

SUSTAINABLE INTERVENTIONS TO MANAGE RETAIL FOOD WASTE: A SCOPING REVIEW

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ABSTRACT

Food waste (FW) affects the economy, sustainability, food security, and climate but effective practices to reduce waste in the food retail sector have received limited attention in existing studies. To address this gap, a scoping review was conducted to systematically identify and categorise research about interventions targeting retail FW. After searching four electronic literature databases, study selection allowed for the inclusion of 43 studies in the review. The narrative synthesis illustrates possible outcomes of such responses to retail FW and aggregates similar interventions and actors involved. Findings comprised 132 interventions from 41 countries, mostly European (73.2%). While supermarkets were responsible for implementing 86.4% of the initiatives, the interventions targeted both consumers (50.8%) and their own businesses (46.2%). Utilising a FW hierarchy framework, interventions were classified into seven categories, predominantly focusing on preventative measures such as awareness campaigns, price reduction, operational optimization, legal regulation, and FW repurposing for human consumption through donations. These prevention and reuse strategies hold promise across diverse contexts and warrant further exploration. About half of the interventions quantified their effects, and we address the most relevant environmental, social, and economic impacts. The findings underscore the need for research investment in the global South.

1. INTRODUCTION

In recent years, food waste has emerged as a pressing global issue. Growing concerns about food security and the socio-environmental impacts associated with food waste have attracted the attention of national and international policymakers, non-governmental organisations (NGOs), and academics. The Food and Agriculture Organization of the United Nations (FAO) underscores the urgency, noting that food loss and waste contribute significantly to global greenhouse gas emissions, making it a critical factor in addressing climate issues and global sustainability (FAO, 2022). Food waste's impacts on different fields such as food security, human health, and the environment make it a pressing area of study (Xue et al., 2017).

The literature lacks a universally agreed-upon definition of food waste, often adapting the term to suit the focus of investigations (Hanson et al., 2016). The FAO distinguishes

between food loss - occurring between agricultural production and arrival at retail - and food waste, occurring at the retail and consumption stages (FAO, 2019). However, within this framework, both food loss and food waste pertain solely to the edible portions of commodities intended for human consumption. Determining what is considered edible or inedible is complex, context-dependent, influenced by culture, evolving over time, and variable within and between populations (Nicholes et al., 2019).

This study follows the FAO definition, considering the stage of the chain where the food waste was generated while also considering the inedible parts of commodities, as in Rolker et al. (2022). Following the suggestion of Hanson et al. (2016), this broader definition was selected based on the research goal of this study: to identify food waste intervention strategies in retail. On the one hand, including the inedible part provides a more complete pic-



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ture of possible interventions; on the other, the focus on different stages of the food system helps to tackle specific interventions in the retail sector.

The global problem of food loss and waste requires more attention in food and sustainability research as well as food politics. In 2007, around a third of food produced for human consumption was lost or wasted, roughly 1.3 billion tons per year (FAO, 2011). Approximately 14% is lost between harvest and retail (FAO, 2019), while an estimated 17% is wasted in households, retail and food services (United Nations Environment Programme - UNEP, 2021). Various factors contribute to food waste, including mould (Lanfranchi et al., 2016), pests (Beausang et al., 2017), weather conditions (Göbel et al., 2015), cooking losses, and inadequate storage systems (Parfitt et al., 2010), with fundamental effects on global food insecurity (Mc Carthy et al., 2018; Munesue et al., 2015). Today, 822 million individuals face insufficient access to food required for an active and healthy life (Skaf et al., 2021).

Food waste contributes to global warming, acidification and eutrophication (Scherhauser et al., 2018; Tang, 2020). Approximately 8-10% of global greenhouse gas emissions are associated with edible food that goes to waste (UNEP, 2021). Food waste contributes negatively to climate change, fossil and water depletion and nitrogen pollution (Skaf et al., 2021; Grizzetti et al., 2013)

The Food Waste Index Report (UNEP, 2021) and Food Loss Index (FAO, n.d.) indicate that this challenge continues to threaten progress towards Sustainable Development Goal 12.3: to halve per capita global food waste at retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses, by 2030. In 2019, food waste from households (61%), the food service industry (26%) and retail outlets (13%) amounted to 931 million tonnes per year (UNEP, 2021). To commit to the SDG, many governments such as Australia (Commonwealth of Australia, 2017), Brazil (CAISAN, 2018), and Germany (BMEL, 2017) developed specific strategies to tackle these various and interconnected problems related to food waste on the national or local scale. A prominent example is the Food Waste Reduction Roadmap which includes a sector specific action list also addressing food waste in the retail sector as part of the UK's Waste and Resources Action Plan (WRAP, 2023).

Despite contributing minimally to overall food waste, retail remains a critical node of the food chain to explore since retailers have the capacity to influence policies, decision-making and behaviours of both consumers and producers. Presently, however, more focus is paid to other stages of the food chain, and recent literature reviews identifying viable and applicable solutions for the retail context, considering both preventive and mitigative actions, are lacking. To identify food waste intervention strategies in retail, this article proposes a scoping review to analyse and systematise existing research in this field and extract relevant gaps for this pressing global issue.

1.1 Food waste research

Food waste is an established field of research, but many studies use a supply chain perspective (Aramyan et

al., 2021; De Boni et al., 2022; Lemaire and Limbourg, 2019; Magalhães et al., 2021; Mmereki et al., 2023; Nicastro and Carillo, 2021) rather than focusing on a specific stage. This offers a broader systemic perspective but makes it difficult to identify concrete possibilities of intervention at each stage of food waste management.

Some studies were identified that focus on a specific stage of the chain, such as Onwude et al. (2020), which studied tools to reduce the quality loss of fruits and vegetables during packaging, storage, and transportation cold chain operations. Wunderlich and Martinez (2018) studied the causes of food loss and waste at the production and consumption stages, their environmental implications and the actions needed to deal with them. Lebersorger and Schneider (2011) discussed how to calculate the food waste in the household level. Meanwhile, Yetkin Özbük and Coşkun (2020) focused on downstream entities of the supply chain, showing that most existing studies focus on food services due to their relatively high contribution to food waste generation. The authors identify a research gap concerning wholesale food waste. This last study suggests that research about food waste management in the retail sector remains neglected. The absence of systematic studies focused on retail in the food chain is evident from the wider literature.

Many studies focus on specific interventions to manage food waste, such as anaerobic digestion (An et al., 2024; Assis and Gonçalves, 2022; Pilarska et al., 2023; Zhang et al., 2023), composting (Awasthi et al., 2020; Sánchez, 2022), hydrothermal carbonization (Wu et al., 2023), and animal feed production (Boumans et al., 2022; Shurson et al., 2023; Torok et al., 2021). Such research studies waste recovery and valorisation options in greater depth, but broader studies are needed that include more than one intervention and allow for their comparison while considering specific stages of the food chain.

Furthermore, studies focused on quantification of retail food waste, such as the research of Eiçaitė et al. (2022) in Central and Eastern Europe, show the large quantity generated and the reasons, which include expired shelf-life, spoilage, damage, and overstocking, and discuss the need for interventions to solve this issue. These authors even conclude the article by recommending that future research identifies actions that are being adopted in retail to reduce food waste.

We identified only three reviews specifically focused on retailers (supermarkets, markets, and wholesale), two focused on specific interventions - promotional pricing (Tsalis et al., 2021) and valorisation of animal by-products (Pinto et al., 2022) - and the final on causes of food waste and reduction practices (Moraes et al., 2020). This paper's strong contribution was limited by inclusion of studies published only between 2008 and 2017. Later reviews show an increase in relevant studies after 2015 (Rolker et al., 2022; Tamasiga et al., 2022; Yetkin Özbük and Coşkun, 2020), reinforcing the need for updated literature reviews on this topic. Furthermore, Moraes et al. (2020) only address reduction interventions, neglecting the significance of mitigation interventions, which are prevalent in low and middle-income countries' retail industries (Rolker et al., 2022).

This scoping review aims to address the identified

gaps through answering the question: what interventions by civil society, state and market to manage food waste in supermarkets and markets (retail) can be identified in the literature? By doing so, we provide an overview of existing research on interventions targeting food waste in the retail sector, including both preventive and mitigative actions, and covering more years, languages and knowledge areas than previous reviews.

The article is structured as follows. Section 2 outlines the scoping review process. In Section 3, we present our results and discussions, and some suggestions for future research. Finally, section 4 presents our conclusions.

2. METHODS

This scoping review was designed and executed in accordance with the JBI Methodology for Scoping Reviews (Peters et al., 2020) and is reported following the PRISMA Extension for Scoping Reviews guidelines (Tricco et al., 2018). Prior to commencing the review, a protocol was published on OSF Registries (Castro et al., 2022). All relevant data and procedure was made available on the review OSF page, available at: doi.org/10.17605/OSF.IO/5ES2T

2.1 Eligibility Criteria

The PCC (Population-Concept-Context) framework was used to structure the research question and determine specific selection criteria.

2.1.1 Population

This review included studies from any country introduced by three organisational types: civil society, the state and the market. Initiatives were categorised under 'civil society' where introduced by social movements, community/local actors, and non-governmental organisations. 'State' actors included political parties, national governments and transnational political coalitions. 'Market' interventions involved companies, cooperatives and business associations.

2.1.2 Concept

In this review, research concerning strategies intended to reduce food waste was considered for inclusion. This includes strategies to prevent, reduce, mitigate, repurpose or treat food waste. Studies that did not discuss actioned strategies or solutions were excluded.

2.1.3 Context

Included studies concerned food waste interventions in the retail sector: markets, supermarkets, wholesale, grocery stores, local shops and other similar food retail settings. Results from the personal/household level or concerning retail for immediate consumption (i.e. restaurants, cafes, catering etc) were excluded.

2.1.4 Types of sources

Qualitative, quantitative, and mixed-methods studies were considered. These include experimental and quasi-experimental designs, analytical and descriptive observational studies, and qualitative designs such as phenomenology, grounded theory, ethnography, qualitative

description, action research and feminist research. Journal articles and other peer-reviewed published research pieces were included, but non-academic reports and reviews of any type were excluded.

2.2 Search

The search strategy performed in October 2022 aimed to locate published studies in four electronic databases: Scopus, Web of Science Core Collection (WOS), Embase, and GreenFILE (Supplementary material - Table S.1). An initial exploratory search of Scopus, WOS, and Embase was undertaken to identify articles on the topic. Words contained in the titles and abstracts of relevant articles were used to develop the search strategy, adapted for each specific database. Search terms included synonym variations and controlled vocabulary related to "food waste", "prevention/reduction", "initiatives", and "retail" (Supplementary material - Table S.2). Studies published in Portuguese, Spanish, and English were included without time constraints.

2.3 Selection

After the search, all identified references were collated and uploaded into the Rayyan QCRI web application (Ouzzani et al., 2016), and duplicates were removed. After a pilot test, titles and abstracts were screened in Rayyan by two or three authors assessing against the inclusion criteria for the review. The full text of included documents was assessed in greater detail against the inclusion criteria by two authors. All authors (AMRCC, LLZ, CDLJ, RM, DJSC) were involved in this process, interchangeably, in pairs when necessary. After full-text evaluation, reasons for exclusion of rejected sources were recorded and reported in this scoping review. Any conflicts that arose between authors at each stage of the selection process were resolved by a third author.

2.4 Data collection

The data for studies included in this analysis were gathered using a standardised extraction form that was tested by all authors on a subset of studies (Supplementary material - Table S.3). In addition to details about the article's publication (author, year), data was recorded about the study's aims, location, scope, the actors responsible for carrying it out, the intended audience, the specifics of the intervention (including delivery methods, materials used, and duration), and other findings related to food waste.

2.5 Data analysis

Following data extraction, certain elements were compiled, such as information pertaining to the countries involved and the extent of the intervention's scope. Our primary focus was on categorising these interventions into themes. This categorisation process unfolded through a four-step iterative procedure: (1) two authors described interventions in one sentence (LLZ, CDLJ); (2) a third author compared descriptions and suggested adjustments to summarise them into robust categories (DJSC); (3) all five authors read the resulting categories and commented based on the whole process to determine the final category

(AMRCC, LLZ, CDLJ, RM, DJSC); (4) a final author (CDLJ) checked the suggestions and approved the final categories according to the seven steps of waste hierarchy (Joint Research Centre, 2020). The whole categorization was reviewed at the end by the two expert authors in the area who have the most experience with the topic, one on waste (AMRCC) and the other on food (LLZ).

In order to systematise food waste interventions, this article follows the waste hierarchy framework, which indicates an order of prioritisation of actions in waste management (Williams, 2015). The waste hierarchy aims at reducing waste generation and opting for more circular management options such as reuse, recycling and recovery, in line with the circular economy model (Ellen MacArthur Foundation, 2013).

Variations of the WH have emerged (Redlingshöfer et al., 2020; Papargypoulou et al., 2014) and, since 73.2% of the articles retrieved in this review highlight European cases, this review uses the “Hierarchy for prioritisation of food surplus, by-products and food waste prevention strategies” (Joint Research Centre, 2020). This WH has 7 stages, in

the following preference order: prevention, redistribution of food for human consumption, animal feed, reuse of by-products and recycling of food waste, recycling with nutrient recovery, incineration with energy recovery, and disposal.

3. RESULTS AND DISCUSSION

The search yielded a total of 1,316 references (see Figure 1). After eliminating duplicates, 850 references remained to be screened. These were reviewed independently by two researchers, who determined 720 of them irrelevant based upon their titles and abstracts. The remaining 130 texts underwent a thorough examination, with at least one author reading each text in full. In cases where authors chose to exclude a study, a second author checked the complete text for confirmation. Any conflicts in decision-making were resolved by a third author. Excluded full-texts are presented in supplementary material (Table S.4), with justifications. After selection, this scoping review included a total of 43 studies. All included publications are listed in Table A.1.

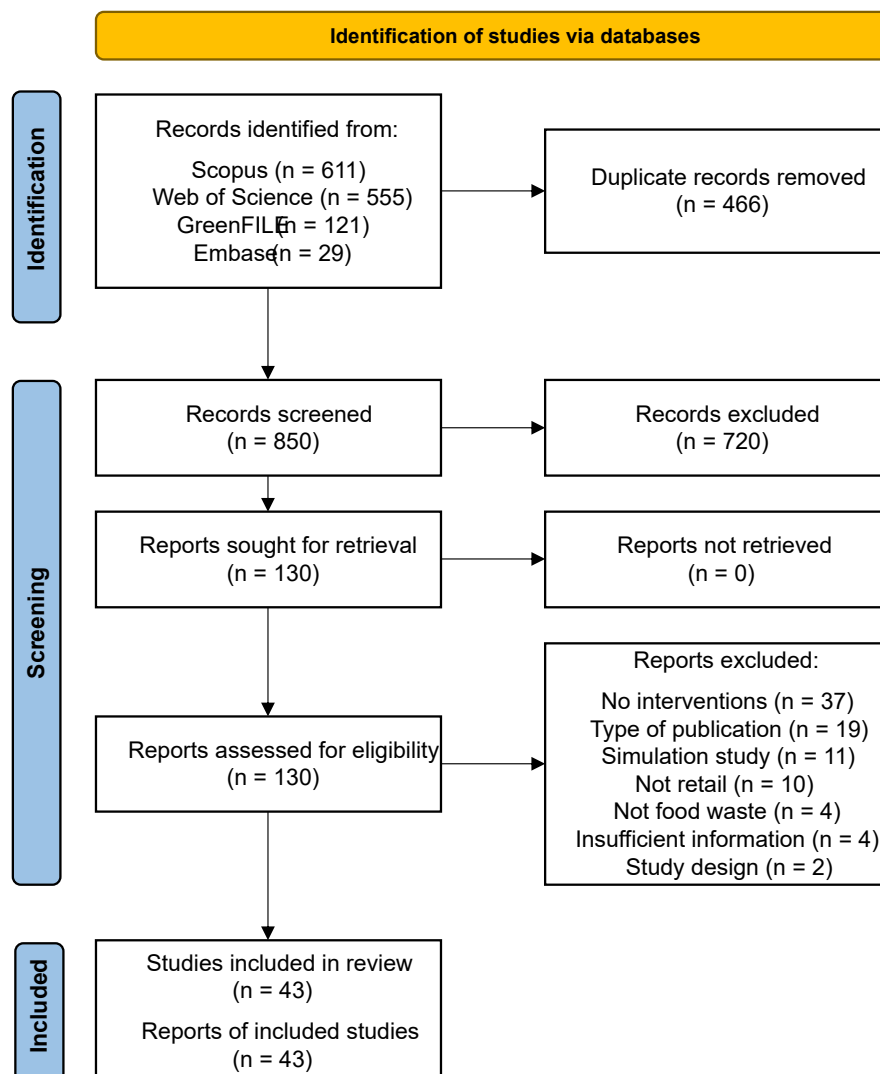


FIGURE 1: Study selection flow diagram. Adapted from Page et al. (2021).

3.1 Study characteristics

We identified studies from 2001 to 2022, a third of which were published from 2020 onwards. Most were published after 2014 (95.3%). With the exception of three cases (Holweg et al., 2016; Mullick et al., 2021; Schinkel, 2019), all studies provided details of the case's geographical location. The included studies explored initiatives spanning 41 countries, most being in Europe (73.2%). While most studies focused on cases within individual countries, two presented extensive international analyses (Chalak et al., 2018; Pulker et al., 2018).

Italy, Germany, and the UK feature most frequently in the included studies (Figure 2). The preponderance of results from Europe may be attributed to our review's language criteria, which included studies published in English, Spanish, and Portuguese. However, this imbalance raises questions about food waste management and its study elsewhere. The limited studies emerging from Latin America, despite inclusion of Spanish and Portuguese language research, might suggest little academic focus on food waste in this region. Yet Rolker et al.'s (2022) review, which extracted research in multiple languages, highlighted cases in Africa and Asia. This demonstrates the limitations of our language selection in globalising our research. Given that most literature identified in both our and Rolker et al.'s (2022) study were in English, it may instead be true that most relevant research is published in English, regardless of the researcher or case study's origins. More likely, our requirement for included publications to peer-reviewed academic works has generated a bias towards works in English, given that the language dominates academic publishing globally.

3.2 Intervention categories

We identified 132 interventions in the literature, and separated them into the 7 FW hierarchy categories to organise and discuss the results (Figure 3 and Appendix - Table A.2), using the "Hierarchy for prioritisation of food surplus,

by-products and food waste prevention strategies" (Joint Research Centre, 2020), as described in section 2.5. The majority of interventions relate to the hierarchy's most favoured approaches, prevention (50%) and re-use for human consumption (30.3%), and can be classified as preventive measures (Rolker et al., 2022). These results contrast with Rolker et al.'s (2022) findings in low- and middle-income countries, which showed that retail has more mitigative interventions (e.g., other types of reuse, recycling, energy recovery) than preventive ones.

The fourth stage of the food waste hierarchy, "re-use of by-products and recycle food waste", which includes "revalorise i) by-products from food processing and ii) food waste into added-value products by processes that keep the high value of the molecule bonds of the material" (Joint Research Centre, 2020) was not found amongst our included research. The lack of results in this category leads us to raise some hypotheses: 1) this category is still little studied since more academic attention is being given to previous stages of the hierarchy; 2) the authors may be using other words to describe these processes, other than reuse and recycling, and that is why these articles did not appear in our searches; 3) this technique may be more widely used for food waste from other stages of the chain, such as manufacturing (Mirabella et al., 2014), and is still little explored in the retail sector; 4) This category is still being further explored at a theoretical or laboratory level, as Lee and Tongarlak (2017), and as we only included concrete cases already applied by retail in our review, we did not have results.

In any case, we chose to maintain the 7 levels of the hierarchy in this article, to highlight that the lack of data found is also a result and indicates a research gap. The results found in other categories of the hierarchy are detailed below.

3.2.1 Prevention

Preventive interventions are those aimed at directly or indirectly preventing the generation of food waste. These

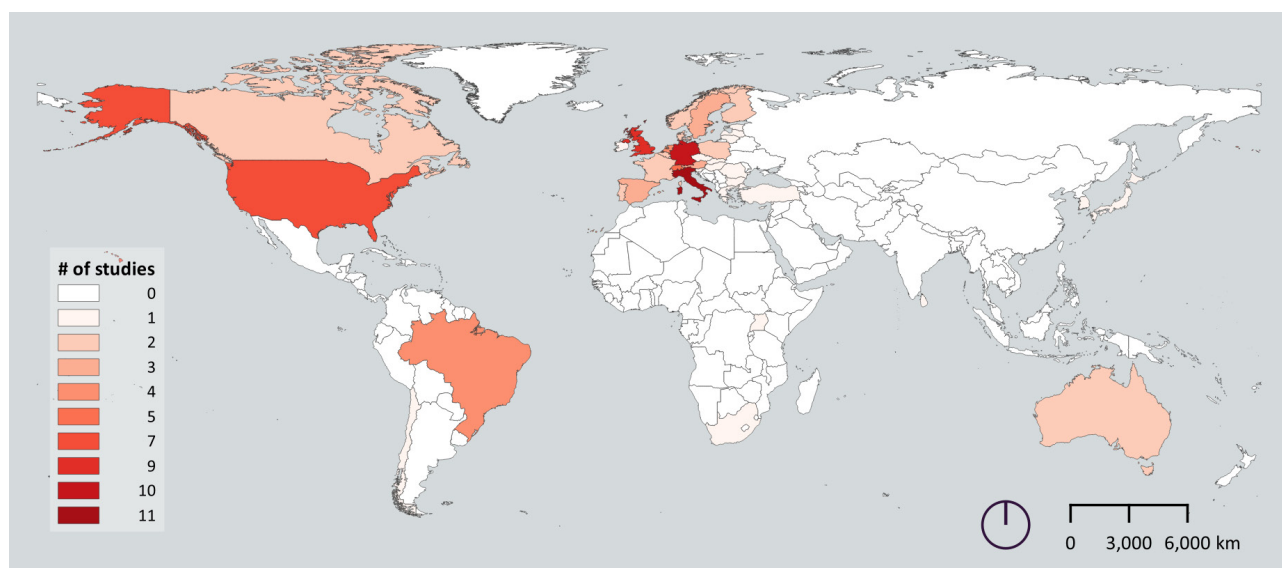


FIGURE 2: Map of studies included per country. Source: Created by the authors using QGIS (v. 3.22 Białowieża).

INTERVENTIONS ALONG THE WASTE HIERARCHY

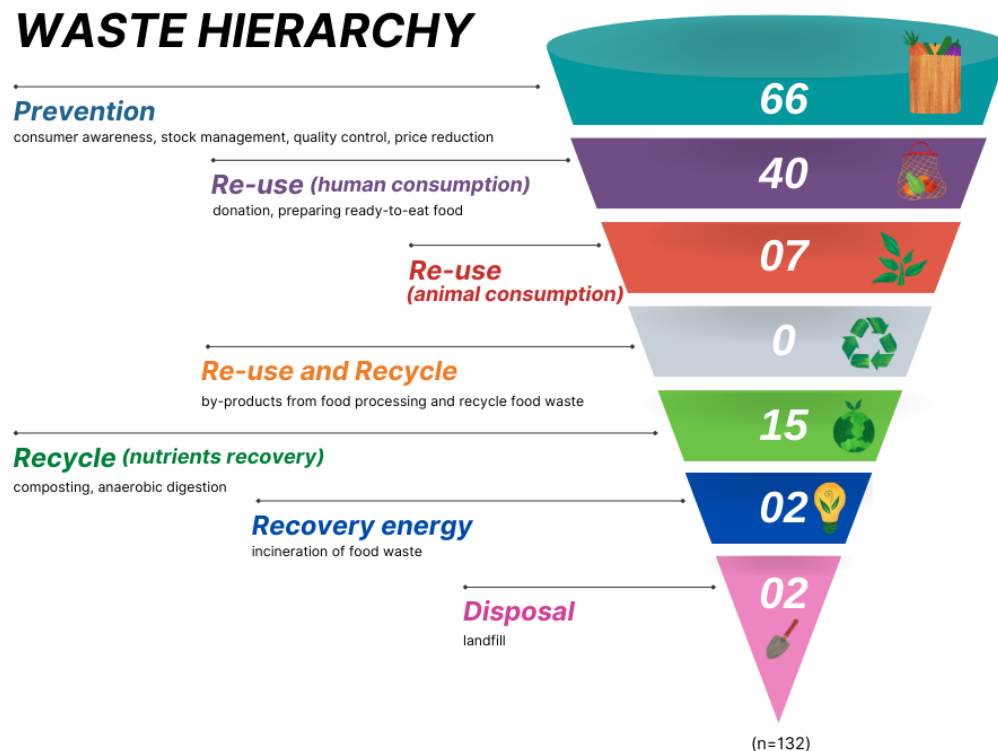


FIGURE 3: Adaptation of the European Food Waste Hierarchy according to findings (by the authors).

interventions were identified most frequently in the literature ($n = 66$) and were separated into 4 subcategories: awareness, corporate social responsibility practice, operations and regulations, as shown in Table 1. The four subcategories were created based on a qualitative content

analysis (Mayring and Fenzl, 2014) and a thematic coding approach (Saldaña, 2021).

Regarding the first subcategory on awareness, we found interventions focused on the actions of both employees and consumers. As pointed out by Mattsson and

TABLE 1: Categories and subcategories based on studies included in the scoping review in the waste hierarchy stage of prevention ($n = 66$). Source: Authors.

Category	Subcategory	n	References
Awareness	Consumer awareness	7	Busetti, 2019; Chalak et al., 2018; Fassio and Minotti, 2019; Filimonau and Gherbin, 2017; Mura et al., 2019; Schinkel, 2019; Trewern et al., 2022
	Employee awareness	5	Marrucci et al., 2020; Mattsson and Williams, 2022; Reitemeier et al., 2021; Watanabe et al., 2022; Wenderits Silva et al., 2021
Corporate social responsibility practice	-	2	Chalak et al., 2018; Moggi et al., 2018
Operations	Digital operation	1	Strotmann et al., 2017
	Packaging strategy	6	Beitzen-Heineke et al., 2017; Blanke, 2015; Filimonau and Gherbin, 2017; Mattsson and Williams, 2022; Shrivastava et al., 2022; Wu and Honhon, 2023
	Price reduction	17	Bech-Larsen et al., 2019; Blanke, 2015; Filimonau and Gherbin, 2017; Gustavo et al., 2021; Hermsdorf et al., 2017; Holweg et al., 2016; Horoš and Ruppenthal, 2021; Mattsson and Williams, 2022; Mullick et al., 2021; Reitemeier et al., 2021; Ribeiro et al., 2019; Souza et al., 2021; Tröger et al., 2020; Watanabe et al., 2022; Wenderits Silva et al., 2021; Wu and Honhon, 2023
	Purchasing management	3	Horoš and Ruppenthal, 2021; Pulker et al., 2018; Wenderits Silva et al., 2021
	Quality control	6	Horoš and Ruppenthal, 2021; Mattsson and Williams, 2022; Ribeiro et al., 2019; Souza et al., 2021; Watanabe et al., 2022; Wenderits Silva et al., 2021
	Source reduction	2	Chen and Chen, 2018; Evans and Nagele, 2018
	Stock management	12	Beitzen-Heineke et al., 2017; Holweg et al., 2016; Horoš and Ruppenthal, 2021; Marques et al., 2022; Marrucci et al., 2020; Mattsson and Williams, 2022; Reitemeier et al., 2021; Ribeiro et al., 2019; Souza et al., 2021; Watanabe et al., 2022; Wenderits Silva et al., 2021
Regulation	Legal regulation	4	Busetti, 2019; Chalak et al., 2018; Evans and Nagele, 2018; Schinkel, 2019
	Government incentive	1	Busetti, 2019

Williams (2022), although employees are usually identified as a cause of food waste in retail, they are also essential actors in its prevention when well-trained. These authors demonstrated this through a case in which employees received training and participated in regular meetings where they discussed waste quantities and goals.

Consumer awareness is also important in combating food waste. This was found in Fassio and Minotti (2019)'s study about the Re-design Project of Organic waste in Porta Palazzo market, Turin. A communication campaign focused on consumers, traders, and volunteers was amongst the approaches used to manage food waste, promoting the recovery and redistribution of food and improving the source separation of organic waste.

The second subcategory, focusing on the implementation of corporate social responsibility, was explored in a study by Chalak et al. (2018). They provided various examples of such interventions, including the 2010 commitment made by members of the Food and Drink Federation in the UK to achieve individual targets for reducing food waste, monitoring waste generation, and diverting waste away from landfills. The ultimate objective was to completely eliminate the disposal of food waste in landfills within five years. Notably, two of the country's largest food retailers embraced these initiatives. One of these, Marks and Spencer, implemented measures like price discounts on products with a short shelf life.

Prevention in retail operations can include processes to increase operational efficiency through new digital operational platforms (Strotmann et al., 2017) and management innovations in purchasing (Horoš and Ruppenthal, 2021; Pulker et al., 2018; Wenderits Silva et al., 2021), stock management (Beitzen-Heineke et al., 2017; Holweg et al., 2016; Horoš and Ruppenthal, 2021; Marques et al., 2022; Marrucci et al., 2020) and product quality control (Souza et al., 2021; Watanabe et al., 2022; Wenderits Silva et al., 2021) implemented through staff training and protocols.

Reitemeier et al. (2021) examined food waste management in Colombo amidst growing public and policy interest, highlighting stock management as a method to predict and monitor demand to minimise surplus and waste. Retailers also adopt strategies like discounting near-expiry items and staff training. Bech-Larsen et al. (2019) also focus on expiration date-based pricing. Danish retailers lower prices of items nearing expiration, without affecting sales of regular-priced goods. Beitzen-Heineke et al. (2017) examine the role of zero-packaging stores in diminishing food and packaging waste. Utilising interviews with store owners and experts, the study evaluates various operational and logistical aspects of these stores.

The last subcategory of preventive strategies comprise regulatory interventions which enforce legislation and promote fiscal and financial incentives (Chalak et al., 2018; Evans and Nagele, 2018; Schinkel, 2019). Chalak et al.'s (2018) study on food waste in the hospitality and food retail sectors highlights the effectiveness of legal regulation. The paper underscores a multi-faceted approach, combining legal, fiscal, and educational strategies, as the most effective way to address food waste in these sectors.

3.2.2 Re-use for human consumption

The second main intervention strategy identified in the literature was the reuse of food for human consumption ($n = 40$), which primarily involves interventions to repurpose food that would otherwise be wasted (see Table 2). Studies often explored donating food to food banks (Alexander and Smaje, 2008), staff (Marrucci et al., 2020), or consumers (Buseti, 2019; Chalak et al., 2018).

Alexander and Smaje (2008) evaluate the impact of large retailers' food donation programs through the British charity FareShare, tracing back to understand the donation flows. What stood out in FareShare's donation system were the different food waste destinations. A considerable amount was donated to projects working against food pov-

TABLE 2: Categories based on studies included in the scoping review in the waste hierarchy stage of re-use for human consumption and recycling. Source: Authors.

Stage	Category	n	References
Re-use for human consumption	Donation (non specified)	24	Alexander and Smaje, 2008; Arnold, 2022; Beitzen-Heineke et al., 2017; Cakar, 2022; Cannavò et al., 2019; Chen and Chen, 2018; de Hooge et al., 2018; Evans and Nagele, 2018; Fassio and Minotti, 2019; Filimonau and Gherbin, 2017; Garrone et al., 2014; Hermsdorf et al., 2017; Holweg et al., 2016; Horoš and Ruppenthal, 2021; Mattsson and Williams, 2022; Mura et al., 2019; Ng et al., 2019; Pulker et al., 2018; Reitemeier et al., 2021; Ribeiro et al., 2019; Sisson, 2016; Warshawsky, 2016; Watanabe et al., 2022; Werderits Silva et al., 2021
	Donation to food bank	6	Alexander, 2021; Bech-Larsen et al., 2019; Blanke, 2015; de Hooge et al., 2018; Garrone et al., 2014; Mura et al., 2019
	Donation via digital platform	3	Filimonau et al., 2017; Gollnhofer, 2017; Sewald et al., 2018
	Preparing ready-to-eat food	6	Alexander, 2021; Arnold, 2022; Beitzen-Heineke et al., 2017; Holweg et al., 2016; Reitemeier et al., 2021; Watanabe et al., 2022
	Social supermarket	1	Bech-Larsen et al., 2019
Recycling	Anaerobic digestion	3	Mattsson and Williams, 2022; Ng et al., 2019; Warshawsky, 2016
	Composting	7	Alexander, 2021; Chen and Chen, 2018; Evans and Nagele, 2018; Fassio and Minotti, 2019; Holweg et al., 2016; Reitemeier et al., 2021; Ribeiro et al., 2019
	Biodiesel production	1	Chen and Chen, 2018
	Industrial use	1	Evans and Nagele, 2018
	Recycling (unspecified)	3	Filimonau and Gherbin, 2017; Marrucci et al., 2020; Werderits Silva et al., 2021

erty; FareShare delivered fresh fruit, vegetables, and ready-to-eat meals donated by retailers. Another flow comprised direct donations to elder care centres, hostels and homeless shelters. Some donations were also used in animal feed.

The study by Sewald et al. (2018) described the potentials and limitations of food donation via digital platforms. They assessed the 'Food Rescue Robot', a digital tool used by Boulder Food Rescue for managing fresh food donations and distribution. This web-based application was replicated in over 40 cities and focuses on facilitating community participation in the donation process.

Fassio and Minotti (2019) present their case study, RePoPP (Re-design Project of Organic Waste in Porta Palazzo market), in Turin, Italy as a key example for successful food waste donation. Here, the redistribution of food recovered occurs through distributing fruit and vegetable boxes aiming to feed a family for two days. Further, the initiative has a strong social and integrative facet, since 43 of the programme's volunteers are asylum seekers.

Alexander's study (2021) explores donation interventions by Cultureghem, a Brussels-based NGO. The paper focuses on programs like "Barratoir," a zero-waste pop-up restaurant, and "Collectmet," which distribute surplus market produce to people in need. The initiative repurposes unsold food for communal meals and distribution, effectively reducing food waste while promoting community involvement and social inclusion.

3.2.3 Re-use for animal consumption

Re-use for animal consumption was only mentioned in 7 studies (Chen and Chen, 2018; Evans and Nagele, 2018; Holweg et al., 2016; Horoś and Ruppenthal, 2021; Ng et al., 2019; Reitemeier et al., 2021; Watanabe et al., 2022), suggesting that limited research focuses on this strategy. Ng et al. (2019), for example, explore valorisation of food waste into animal feed as a facet of resource recovery. The study assesses the approach's potential in contributing to a circular economy and lessening environmental impacts. It underscores the need for cohesive and collaborative waste management strategies that encompass both commercial and domestic sectors, demonstrating the viability of transforming food waste into animal feed.

3.2.4 Recycling

When reuse is not possible, recycling provides an opportunity to recover the value of food waste, promoting recovery of nutrients through composting, and energy through anaerobic digestion. The works that addressed recycling initiatives in retail are listed in Table 2, including biodiesel production, unspecified industrial use and recycling.

Fassio and Minotti (2019), for example, analysed composting as a measure to manage food waste at the Porta Palazzo market in Turin, Italy. The composting initiative was a part of the RePoPP project since the very beginning, aiming to reduce waste by transforming it into compost for agricultural use to close the circle of food waste to production through recycling.

Three studies explored energy generation through anaerobic digestion. One example, Warshawsky (2016),

presents the Kroger Recovery System (KRS) in California, where anaerobic digestion is used to transform 150 tons of unused food daily into renewable energy.

3.2.5 Energy recovery

Alongside Warshawsky (2016), two studies focused on energy recovery from FW, including incineration as well as anaerobic digestion. However, it is worth noting that these two options are separated within the waste hierarchy. Anaerobic digestion should be prioritised and has more desirable by-products (fertiliser and energy) than incineration (ash and gas).

Mattsson and Williams (2022), showed that waste generated in the stores studied was collected by a waste company and used for biogas production or incinerated for energy recovery. Ng et al. (2019) also highlight these two approaches in their case study of Tesco supermarkets, where 54.3% of surplus food considered unsafe for human consumption was sent to anaerobic digestion and 11.3% to incineration.

3.2.6 Disposal

Disposal, which is the least preferred strategy for managing food waste according to the hierarchy, was mentioned in only two included publications. Garrone et al. (2014) showed that 95% of surplus food waste generated in a large Italian retailer were sent to disposal by the municipal waste management system. They attribute this to the standard practice of keeping products on shelves until their expiration date, making redistribution impossible. The authors also highlighted the lack of economic incentives to avoid landfills, since waste disposal tariffs are mainly fixed fees.

In another example, Holweg et al. (2016) discusses a differentiated collection system, with separation between organics (fruits, vegetables, bread and dairy products without packaging) and waste (everything else not donated or sent to recycling). Both are collected by companies however no data showed the percentage of total waste sent for final disposal. Furthermore, the low number of studies found and their year of publication corroborates the argument that disposal is the least desirable strategy for food waste management and researchers are likely dedicating more time investigating alternative options.

3.3 Stakeholders: implementation actors and target population

The 132 different interventions identified were implemented by a range of different actors (see Figure 4), with supermarkets involved in 86.4% of them. Notably, the only interventions where supermarkets typically did not take on the implementation role were regulatory initiatives. Following supermarkets, government (14.4%), NGO (14.4%), community (8.3%) and academic (7.6%) actors were responsible for implementing food waste interventions.

The included studies described interventions targeted mostly consumers (50.8%) and supermarkets (46.2%). Charities (16.7%), food banks (13.6%), farmers (12.1%) and markets (8.3%) were also key beneficiaries. Reflecting our findings, Moraes et al.'s (2020) review showed a myriad of

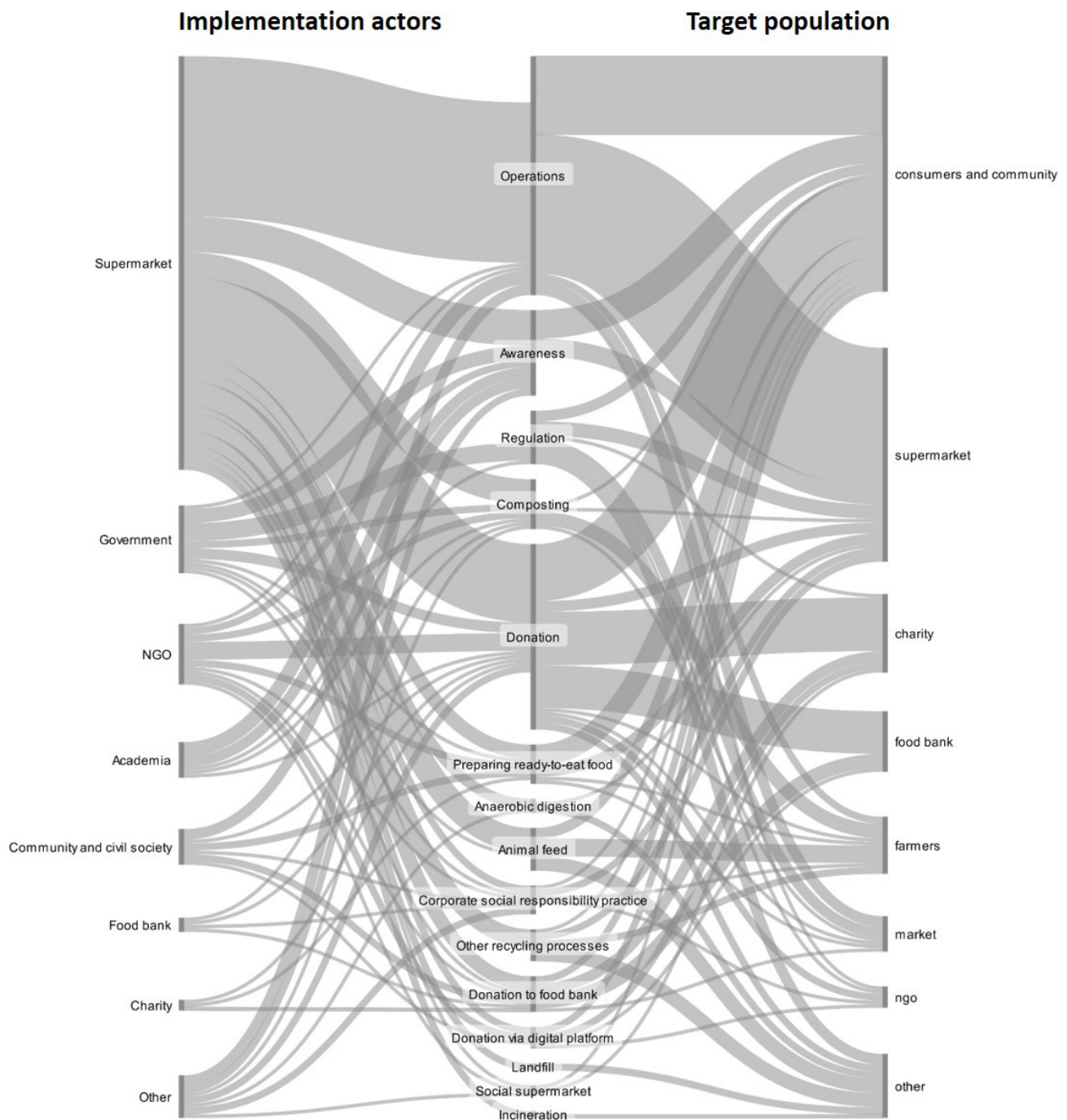


FIGURE 4: Types of actors involved in the implementation and target population of interventions described according to category. Source: Created by the authors using SankeyMATIC.

stakeholders involved in the problem of retail food waste. Consequently, the complexity of solutions to retail food waste persists.

3.4 Intervention outcome

To evaluate the impact of the interventions identified in the literature, we mapped outcomes of each study and added them to our database (see dataset on OSF). However, identifying and assessing the outcomes of interventions posed a challenge since few articles offered identifiable direct and measurable outcomes. Only 22 of the 43 analysed

articles identified quantifiable outcomes, with a total of 91 concrete measurable results (see supplementary material - Table S.5). Most articles instead presented not clearly measurable, superficially described or no intervention outcomes at all. Consequently, systematised outcomes here do not represent all interventions identified and categorised in Section 3.2. Below, we instead present a collection of outcomes mentioned in the articles.

After data extraction, in the initial systematisation step, we organised outcomes along the interventions and stages in the waste hierarchy. Appendix Table A.3 summarises

the main outcomes of prevention interventions identified in our literature review. Of the 66 preventive interventions, outcomes were defined in only 19 cases (28.8%). Results were quantifiable in only eight cases (marked in green). Furthermore, no information about outcomes was found for five of the preventive intervention subcategories identified: employee awareness, purchasing management, quality control, source reduction, and government incentive.

Table A.3 shows the broad range of outcomes found through the review, demonstrating the challenge of systematically presenting these findings. Consequently, we present here a selection of exemplary interventions that have a demonstrable, quantifiable and direct outcome on food waste in the retail sector, focusing on interconnected environmental, social, and economic impacts of these interventions.

Exemplifying quantifiable direct environmental outcomes, Warshawsky's (2016) research about supermarket chain Kroger's food waste recycling initiative highlighted their conversion of 150 tons of food waste into biogas daily, powering 20% of their distribution centre with 13 million kWh of electricity. Despite this effectiveness, Warshawsky notes the project's high cost, and lack of data on environmental impact provided by Kroger management. Consequently, he argues that promoting this initiative aims to project a positive image of the company, rather than having tangible environmental benefits.

Another example of positive environmental impact is Reitemeier et al.'s (2021) study of the food waste landscape in Colombo, Sri Lanka. There, many hotels, restaurants, markets and canteens redistributed food waste unsuitable for commercial use for re-use through animal consumption. 23 of 24 piggeries surveyed employed this practice, collecting a daily average of 1480 kg of food waste. Farmers independently collected waste, visiting up to 20 sites each and collecting around 80% of the food businesses would otherwise waste. In minimising required resources for animal feed production, farmers have a positive environmental impact here.

An example of quantifiable social outcomes is Fasio and Minotti's (2019) study of the effects of consumer awareness campaigns in Turin, Italy. They noted an 11.3% decrease in total waste from 2018 to 2019, primarily due to a 9.5% reduction in general waste. This reduction indicates that increased consumer awareness led to a decrease in food waste. Approximately 150,000 kilograms of food was rescued and distributed to individuals in need. Consequently, food waste was reduced while simultaneously making a social contribution.

Social impact is also demonstrated through the donation via digital platform described in Sewald et al. (2018). Its implementation by Boulder Food Rescue significantly reduced food waste through redistributing for human consumption. In 2016, the organisation saw a 423% increase in redistributed food compared to the previous year, equaling 4.1 million pounds annually. Their Food Rescue Robot facilitated 443,000 pick-ups, handling 44 million pounds of food in 40 cities, with help from 42,000 volunteers. This approach mitigated food waste while also enhancing food security in communities.

Direct economic outcomes are illustrated in Alexander's (2021) ethnography of the Cultureghem NGO and its work in a Brussels market. The organisation established a zero-waste pop-up restaurant on the site, serving regular meals produced using vendors' unsold produce. This reduced vendors' waste disposal costs, ensuring 40% of their edible food waste was recirculated instead of incinerated, while feeding up to 200 people weekly. Cultureghem's weekly food bank also distributes fresh goods to anyone attending, and their composting initiative allowed cattle farmers to collect waste for fertilising when bringing their animals to the market. Contributing to a circular economy, these initiatives also had a positive social impact on the city's poorest communities residing around the Abattoir, who could receive fresh produce and cooked meals at minimal cost.

The studies discussed above showed direct or indirect linkages between economic, environmental and social impacts of food waste interventions in retail. However, the lack of clear indicators to measure and evidence positive outcomes for the environment, economy or society is a limitation of this body of research, presenting a major challenge for comparative work on food waste, and implementation of interventions. To increase the practical utility of these studies, more systematised research on quantitative and qualitative outcomes of food waste interventions is needed.

3.5 Strengths and limitations

This scoping review was systematically conducted in accordance with established methodologies and reported following recognized guidelines after a protocol was published. The comprehensive search strategy, two-step selection involving all authors and a pilot test, adds rigour to study selection. Data collection and analysis employed a standardised extraction form and a systematic categorization approach aligned with a well established waste hierarchy framework. However, some methodological choices may limit our findings. There is potential language and geographical bias due to the exclusion of grey literature and language restrictions. Additionally, selection bias may have occurred during screening and selection processes, even with efforts to resolve conflicts among multiple authors.

4. CONCLUSIONS

This scoping review identified 132 interventions related to food waste management in retail across the 43 articles analysed. Studies focused on initiatives in the northern hemisphere, especially Europe, and published after 2020, when the 'Hierarchy for prioritisation of food surplus, by-products and food waste prevention strategies' was established in this region, dominated our findings. This policy may have increased the number of interventions in the region, causing greater research interest and, consequently, more publications. We argue that this regional discrepancy is not a problem and that interventions identified in countries where legislation is more advanced in combating food waste can serve as inspiration for other locations, providing they are adapted to the region's unique characteristics.

The FW hierarchy category with the most results was

prevention (50%) while incineration (1.5%) and final disposal (1.5%) had the least. Research therefore appears to prioritise interventions favoured by the hierarchy. This focus may also reflect pressing political discourses in the global North on innovation, circular economy and sustainable transformation, leading research to focus on novel alternatives.

Within the prevention category, price reduction was the most investigated subcategory (25.8%), which can reduce food waste within retail environments while encouraging increased purchasing and later wastage in households. However, recent research has challenged this norm, suggesting that such purchasing can reduce wastage across the food chain as a whole (Wu and Honhon, 2023). These contradictions suggest that retail interventions should be analysed with caution, and support the benefit of whole-systems approaches when dealing with the challenge of food waste.

Donation initiatives were also prevalent in this review (25%), including interventions related to food banks, through digital platforms and other unspecified types. The high quantity of such interventions may be associated with preferences to offer food to those experiencing food insecurity, an intensifying challenge following the pandemic. This reflects the political urgency of addressing food security which involves deep humanitarian and ethical aspects on top of policy challenges.

Identifying and analysing the results of identified interventions was highly challenging since few studies provided quantitative data to contextualise FW reductions, donations or designations. In qualitative studies, identifying the tangible outcomes of each intervention was difficult. The absence of clear and comparable data on outcomes hindered our ability to effectively evaluate the interventions identified. Therefore, we recommend more researchers seek to quantify or qualitatively analyse the impact of each intervention applied. A universal standardised indicator to measure food waste in the retail sector would be an important step in facilitating comparative studies in the future.

This research originated from collaboration between researchers with different disciplinary backgrounds, based in countries across the northern and southern hemispheres. The consequent multiscalar and interdisciplinary perspective this brought to the study led us to recognise the benefits of initiatives which require fewer technology and resource investments, particularly those in prevention and reuse (e.g. price reduction, employee training, donation), which might have greater potential for application in diverse retail contexts.

Thus, future studies must focus on food waste management in retail in the regions of the global South, about which we found fewer publications. Furthermore, we recommend further research on policies relating to food waste, their application and regulation, such as the waste hierarchy in Europe, since such frameworks appear to influence retailers' approach to food waste management.

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