiment) (Chawla et al., 2020). Providing a high level of incentives (paying only for the amount of food served and visualising and smelling the food before it is served) led to a non-significant reduction of 65.8 % (restaurants, non-randomised [quasi] experiment) (Eckert Matzembacher et al., 2020). Studies that used knowledge-enhancement interventions tested different school programmes. The highest non-significant food waste reduction of 35 % (pre- and post-intervention) was achieved using a mix of educational and skill-based programmes and events (school, non-randomised [quasi] experiment) (Boulet et al., 2022). The aim was to encourage children to become more involved in the selection and preparation of food to take to school.

Further, a self-reporting food waste approach to create awareness about one's own food waste led to a reduction of 6.8 % per person per week in the data comparison of pre-intervention and follow-up (5 weeks after the intervention) food waste measurement (household, randomised experiment) (Pelt et al., 2020). The highest share of interventions with a non-significant reduction in food waste was observed for non-experimental studies (60 %).

3.3.3. Interventions with no food waste reduction

Four single-component interventions reported no reduction in food waste. Intervention types without an achieved food waste reduction were as follows: social influence (50 %), awareness raising (20 %), knowledge enhancement (8 %), and nudge (4 %) (Fig. 6). The results of this review showed that a social influence intervention with a food-sharing practice increased food waste by 12.7 % compared to the control group (school, non-randomised [quasi] experiment) (Morone et al., 2018). Moreover, raising awareness of food waste by showing its negative environmental consequences led to higher food waste (pre- and post-intervention) (household, randomised experiment) (Shaw et al., 2018). Similarly, a knowledge-enhancement intervention in which visitors received information about food waste over a period of three weeks failed to achieve a reduction in food waste (university, non-randomised [quasi] experiment) (Visschers et al., 2020). Lastly, a nudging strategy that provided lunch with improved nutritional quality led to more food waste than packed lunch (school, randomised experiment) (Thorsen et al., 2015). However, edible plate waste differed between menus ($p < 0.0001$), with more waste on soup days (36 %) and vegetarian days (23 %) compared with the packed lunch period. Further, self-reported likings were negatively associated with percentage plate waste ($p < 0.0001$).

4. Discussion

We assessed the impact of interventions aimed at reducing food waste at the consumer level by considering the design of the study. Therefore, the selected studies ($n = 49$) with a total of 54 interventions were evaluated based on three criteria: (1) the type of intervention, (2) the study design, and (3) the impact on food waste reduction. In this section, we discuss the results for the three criteria and offer their implications for future food waste interventions.

4.1. Study settings and target population

This review identified mostly in-home intervention settings targeting household members, whereas out-of-home settings were less represented. We also found that universities were the most frequently out-of-home setting, targeting students with higher overall knowledge, interest, and environmental awareness (Zsóka et al., 2013). Therefore, it might be challenging to generalise the results obtained from these university studies. Furthermore, most participants were aware of the intervention, which might reinforce the underreporting of self-reported food waste quantity. Based on these findings, we propose the following

recommendations:

- More studies are needed to test out-of-home interventions in new or so far rarely tested settings, such as airplanes and airports. This is relevant because research has shown that consumers' food waste behaviour varies depending on the context, such as between in-home and out-of-home environments (National Academies of Sciences, Engineering, and Medicine, 2020; Qusted, 2019). Replicating effective interventions in different settings could enhance our understanding of which interventions work best in specific contexts and how to design them for maximum effectiveness in each environment.
- For out-of-home interventions, future studies should aim to reduce the selection bias of participants (e.g. other than university students). This is relevant because participants with a higher level of education may have a greater awareness of environmental issues, which could result in reduced food waste. Therefore, extending studies to participants with lower educational levels could enhance the representativeness of the population and improve the generalisability of food waste data.
- Future investigations should include more participants who are unaware (unconscious that an intervention is happening) of the intervention. This is important because food waste data from unaware participants may be more reliable, as the bias of underreporting is minimised (Merian et al., 2024). Furthermore, since not all participants are motivated to reduce food waste, it is important to implement interventions that utilise unconscious behaviour change methods, allowing participants to make changes without being fully aware of it (Zeinstra et al., 2020). Therefore, employing study designs that include unaware participants could enhance the reliability of food waste data and improve the accuracy of food waste measurements, which is currently lacking (Merian et al., 2024).

4.2. Study design

Most of the studies conducted non-randomised (quasi) experiments, while only a few studies applied RCTs. RCTs are known for their high study design robustness, as the observed behavioural change can be attributed to the intervention itself and not to sources of bias (Nikravech, 2023; The Maryland Scientific Methods Scale (SMS), 2015; Thiese, 2014). Quasi experimental designs are less controlled for potential bias compared to RCTs, and might thus provide less evidence (Nikravech, 2023). Moreover, RCTs are a pertinent tool for promoting legislate evidence-based policies (Kallbekken and Sælen, 2013). However, RCTs have rarely been applied in the field of food waste interventions. This is confirmed by our review, in which only 9 % of the included studies were RCTs. This might be due to the high complexity of the study design and the high requirements for resources and costs. Nevertheless, both randomised and non-randomised designs have been shown to be relevant in providing a holistic and evidence-based view (Pandis et al., 2014).

Most RCTs measured food waste indirectly, either via self-reporting on recall or via photos, which is less reliable and accurate than measuring food waste directly, for example, via a food waste composition analysis (Xue et al., 2017). The analysis of food waste composition is known to be the least biased subject (Qusted, 2019). Conversely, self-reporting can lead to an underestimation of the actual generated food waste, which is therefore at an increased risk of bias. In addition to the heterogeneous methods, a large heterogeneity among the included food waste interventions was observed. This heterogeneity was also recently observed elsewhere (Reynolds et al., 2019; Vittuari et al., 2023).

Based on our findings, we suggest the following recommendations:

- Testing more interventions using harmonised and robust study designs, such as RCTs. RCTs are particularly relevant in the

field of food waste because they reduce the risk of confounding factors and allow for clearer differentiation between effective and ineffective interventions (Jiang et al., 2024). Conducting more RCTs could facilitate a better comparison and assessment of the impact of interventions using a more rigorous approach, such as a meta-analysis. This contributes to more informed decision-making in designing and implementing future interventions, enhancing both replicability and generalisability. Additionally, increasing the use of robust study designs could promote evidence-based policies, which are urgently needed to achieve long-term reductions in food waste (Casonato et al., 2023; Nikravech, 2023).

- Applying more direct and non-self-reported food waste measurements (such as food waste composition analysis) in RCTs. Direct measurement of food waste can enhance data reliability, as it is based on actual quantities rather than estimates. Furthermore, non-self-reported data are important because they reduce the bias of underreporting food waste quantities, as participants cannot reflect on their food waste behaviour (self-improvement). In addition, non-self-reported food waste methods mitigate the risk of participants experiencing decreased reactance and increased fatigue over time (Ahmed et al., 2018). In summary, the increased use of direct and non-self-reported food waste measurements could enhance the accuracy of food waste data and allow for a better evaluation of interventions, which is currently lacking (Quested, 2019).

4.3. Impactful interventions to reduce food waste

4.3.1. Multi-component interventions

We identified multi-component interventions (particularly those combining nudges with other interventions in households) as pertinent leverage to significantly reduce food waste at the consumer level. Multi-component interventions showed the highest percentage reductions in food waste (79 %, $p = 0.001$) and (84.3 %) (Roe et al., 2022; Leverenz et al., 2021). Furthermore, three studies tested the effects of single-versus multi-component interventions. They found that providing information on food waste alone was not sufficient to reduce food waste, whereas information combined with a reduction in portion size (nudge) led to a significant reduction in food waste reduction (Visschers et al., 2020). Similar results were observed in other studies, in which no single-component intervention achieved food waste reduction. However, combining intervention types (combined communication channels with repeated messages and combined tool packages with motivational messages) yielded a significant reduction (van Herpen et al., 2023; Young et al., 2018). This was confirmed previously in a study indicating that multi-component interventions might be more effective than single and isolated interventions alone (National Academies of Sciences, Engineering, and Medicine, 2020).

The effectiveness of multi-component interventions was also confirmed in domains other than food waste (education with nudges and the provision of meat alternatives) were demonstrated to be more effective than single interventions in promoting the consumption of meat alternatives (Broers et al., 2017; Clark, 2017; Hartmann-Boyce et al., 2018). Furthermore, to stimulate weight loss, a study suggested that targeting multiple behaviours (dietary behaviour and physical activity) could be more effective than stimulating only one behaviour (Sweet and Fortier, 2010). The success of multi-component interventions can be attributed to the stimulation of different types of cognitive processing (National Academies of Sciences, Engineering, and Medicine, 2020).

However, when applying multi-component interventions, it might be difficult to disaggregate which intervention has an impact on which behaviour (National Academies of Sciences, Engineering, and Medicine, 2020). Thus, it seems important to further study the interactions between interventions to provide recommendations for the government,

policy-makers, researchers, and other involved stakeholders. Beyond the selection of the most effective intervention types, their success might also depend on the tested intervention setting and the target population (Swannell et al., 2023).

4.3.2. Single-component interventions

In addition to multi-component interventions, single-component interventions, such as awareness raising and nudging, were identified as interesting leverage to reduce food waste. Furthermore, one study indicated that nudges can be efficient as a single intervention (Nisa et al., 2019). The results of a recent meta-analysis focusing on nudges for reducing consumer food waste showed that they were highly effective when applied in public settings instead of private settings. However, the author highlighted the lack of a clear assessment of the effectiveness of nudges in sufficiently supporting evidence-based policymaking (Zhang et al., 2023).

We further identified an interesting awareness-raising intervention, the so-called self-reporting food waste approach, which led to significant food waste reduction. This positive effect was reported earlier in a study that measured household food waste using two different methods (Delley and Brunner, 2018). The created awareness about ones' own waste led to a food waste reduction in the short and longer term (5 weeks after the intervention). This simple and often cost-efficient intervention is thus a promising leverage to reduce food waste in households and among hotel kitchen staff. Another recommendation was to apply self-reporting food waste in combination with coaching sessions to enhance the effectiveness of the intervention (Leverenz et al., 2019). Finally, this review showed that interventions conducted at retailers were effective in helping consumers reduce their food waste at home. This confirms the feasibility and need for retailers to take more responsibility and actions to help nudging consumers towards more sustainable behaviour. Including the retail sector is particularly relevant, as it influences the food supply chain and consumers' behaviour (Bos-Brouwers et al., 2020).

Based on these findings, we propose the following recommendations:

- Overall, more multi-component intervention studies (particularly nudges combined with knowledge enhancement) are needed. Nudges are relevant to helping consumers waste less food, as they change consumers' choice architecture and provide suitable opportunities for behaviour change (perceptual and other unconscious motivational and behaviour components) (Casonato et al., 2023; Stöckli et al., 2018; Vittuari et al., 2023). Further, as the results of this review showed, nudges are an interesting strategy for reducing food waste in various settings (hospital-nursery home, hotel, household, retail, school, and university). In addition, nudges are known for their simplicity and low cost (Stöckli et al., 2018).
- Providing information and increasing knowledge are important for increasing public awareness about unsuitable food waste behaviour, and these efforts can positively affect cognitive attitudes and ideologies (Garrone et al., 2014; Mariam et al., 2022). Further, improving the knowledge and skills with training can enhance consumers' ability (Ioannou et al., 2022). However, providing only information might not be sufficiently effective in promoting behavioural change (McKenzie-Mohr, 2011; Stöckli et al., 2018).
- Therefore, incorporating relevant and successful components from single-component interventions into multi-component interventions is especially important in the field of food waste. This has also been noted elsewhere, with scholars highlighting that there is no single best or perfect food waste intervention. However, effectiveness can be enhanced by combining the successful key elements of various interventions (Simões et al., 2022; Swannell et al., 2023). Consumer food waste is a complex issue that involves multiple behaviours and

interactions, making it multifaceted and challenging to address (Zeinstra et al., 2020). Thus, it is even more important to apply a diverse range of instruments to achieve behavioural change (Vittuari et al., 2023). Utilising more multi-component interventions may be more effective in changing consumers' behaviour to reduce food waste, as their design allows for the targeting of several behaviours simultaneously (Evans et al., 2017; Van Geffen et al., 2016; Hartmann-Boyce et al., 2018).

- Most of the reviewed interventions measured short-term effects. Thus, there is a need to test the longitudinal effects of interventions for food waste reduction. To achieve the United Nations' Sustainable Development Goal 12.3, which aims to halve global food waste per capita by 2030, consumer behaviour changes to reduce food waste must be sustained over the long term. Therefore, greater knowledge is needed to better understand the evolution of interventions over time and the persistence of changed food waste behaviour, as previously revealed (Casonato et al., 2023; Jobson et al., 2024; Quested, 2019).
- Another promising strategy to reduce food waste in the long term might be the awareness-raising intervention (i.e. by self-reporting of waste). This is an interesting tool for promoting behavioural change, as it encourages consumers to reflect on their food waste behaviour and to consider the potential negative consequences (Lanzini and Thøgersen, 2014). Furthermore, the self-reporting approach can be applied in various settings, both in-home and out-of-home, and no further intervention beyond self-reporting may be necessary to achieve a reduction in food waste. Thus, the more frequent application of a self-reporting food waste approach as an intervention could contribute to a simplified and harmonised study design, facilitating a better comparison of outcomes.
- There is a high potential for more interventions conducted in retailers to positively influence consumers' food waste behaviour at home. Retailers have a significant impact on what consumers buy and eat (Trewern et al., 2022). Therefore, retailers play a crucial role in influencing the pro-environmental behaviour of consumers. Moreover, since retailers have access to various communication channels, they can reach a wide audience to recruit participants, potentially leading to an increased sample size. As recently highlighted, there is a need for larger sample sizes when testing food waste interventions (Casonato et al., 2023).

Along with the recommendations outlined, it is essential to point out the critical importance of food valorisation within households. More knowledge and training are needed to enhance the awareness of a mindful consumption and to build abilities for food valorization. This was done in a national campaign called 'Love Food Hate Waste' (LFHW) in the UK (Carver, 2014; Quested et al., 2011; Yamakawa et al., 2017). This educational campaign provided flexible recipes and tips on how to use leftovers. The 'Love Food Hate Waste' campaign, which targets both adults and children, has been successful in reducing consumer food waste at household level. Since consumers often lack the time to engage in food waste-reducing behaviours (Quested and Luzecka, 2014), there is a need for more education and training in areas such as meal planning, cooking skills, food shelf life and safety, as well as understanding of date labels.

Another interesting approach to food valorisation while simultaneously addressing food insecurity are food sharing or leftover-sharing practices (Falcone and Imbert, 2017; Kirmani et al., 2023; Michelini et al., 2018). This approach is promising, as a recent study has demonstrated that young consumers have a positive attitude towards food sharing practices (Wiśniewska and Czernyszewicz, 2023). It has been shown that food-sharing platforms and mobile applications can help reduce food waste by enabling consumers to share their surplus food

with others (Harvey et al., 2020). In addition to digital platforms, initiatives like the 'Community Fridge' movement and the provision of 'smart' fridges can also contribute to enabling community members share surplus food through a common refrigerator (Berns et al., 2024; Jo et al., 2024). As previously stated, more research is needed to identify the full potential of food sharing practices (Morone et al., 2018).

4.4. Limitations and outlook

This review has some limitations. First, it included studies until September 2023; thus, the year 2023 was not fully covered. However, to obtain a broad data basis on the studies, we had no limitations for geographical regions or for the year of publication. Second, this review identified only a limited number of multi-component interventions, which might reduce the generalisability of the findings. Third, due to the large heterogeneity of the studies, a direct comparison of the percentage reductions in food waste for different intervention types was difficult. We thus encourage a follow-up meta-analysis (which takes into account heterogeneous data) on quantitative food waste reduction outcomes.

5. Conclusions

This study assessed the impact of interventions aimed at reducing food waste at the consumer level by considering the robustness of the study design. Three criteria were evaluated: the intervention type, the study design, and the impact on food waste reduction. Our findings show that most of the interventions (mainly conducted in households or universities and predominantly non-randomised [quasi] experiments) had a significant impact on food waste reduction. In particular, multi-component interventions with nudges were effective in reducing food waste at the consumer level (significant impact, high reduction level, and randomised experiments), although they were rarely investigated.

This review provides several recommendations to enhance the evidence of potentially effective interventions aimed at reducing food waste:

- First, more out-of-home settings and fewer possible biased participants (other than university students) are needed for future intervention studies.
- Second, there is a need to test more multi-component interventions with nudges, awareness raising, training, knowledge enhancement, and social influence by applying a robust study design (such as RCTs). This might enhance legislative evidence for more binding food waste reduction targets.
- Third, a harmonisation of the applied methodologies is necessary to enable a better data comparison and meta-analysis.
- Finally, to achieve a long-lasting food waste reduction, the government and retailers are highly relevant and influential players to nudge consumers towards more sustainable behaviour.

CRediT authorship contribution statement

Carole Liechti: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Gabriele Mack:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Conceptualization. **Jeanine Ammann:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization.

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Declaration of competing interest

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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.2024.11.023>.

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