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Review

Food waste interventions in low-and-middle-income countries: A systematic literature review

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ABSTRACT

Reduction of food waste in low-and-middle-income countries (LMICs) can provide multi-layered benefits for their sustainable development, through improved food security, enhanced income as well as the creation of environmentally friendly secondary markets. Food systems, however, are often characterised by a complex network of actors across the value chain, where a parochial intervention at a local scale does not always achieve a globally optimal outcome. Here, we systematically reviewed 8318 studies for the current evidence associated with the impact of interventions pursuing food waste reduction in LMICs. We first classified interventions by the target stage within the value chain and by the mechanism of action, and then further based on whether they are primarily designed to prevent or mitigate (recycle, reuse, remanufacture, repurpose and recover) the wastage of the commodity. We found a near-complete disconnect between preventive and mitigative interventions amongst the studies, with the former only investigated at production, storage and transportation stages and the latter only at wholesale and consumption stages. No identified study employed preventive and mitigative measures together to explore the combined level of efficacy. We also identified a strong bias in favour of material-based interventions, with little attention given to knowledge-based alternatives or local capacity building.

1. Introduction

The United Nations Sustainable Development Goals set out to halve food waste by 2030 (FAO 2022). Despite this target, the amount of food waste generated across global food value chains is increasing to date, and more rapidly amongst low-and-middle-income countries (LMICs) (Porter et al., 2016; Barrera and Hertel, 2021). Wastage occurs in greater quantities with the perishable commodity groups of fruits, vegetables (Guo et al., 2020) and animal products (Alexander et al., 2017) . Importantly, these are precisely the goods whose demand typically increases as an economy grows and diets change; as such, the upward trend of food waste in LMICs is expected to continue long into the future (Barrera and Hertel, 2021).

While food waste is socially undesirable anywhere in the world, its prevalence in LMICs is particularly problematic for a number of reasons (Kuiper and Cui, 2020). Food waste has a considerably negative impact on the nutritional status of LMIC populations; in some cases, waste prevention alone would likely result in a nationally sufficient supply of fruits and vegetables (and by extension sufficient intake of minerals and vitamins) (Mason-D'Croz et al., 2019). In rural households, a reduction in food waste can contribute to higher income and better livelihoods (Sethi et al., 2020), both through increased sales of primary food commodities and the creation of secondary markets that utilise degraded food as an alternative resource within a circular economy (Jayathilakan et al., 2012; Rosenzweig et al., 2020; Redlingshöfer et al., 2020). At a coarser spatial resolution, a society with less food waste does not only benefit from greater food security but also from lower environmental impacts (Kuiper and Cui, 2020; Springmann et al., 2018) by achieving a higher nutrient use efficiency and requiring a lower level of waste management across the entire value chain (Crippa et al., 2021; Adhikari et al., 2006). Strengthening alternative destinations for otherwise unutilised food is crucial to avoid further expansion of areas used for landfill, its associated methane emissions and environmental pollution by leachates (Adhikari et al., 2006).

As food systems are characterised by a complex network of local and global actors and stakeholders, an intervention into an individual stage of the value chain does not necessarily deliver a desired system-level outcome (Zurek et al., 2021). For example, simplistic prevention of

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food waste at the site of production (e.g. farms) can cause a food surplus beyond consumer needs and therefore greater overall wastage (Messner et al., 2020; Chaboud and Daviron, 2017). Reducing waste at the consumption stage does eliminate this issue but, in return, can impair both producer wellbeing (by creating negative cascading effects (Sethi et al., 2020)) and consumer health (through overconsumption (Hiç et al., 2016)). More generally, interventions targeting food waste reduction often invite unintended consequences for the environment, food security and human nutrition alike (Salemdeeb et al., 2017; Ahmed et al., 2021), as contrasting benefits from different strategies are bound to compete against one another (Goossens et al., 2019). How best to address these trade-offs and identify optimal intervention packages remains an unresolved question (Cattaneo et al., 2021; Xue et al., 2017; Parfitt et al., 2021).

This crucial knowledge gap notwithstanding, the existing reviews of the literature evaluating the effectiveness of food waste interventions only possess a relatively narrow scope, either limited to a small range of commodities (Stathers et al., 2020), a single value chain (Kruijssen et al., 2020), or a short subsegment of value chains (Goossens et al., 2019; Moraes et al., 2020). Moreover, a stronger focus has been placed on grains (Stathers et al., 2020; Affognon et al., 2015) while, curiously, interventions into (nutritionally richer yet more perishable) fruits, vegetables and animal products have been evaluated less frequently. As a direct consequence of each study's narrow remit, waste prevention and mitigation are almost always treated separately (Goossens et al., 2019), with opportunities for their integration rarely considered (Kasavan et al., 2022). This also means that the design of interventions is not fully assessed in the context of local resource constraints and sociopolitical priorities, likely overlooking potential co-benefits and negative consequences that occur upstream and downstream of the value chain (Cattaneo et al., 2021; FAO 2019; Papargyropoulou et al., 2014). Combined together, there is a serious lack of systematically gathered evidence on the effectiveness of food waste interventions and onward consequences (Goossens et al., 2019; Xue et al., 2017).

The objective of the present study, therefore, is to review holistically the current evidence concerning the impacts of the widest possible range of interventions on food waste reduction in LMICs. In doing so, we will consider preventive and mitigative interventions side by side as viable strategies to reduce the overall waste at the value chain scale while explicitly acknowledging the interrelationship between them (Redlingshöfer et al., 2020; Dora et al., 2021). We will also identify context-specific barriers and enablers to implementation as well as positive and negative indirect outcomes on economy, environment and wider society, and from this information draw lessons for future intervention studies.

2. Methods

2.1. Scope of the study

2.1.1. Food waste

There is no universally agreed definition of food waste in the literature, with the exact meaning of the term often varying to fit the purpose of the investigation (Hanson et al., 2016). The FAO, for example, distinguishes *food loss* that occurs between agricultural production and arrival at retail from *food waste* that occurs at retail and consumption stage (FAO 2019). At the same time, food loss and food waste under the FAO definition only concern edible parts of commodities that are intended for human consumption. Yet, the determination of edible and inedible parts of food is not necessarily straightforward, as what is considered edible is context and culture specific, changes over time, and differs both within and across populations (Nicholes et al., 2019).

In this study we adopt the definition by the World Resources Institute (WRI), or "both food and associated inedible parts" that are diverted from the value chain to a destination where it is not further valorised (Hanson et al., 2016). As elaborated below, adopting this definition allows us to include the widest possible range of commodity-intervention combinations across global food value chains and also capture associated co-benefits and unintended consequences of intervention efforts. As such, food waste in this study encompasses what is sometimes referred to as food losses (or post-harvest losses), and by-products that are discarded.

2.1.2. Food value chain

Food can be removed from its value chain at any point between production and consumption and thereby considered wasted if not valorised at subsequent destinations. Here, we define the food value chain according to the High Level Panel of Experts framework (HLPE 2020) and separate it into six stages: (1) production, (2) storage, (3) transport, (4) processing & packaging, (5) wholesale & retail, and (6) food services & consumption. Under this definition, production (stage 1) encompasses both agriculture and immediate post-harvest activities of sorting, washing and drying. Not all food commodities pass through all food value chain stages and the order in which they go through them may differ depending on the local market structure.

2.1.3. Food commodities

We consider all major food commodities that are highly perishable, either due to a high water content or susceptibility to bruising as well as microbial decay. This includes fruits, vegetables (including roots and tubers), eggs & dairy products, meat & meat products, and fish & fish products (including seafood and shellfish). We further consider general mixed food waste if the study specifies that the relevant waste includes highly perishable foods or it is reasonable to assume that it does. As per the definition of food waste given above, we include parts of commodities that may be considered inedible in some contexts, for example peels, pits, bones, blood and feathers.

2.1.4. Interventions

Interventions are defined as one or several specific actions that are implemented on a food value chain with the primary objective of reducing food waste (Craig et al., 2013). These actions can further be broken down according to the pathway through which they achieve the cause: Stathers et al. (2020), for example, suggested categorising post-harvest interventions into those based on technology, tool/equipment use, change of handling practices, knowledge transfer, and infrastructure. More commonly, other authors (Moraes et al., 2020; Bilska et al., 2016) have classified the causes and corresponding interventions of food waste into Ishikawa Diagram categories. The Ishikawa Diagrams are typically used to identify causes of a particular problem, whereby causes and proposed solutions have been shown to co-occur in the same categories (Moraes et al., 2020). In this study we group interventions into Ishikawa Diagram categories that describe the primary mode of delivery, namely via: (1) machinery, (2) materials, (3) methods, (4) people (knowledge and abilities), and (5) environment (factors external to the food value chain such as infrastructure and legislation). It is possible for a single intervention to make use of multiple categories.

2.1.5. Outcomes

Interventions achieve a reduction in food waste through two mechanisms: prevention and mitigation. *Preventive interventions* aim to preserve the quality, quantity and other relevant characteristics of food targeting one or more stages of the food value chain (European Parliament, 2008). The sole purpose of these measures is to maintain food for human consumption as originally intended (Teigiserova et al., 2020). We therefore consider redistribution and donations of food (sometimes referred to as *food recovery*) as preventive interventions. *Mitigative interventions*, on the other hand, aim to minimise the amount of discarded material by means of recycling, reusing, remanufacturing, repurposing and recovering for energy (Table 1). Acknowledging that the terminology on the component categories within mitigative interventions is yet to be standardised in the literature (Teigiserova et al., 2020), we start

Table 1
Definitions for waste mitigation categories.

Term	Definition	Example
Recycling	Preserving the value of the product that is reintroduced in the food system	Discarded tomatoes processed into pasta sauce
Reuse	Alternative destinations for food when primary human consumption is not an option	Animal feed
Repurposing	Recovering the value (mainly nutrients) from waste material for alternative purposes	Compost or fertiliser
Remanufacturing	Use of waste material to create new products distinct from their original function or purpose	Construction material or clothing
Recovery	Waste used for energy generation	Biogas

with the food waste hierarchy definitions for recycle, reuse and recovery (Teigiserova et al., 2020) and further expand the categories iteratively using the wider circular economy literature, to include remanufacturing and repurposing (Kirchherr et al., 2017). This approach was adopted with the explicit goal of distinguishing between different destinations of food; of the five pathways, the first three typically keep the commodity within the food system while the latter two divert food waste to other purposes and industries.

For the purpose of this review, we consider both waste prevention and waste mitigation as valid aims of intervention and henceforth refer to them jointly as *waste reduction* (Fig. 1). We thus set the primary outcome of interest as a direct decrease in the overall amount of food wasted (i.e., food removed from the supply chain without value addition). This decrease, in turn, is measured through the weight, volume, quantity or proportion of a food commodity prevented from becoming a waste material or, in some cases, through the weight, volume or quantity of food used to produce alternative goods and services.

2.1.6. Indirect impacts

We include indirect outcomes brought about by interventions as part of this review. We primarily consider effects on the food system impact domains of nutrition & health (including food security), economic & social wellbeing, and the environment (HLPE 2020; Ingram and Zurek, 2019). This selection is also consistent with the FAO recommendation that food waste intervention should be tailored to simultaneously achieve improvements in food security, economic opportunities and nutrient efficiency (FAO 2019). Where relevant, we also report indirect impacts outside these domains as reported in qualified studies.

2.1.7. Spatial and temporal boundaries

We limit our focus to studies from LMICs published in or after 2011, the year when the FAO issued the first-ever global assessment of food loss and food waste (under their own definition) in a landmark report (FAO 2011). Since then, scientific publications related to food loss and food waste have increased, and significantly so from 2017 onwards. We define LMICs according to the World Bank classification between 2011 and 2021 (World Bank, 2022). Countries that temporarily transitioned to high-income countries (HICs) but came back to the LMIC group within this timeframe (Argentina and Venezuela) are included, while those that transitioned and remained in the HIC group to the end of the study period (Chile, Hungary, Lithuania) are excluded.

2.2. Search strategy and study selection

We conducted this study following the Cochrane guidance for systematic reviews (Higgins et al., 2021) and report our findings according to the Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). We selected four scientific databases (CAB Abstracts, EconLit, Web of Science, Scopus) and six grey literature sources (OpenGrey, FAO AGRIS, IFPRI e-library, PubAg, GAIN, World Bank) that are most relevant for agriculture and food system literature. The full inclusion criteria are provided in the Appendix. Briefly, we used terms related to perishable food products, food loss/waste, and waste prevention and mitigation, with multiple terms combined by Boolean and proximity operators where appropriate. The search syntax was developed with the help of a subject librarian, and initial results were screened for relevance and evaluated based on

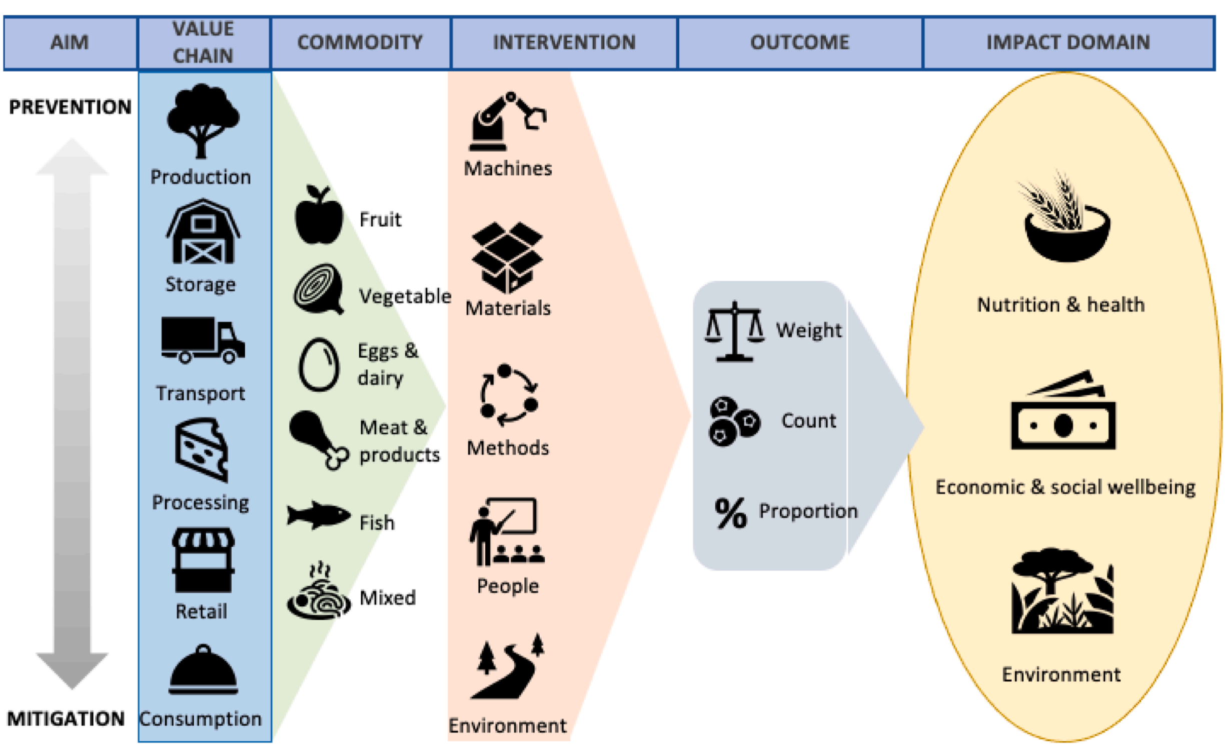

Fig. 1. Theoretical framework of literature review.

previously identified index studies (Rahman et al., 2018; Kinyanjui and Noor, 2013). We removed duplicates and screened the remaining entries against eligibility criteria, initially on title, abstract and keywords (TA&K) and subsequently using the full-text. Following a rigorous training session, a 10% sample was screened by a second screener. Discrepancies in screening decisions were discussed extensively and the screening protocol was modified to ensure consistency.

Eligibility criteria were developed based on the Population, Intervention, Comparison, Outcome (PICO) framework (Higgins et al., 2021). Specifically, amongst publications that assessed one or more interventions along food value chains of perishable foods (population), those aiming to prevent or mitigate food waste (intervention), comparing the outcome between different treatments or before/after treatment (comparison), *and* quantifying the waste prevented or mitigated (outcome) were selected. Studies that include no food value chain actors and where the entire lifecycle of food occurs in experimental/laboratory settings were excluded. Screening for eligibility was conducted using the online tool Rayyan (Ouzzani et al., 2016). The full protocol was stored in University of Bristol's data depository (Rolker et al., 2021) to ensure transparency. The search was undertaken between January and March 2021. The the graphical representation of the framework used is provided as Fig. 1.

2.3. Quality appraisal

For each publication deemed eligible, we assessed the study's quality and the risk of bias using an adapted checklist for randomised trials compiled by the Critical Appraisal Skills Programme (CASP) (CASP 2019). Based on the CASP tool and referring to similar approaches adopted in comparable interdisciplinary work (Moss et al., 2019; Harris et al., 2019), we devised eleven questions listed below. For each question we assigned the value 1 if the criterion was fulfilled, and 0 otherwise. The overall score for each publication was subsequently divided into the three discrete quality categories of low (0–5), medium (6–8) and high (9–11):

Q1. Is there a clear description of the food commodity of interest?
Q2. Is the choice of study area clearly justified?
Q3. Does the intervention directly target and involve local value chain actors?
Q4. Were human participants or food commodities randomly assigned to interventions or, if not, were adequate methods used to minimise statistical bias (e.g. propensity score matching, difference-in-differences)?
Q5. Are the intervention design and implementation methods clearly described?
Q6. Was the intervention compared to an appropriate control or different (baseline) intervention situation?
Q7. Were baseline characteristics of the commodity clearly described and are they similar across intervention groups?
Q8. Are the methods and measures of outcome assessments clearly justified?
Q9. Were the effects of the intervention reported in full?
Q10. Is sufficient data presented to support the findings, including the precision of the estimate?
Q11. Does the study consider unintended consequences, local availability of inputs, required upkeep or long-term sustainability of the intervention?

2.4. Data extraction and analysis

For each included study, we extracted bibliographic details (authors, title, year, publication type, source, DOI) as well as qualitative and quantitative information summarising target commodities, types of interventions, the timing of interventions along the value chain and observed outcomes. These data were analysed through cross-tabulation and frequency distribution to assess the patterns and combinations between them. In addition, texts discussing either context-specific causes/challenges related to the food waste generated, barriers/enablers to intervention effectiveness or indirect impacts (both intended and unintended) were manually recorded for in-depth analysis and narrative synthesis. Data management and analysis was conducted with R version 4.0.3 (R Core Team, 2020). Data visualisation was carried out with Tableau Desktop 2021.3 (https://www.tableau.com/products/desktop).

3. Results and discussion

3.1. Search results

The initial search returned 10,202 publications from scientific literature. Following the removal of duplicated entries 8216 unique studies were screened for eligibility based on TA&K, producing a shortlist of 462 studies. The examination of their full-texts resulted in an interim list of 79 publications (Fig. 2). The rate of agreement between the original and second screeners was 92% and 82% at TA&K and full-text stages, respectively. An additional two publications from grey literature sources met the inclusion criteria and a further seven scientific publications were added through snowballing from an existing review with a narrower scope that used a wider range of databases (Stathers et al., 2020). The final set therefore included 88 publications.

Out of the 88 studies selected for inclusion, 76% (n = 67) were published in or after 2016. Geographically over a third of the studies were conducted in sub-Saharan Africa (n = 34), while Latin America and the Middle East yielded fewest entries (n = 7 each). Only one study from Central Asia was included. By individual country, the largest number of studies originated from India (n = 12), followed by Nigeria (n = 9), Bangladesh (n = 6) and the Philippines (n = 5). The global map (Fig. 3) shows the breakdown of preventive and mitigative studies by country. We also classified the publications based on study design definitions used in implementation science (Hwang et al., 2020). Accordingly, 56 studies followed an experimental design and compared different interventions between and within sites. A further 25 followed a quasi-experimental design and observed changes over time in response to an intervention or project implementation. A further six studies used a modelling approach to simulate the intervention effect. Lastly, one study was observational and applied statistical methods to compare intervention groups.

The results of the quality appraisal showed that 16 studies were of high quality, 37 medium quality and 28 low quality (see the Appendix). This breakdown does not include the six modelling studies and a working paper for which the appraisal tool was unsuitable. Noticeably, as few as 26 studies provided confidence intervals or standard errors for the estimates of effectiveness of the interventions (Q9). Only 28 studies included a formal statistical analysis to evaluate the statistical significance of the conclusion (Q10).

3.2. Commodities and value chain stages of interventions

Two-thirds (n = 59) of the selected studies investigated preventive measures, while the rest considered mitigation strategies. Across both groups, about half of the studies focused on vegetables (n = 42), followed by fruits (n = 19). Mitigative studies, largely focused on mixed food waste (n = 10), a small number of studies solely targeted vegetables (n = 6). Three studies examined meat & meat products, all aiming to mitigate waste, and one study aimed at preventing dairy waste. In eight studies multiple commodity groups were independently investigated side by side, rather than pooled together as general mixed food waste. None of the selected studies considered both preventive and mitigative measures within a single publication.

Across all stages of the food value chain, processing & packaging (stage 4) was the most frequent target of interventions, followed by

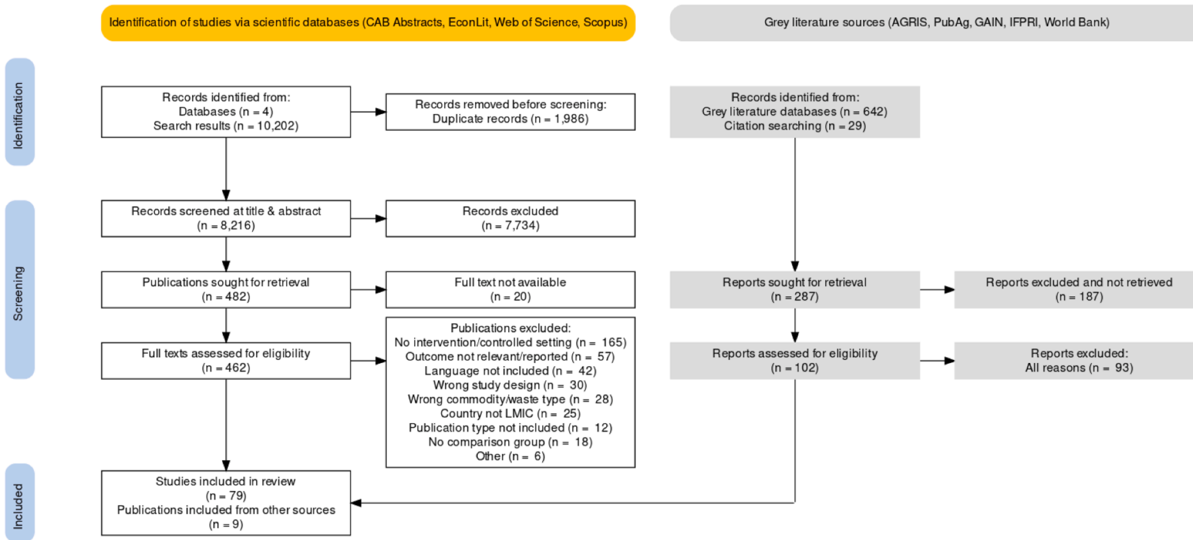

Fig. 2. Prisma flowchart.

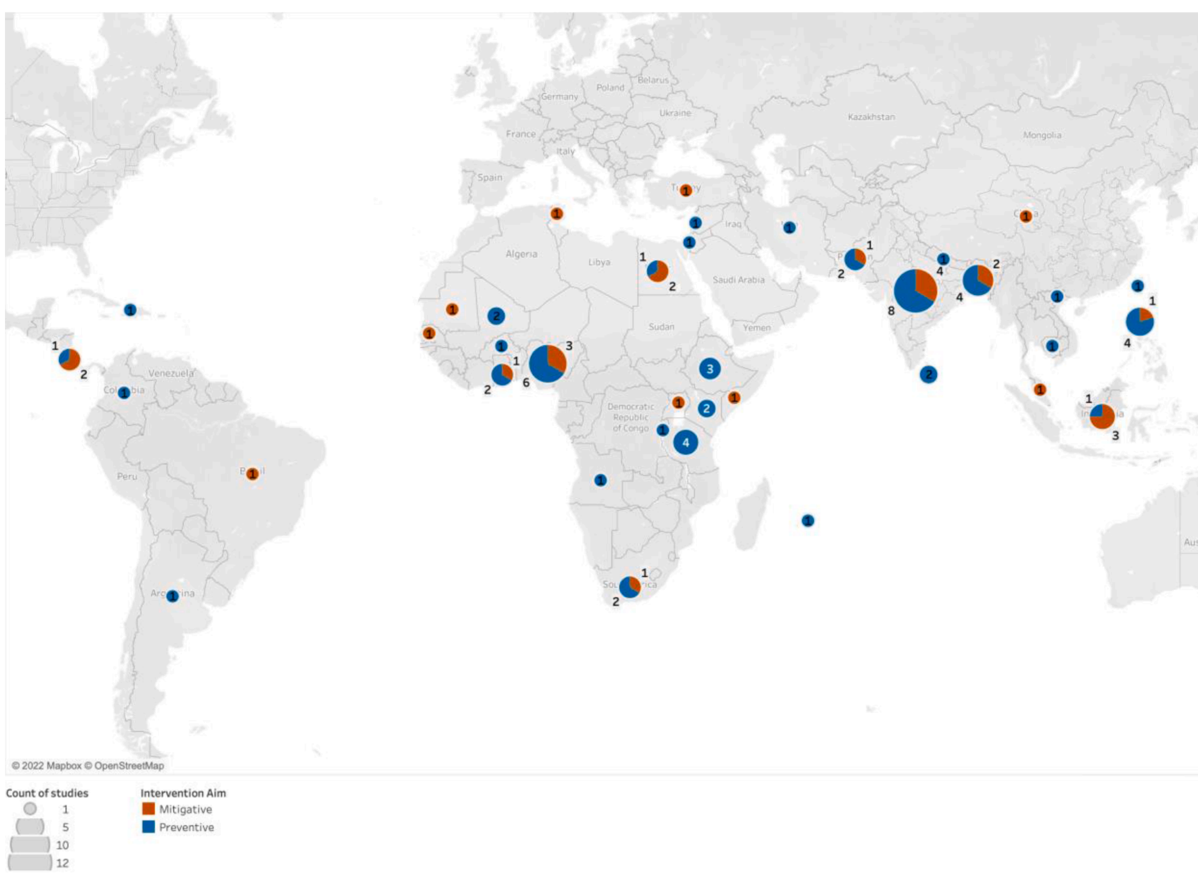

Fig. 3. Number of studies by country and aim.

production (stage 1) and storage (stage 2) (Fig. 4). Studies with a preventive aim tended to focus more frequently on interventions at production, storage and transport (stage 1 to 3). In contrast, studies with a mitigative aim were more frequently observed at retail (stage 5) and food services & consumption (stage 6). Processing & packaging (stage 4) was commonly investigated by both preventive and mitigative studies.

3.3. Types of interventions

Across the 88 studies we identified a total of 265 commodity-intervention combinations. Fig. 5 shows the breakdown of these interventions by the six value chain stages and by the five modes of delivery defined in Section 2. With an average of 3.0 commodity-intervention combinations per publication, most studies tested multiple sets of interventions at either a single or multiple stages of the food value chain. A range of studies ($n = 25$) evaluated intervention packages

Aim	Commodity group	Food Value Chain: Production	Storage	Transport	Processing & packaging	Wholesale & retail	Food services & consumption	Multiple	Not clear	Total
Prevention	Fruit	7	4	3	11	1		2	2	**16**
	Vegetable	10	15	9	15	2		1		**36**
	Eggs & dairy	1			1					**1**
	Fish	3			1					**3**
	Mixed						1			**1**
	Multiple		1							**1**
Mitigation	Fruit					3				**3**
	Vegetable	2			1	2		1	1	**6**
	Meat & meat products				3					**3**
	Fish				2	1	1			**4**
	Mixed	1			1		6	2		**10**
	Multiple					1	1	2		**4**
Total		**24**	**20**	**12**	**35**	**10**	**9**	**8**	**3**	**88**

Fig. 4. Number of studies by commodity and value chain stage.

Aim	Intervention type	Food Value Chain: Production	Storage	Transport	Processing & packaging	Wholesale & retail	Food services & consumption	Multiple	Not clear	Total
Prevention	Machines	2	10	5	2					**19**
	Materials	16	27	25	52	2				**122**
	Methods	14	8	2	10	6		1		**41**
	People	7	1		2		1	3		**14**
	Environment	2		3			1			**6**
Mitigation	Machines	3			5	4	7		1	**20**
	Materials	1			3	1				**5**
	Methods				8	9	4	3		**24**
	People	1			1		1	1		**4**
	Environment	1					3	1		**5**
Total		**47**	**46**	**35**	**83**	**22**	**17**	**14**	**1**	**265**

Fig. 5. Number of interventions by type and value chain stage.

of which individual components could potentially be implemented and evaluated in isolation. We therefore include the count of the individual components in the total number of interventions rather than considering the intervention package as a single intervention.

Across the five modes of delivery, by far the most common type found in the literature was *materials* (127/265, 47.9%), largely as a means for prevention rather than mitigation. These interventions were most frequently used at the processing & packaging stage, followed by storage and transport stages. Preventive studies under this category primarily investigated the efficacy of new packaging material, coating/dipping solutions, storage/transport containers, crates or bags. At the production stage, a number of manual harvesting tools were also evaluated.

Overall, 65 *methods* were used to either prevent or mitigate food waste. Common examples from preventive studies included a change in harvesting time, a new storage location and the use of different on-farm handling practices (e.g. sorting, washing or drying). In mitigation studies, they were almost exclusively related to composting practices.

A total of 39 *machineries* were evaluated, equally split between preventive and mitigative studies. Examples in preventive studies included drying technology and powered harvest tools on the farm as well as cooling technologies across the value chain. Mitigative studies, on the other hand, primarily used machineries to recover energy in biogas plants and anaerobic digesters. They also used devices to preprocess waste (e.g. for dewatering) and to transfer and store electricity.

Only 18 interventions focused on *people*. This included training programmes, workshops, capacity building, peer-to-peer knowledge dissemination and participatory approaches to improve stakeholder practices. The least common mode of delivery was through *environment* (external factors). For preventive studies this primarily entailed enhanced access to markets, finance and infrastructure. In mitigative studies examples included contracts and waste management surveillance systems.

A moderate number of publications reported the results of two or more experiments ($n = 23$). Just below half of the studies compared the outcome of multiple interventions ($n = 42$), followed by treatment-control comparisons ($n = 26$). Pre-post comparisons were slightly less common ($n = 24$). In some studies multiple interventions of the same mode of delivery (e.g. multiple materials) were tested, whereas others examined a combination of multiple modes of delivery. *Materials* and *methods* were paired in six studies. Four of the *people*-focussed studies developed a tailored training programme to accommodate the use of new materials.

3.4. Direct outcomes of interventions

3.4.1. Preventive interventions

Fig. 6 provides a summary of the 59 preventive studies identified, showing the location, commodity and value chain stages of the interventions investigated by each study. The symbols represent the different types of interventions applied across the food value chain, while the colours depict the number of interventions evaluated. The

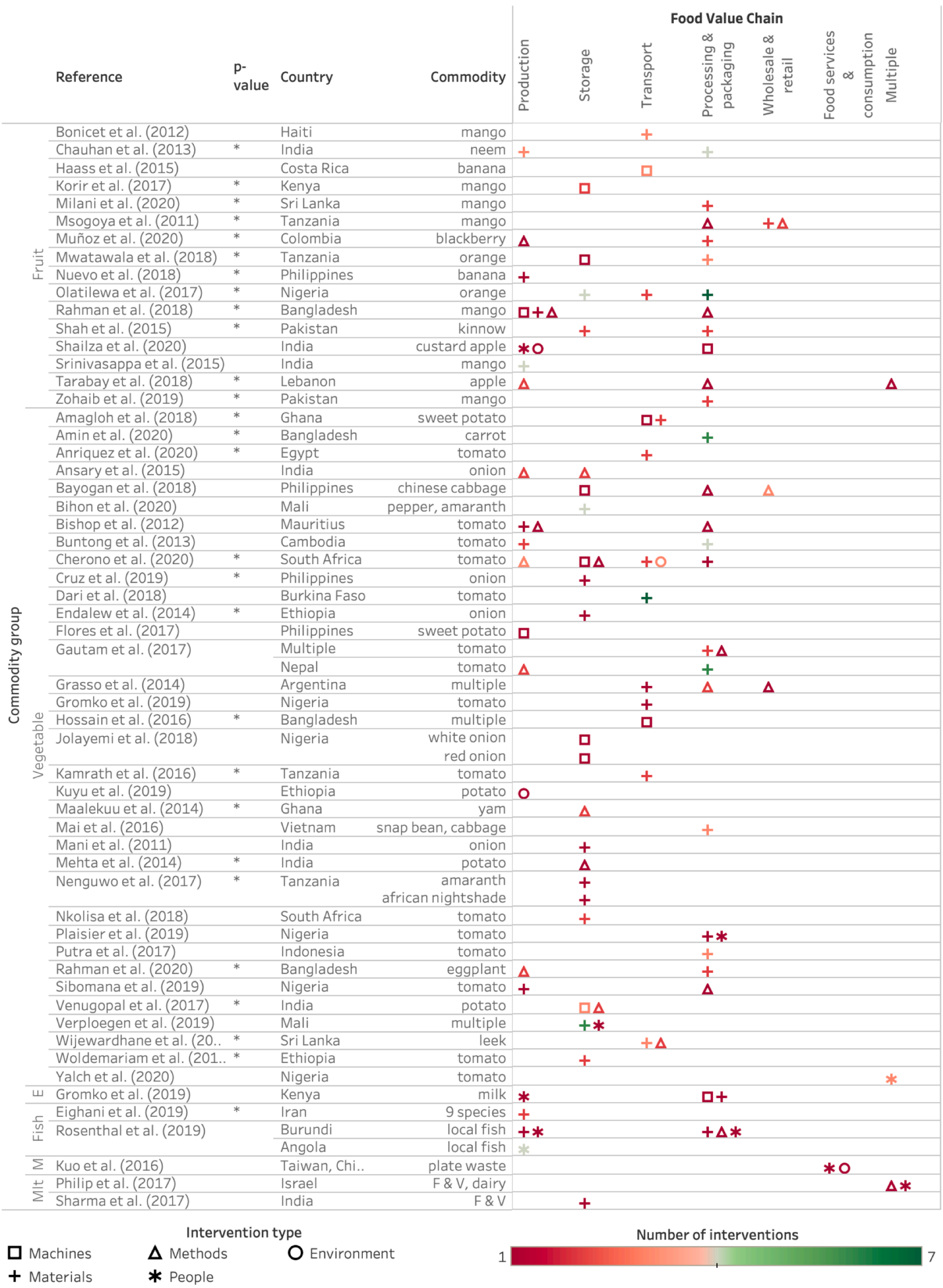

Fig. 6. Overview of preventive studies.

figure also indicates whether each study provides a statistical assessment to formally test the effectiveness of the interventions implemented.

3.4.1.1. Vegetables. Across 16 publications, a total of 61 interventions were applied in the tomato value chain. In intervention groups weight loss ranged 0–75% compared to 1–80% in the control groups, although only four studies conducted a formal statistical test to evaluate the inter-group difference (Woldemariam and Abera, 2014; Nkolisa et al., 2018; Cherono and Workneh, 2020; Anriquez et al., 2020). For instance, a study in Umsinga, South Africa showed that storage in a cold room significantly ($p<0.05$) reduced the 20-day weight loss to 5%, as compared to evaporative cooling (10.1%) and room temperature (11.4%) (Nkolisa et al., 2018). Another South African study applied successive interventions at production, storage and transport. Tomatoes were harvested at three different maturity stages, packaged in either plastic crates or raffia bags and stored in ambient or cold storage conditions. Additionally, the tomatoes were transported along three routes that differed in distance and road condition. This design resulted in 36 different experimental conditions. Across experimental conditions 30-day weight loss was lowest for the shortest transport route with best road quality ($p<0.05$) (Cherono and Workneh, 2020). A more detailed breakdown of the results is not given. In a study in Egypt, using reusable plastic crates instead of palm crates reduced losses between 8.8 and 31.2 percentage points ($p<0.01$), although the economic viability of this intervention was questioned (Anriquez et al., 2020). A further handful of studies evaluated the weight loss during transport from field to retail (Anriquez et al., 2020; Kamrath et al., 2016; Gromko and Abdurasalova, 2019; Gautam et al., 2017; Dari et al., 2018; Sibomana et al., 2019). In control scenarios tomato losses ranged from 40 to 55%; with intervention the losses were reduced to 10–44%.

Studies with interventions targeting onions ($n = 7$) mostly focused on storage structures, with generally positive results. In one study in India the same storage barn was constructed across the district and losses were evaluated in six randomly selected villages. Onions were placed in different locations within the barn, based on the assumption that the proximity to building material would result in better protection against environmental influences (e.g. heat, humidity and rain). In months with higher overall losses the differences between within-barn locations were more pronounced, but average annual losses were similar and ranged between 7.5 and 8.4% (Mani and Kumar, 2011). At storage temperatures of 22–30 °C across experimental conditions in Ethiopia, ventilated storage structures reduced 8-day losses by 7 to 12% compared to the traditional practice of storing onions on the house floor ($p<0.05$) (Endalew et al., 2014). At higher average storage temperatures in the Philippines (~35 °C), a plastic-covered tunnel structure reduced losses after 6 months from 69.4 to 49% ($p<0.01$). A study in Bangladesh evaluated the efficacy of racking and hanging storage methods in combination with ventilation systems, but 180-day total losses had no positive effect and remained as high as 40–50% across treatment groups (Ansary et al., 2015).

Three studies looked at improved storage conditions for roots and tubers (Mehta et al., 2014; Venugopal et al., 2017; Maalekuu et al., 2014). Under traditional heap storage in northeast India, potato losses were as high as 54% on day 90 but as low as 6% with prior chemical treatment (Mehta et al., 2014). Another study from south India showed similar results where traditional pit storage generated weight losses of 14–53% after four months while storage in ventilated chambers with and without evaporative cooling systems, reduced losses to 2.6 and 9.2%, respectively (Venugopal et al., 2017). In contrast, one study on yam storage in Ghana found a statistical difference ($p<0.05$) between on floor heap and open-sided shelf storage but neither of the treatments were statistically different from traditional storage where yams were tied to poles (Maalekuu et al., 2014).

3.4.1.2. Fruits. Seven studies evaluated interventions for mangoes (Rahman et al., 2018; Srinivasappa et al., 2015; Msogoya and Kimaro, 2011; Milani et al., 2020; Korir et al., 2017; Bonicet et al., 2012; Zohaib et al., 2019). The original spoilage losses of 31% in India were reduced to 4% when using a harvesting tool instead of shaking trees at harvest (Srinivasappa et al., 2015). Two studies conducted in sub-Saharan Africa also demonstrated the effectiveness of the interventions downstream. Shading the fruits against sunlight exposure at the wholesale location significantly ($p<0.05$) reduced the proportion of damaged products from 15% to 7 and 9% under plastic and net shading, respectively (Msogoya and Kimaro, 2011). Similarly, intended for on-farm storage, an evaporative cooling chamber with infrared reflection reduced weight loss, both compared to the control group and the treatment group without infrared reflection (Korir et al., 2017). In South Asia, two studies evaluated packaging interventions (Milani et al., 2020; Zohaib et al., 2019). Zohaibi et al. (2019) found a significant difference in weight loss between packaged and unpackaged mangoes. Similarly, packaging mangoes in styrofoam sleeves had no significant effect on 21-day weight loss ($p>0.05$) compared to banana leaf wrapping (Milani et al., 2020).

3.4.1.3. Animal products. A number of studies reported the results of FAO projects in sub-Saharan Africa to support small-scale aquaculture farmers with post-harvest efficiency. Amongst them, training and expert exchange programmes implemented in Angola reduced fish waste from 40 to 15% within 23 months (Rosenthal, 2019). Under the same scheme, a project in Burundi distributed drying fish racks to replace the conventional practice of drying fish on the ground and halved losses to between 5.0–7.5% within a year (Rosenthal, 2019). A study in the Persian Gulf investigated food waste reduction through prevention of unintentional harvest of fish below legal size and demonstrated that two types of by-catch reduction devices reduced waste by 32 and 38%, respectively. Finally, the sole identified study of eggs & dairy products reported how collective investment in milk cooling tanks through a cooperative in Burundi reduced milk losses by 6%, and extension services reduced losses by 5% compared to previously incurred losses without interventions (Gromko and Abdurasalova, 2019).

3.4.1.4. Multiple food groups. A single study evaluated preventive measures at the food consumption stage. In a university canteen in Taiwan participants were exposed to an education intervention to increase awareness about food waste and a potential fine when wasting food. Compared to the control scenario (no exposure to any waste related information) the waste generated per person was lower when informed of a fine. Notably, the study found gender differences with male participants wasting most when exposed to information and female participants wasting most in the control situation (Kuo and Shih, 2016). In Israel, a redistribution system was set up to channel surplus supplies and unmarketable produce to low income households (Philip et al., 2017). In 2013, 9700 tonnes of fruits and vegetables were redistributed through this system, while this number increased to 13,660 tonnes in 2015. Dairy products from the hospitality sector were also redistributed at a smaller scale (267 tonnes in 2013 and 138 tonnes in 2015). This was the only identified study that evaluated redistribution of food to prevent waste.

3.4.2. Mitigative interventions

The amount of waste mitigated was reported in a wide range of units, but most commonly either as the amount/percentage of food utilised (for value addition) or the amount of new material produced. In some cases mitigative interventions themselves required other materials to flow into the (diverted) value chain and the mitigated waste was measured relative to this input demand. The most common forms of output were compost ($n = 9$), followed by electricity ($n = 7$) and biogas ($n = 6$). Fig. 7 provides an overview of the 29 studies, where the symbols represent the type of intervention used and the number of interventions considered.

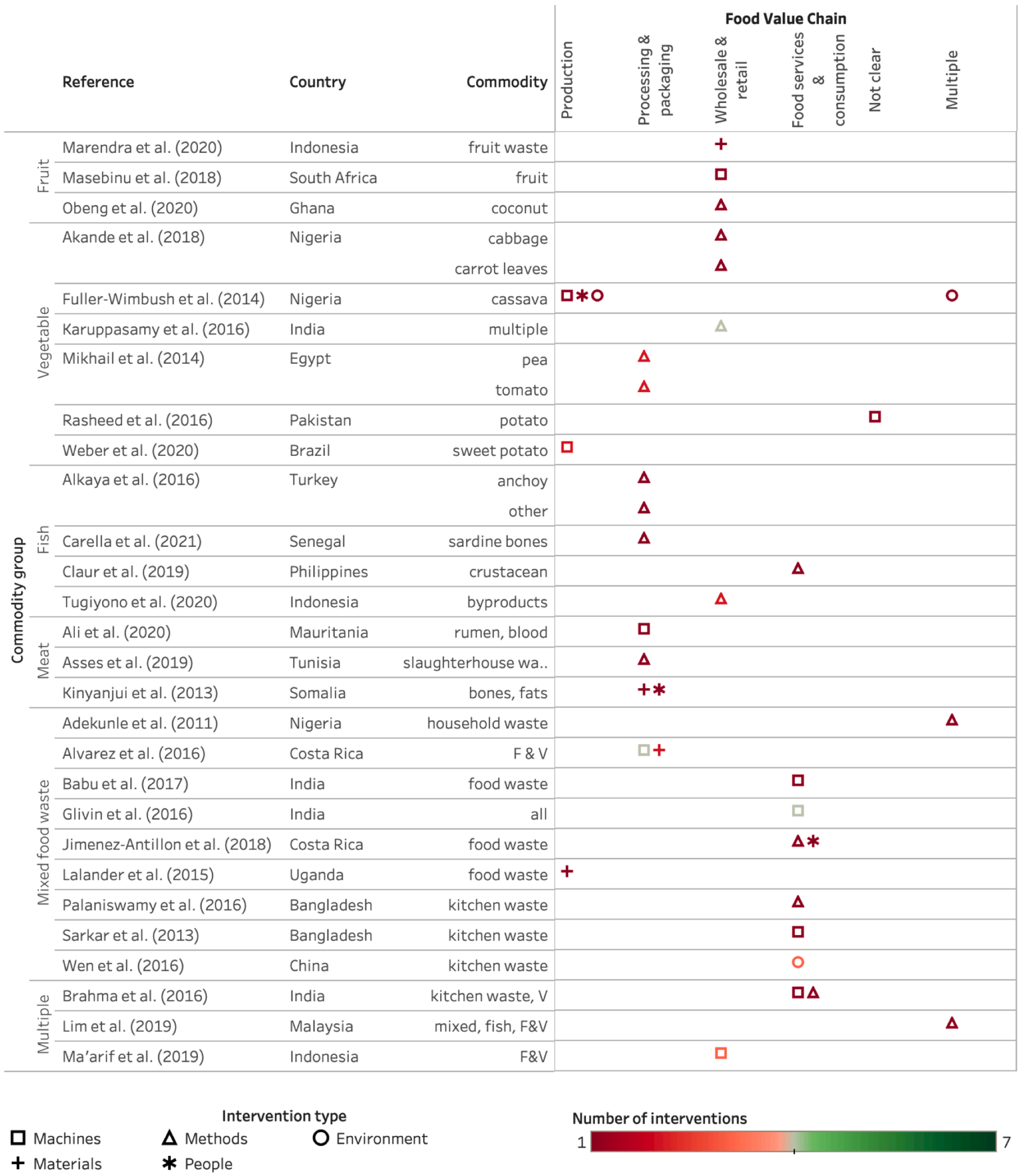

Fig. 7. Overview of mitigative studies.

3.4.2.1. Vegetables & fruits. Studies of mitigative interventions covered a relatively narrow range of vegetables. A modelling study from Brazil estimated that 7.6 t/day of rotten and damaged sweet potatoes could be recycled into ethanol and alcoholic drinks in a central waste biorefinery (Weber et al., 2020). In only one study vegetable waste was sourced at the processing stage to be recycled into new food products. Varying quantities of carrot, tomato and pea peels were processed into chicken burgers to reduce waste and cost, and to improve nutrient content (Mikhail et al., 2014). A project involving 6078 cassava farmers in Nigeria enabled them to dry and reuse up to 263 kg of discarded cassava peels per day into goat feed. The amount of food waste mitigated (as opposed to the processing capacity of wasted food) was unreported (Fuller-Wimbush and Adebayo, 2014). In India, vermicomposting of market vegetable waste showed to be a more resource-efficient alternative to uncoordinated waste disposal on site, yet the maximum processing capacity remained unquantified (Karuppasamy et al., 2016). Lastly, after quantifying various market food waste in Port Harcourt, Nigeria, Akande and Olorunnisola (2018) identified carrot and cabbage leaves as the most widely available material for briquetting. Through a series of technical experiments, the authors concluded that a ratio of 1:9 (paper:vegetable) would result in high-quality briquets.

Only a small number of mitigative studies focused exclusively on fruits ($n = 3$). In South Africa, a pilot biogas plant was tested to process 45 tonnes, or 96%, of fruit waste produced each day from Johannesburg market (Masebinu et al., 2018). Another study in Indonesia also reported the use of a biogas plant, here constructed subterraneously, to exclusively process the total waste from a local fruit market. The plant currently used 0.35 tonnes of fruit waste per day, far below its processing capacity of 4 tonnes per day (Marendra et al., 2020).

3.4.2.2. Mixed food waste & multiple food groups. The largest commodity type used in mitigation studies was mixed food waste ($n = 10$). In six cases the amount of food waste used in the intervention equated to the full amount generated at either market or household level (Abdallah et al., 2019; Jiménez-Antillón et al., 2018; Alvarez et al., 2016; Glivin and Sekhar, 2016; Sarkar and Uddin, 2013; Wen et al., 2016) while other studies used a predetermined amount of food waste to test the technical efficiency of interventions (Adekunle et al., 2011; Babu and Kumar, 2017; Lalander et al., 2015; Palaniswamy et al., 2016). Composting was implemented through interventions on small-holder farms (Adekunle et al., 2011; Lalander et al., 2015), in households (Adekunle et al., 2011), at educational institutions (Jiménez-Antillón et al., 2018; Palaniswamy et al., 2016), and in a community setting encompassing farm, retail and hospitality food waste (Lim et al., 2019). The volume of food waste was reduced between 57% (Adekunle et al., 2011) to 80% (Jiménez-Antillón et al., 2018) across composting interventions. Based on the varying composting techniques, the compost generated was 20% (Jiménez-Antillón et al., 2018), 35–43% (Adekunle et al., 2011) to 55% (Lalander et al., 2015) of the input weight. Food waste was mixed with animal manure and earthworms in a vermicomposting process (Lalander et al., 2015), or manure and sawdust (Adekunle et al., 2011). Three studies added a range of dry plant matter (Jiménez-Antillón et al., 2018; Palaniswamy et al., 2016; Lim et al., 2019). In four studies food waste was utilised as part of an energy production system (Alvarez et al., 2016; Glivin and Sekhar, 2016; Sarkar and Uddin, 2013; Ma'arif et al., 2019). In Costa Rica, an average of 283 kg per day of fruit and vegetable waste originating from food processing facilities were used for an anaerobic digestion system (Alvarez et al., 2016). In Indonesia, a combined dewatering and pyrolysis system put in place for market waste processed 3128 kg of food waste into 172 kg of charcoal each day at maximum capacity (Ma'arif et al., 2019). Two studies in India evaluated small community biogas plants to process kitchen waste (Glivin and Sekhar, 2016; Sarkar and Uddin, 2013). One of them only used a small fraction of food waste (3%) for biogas production (Sarkar and Uddin, 2013) while the other used 50% of waste (Glivin and Sekhar, 2016). This difference is due to the relative availability of food waste and cow dung used as a mix in the biogas feed. The mixed feed from a whole village (Sarkar and Uddin, 2013) contained proportionally more cow dung than that from a university campus with a single livestock (Glivin and Sekhar, 2016).

Two studies analysed components of an entire waste management system in the Middle East and North Africa (Abdallah et al., 2019) and in China (Wen et al., 2016) to reduce waste. Abdallah et al. (2019) evaluated multiple strategies for energy generation in Egypt and identified anaerobic digestion as the optimal technology, capable of using 607,292 tonnes of waste collected in Kafr El-Sheikh governorate at the rate of 1172 kWh per tonne. An intervention package in China encompassing collection, transport and processing stages of waste flows from canteens and restaurants resulted in 350 out of 600 tonnes of daily food waste being diverted to biogas production rather than landfill and incineration. The daily production rate was 7866 m^3, with additional production of fertiliser, animal feed and waste oil for industrial purposes (Wen et al., 2016).

3.4.2.3. Animal products. Two studies on animal products investigated the waste mitigation potential by enhancing food production efficiency (Alkaya and Demirer, 2016; Carella et al., 2021). A technical intervention at an anchovy processing facility in Turkey resulted in a more efficient separation of waste water from fish waste, enabling 140 kg of oil/grease per month that would otherwise have been discarded to be sold as unspecified valuable by-product (Alkaya and Demirer, 2016). In Senegal, fish bones and other fish by-products were converted into fertiliser by means of thermal conversion (Carella et al., 2021). Elsewhere, a composting study in Tunisia successfully utilised up to 60% of poultry waste from a slaughterhouse over a 90-day composting cycle (Asses et al., 2019). Ali et al. (2020) provided a thorough geospatial assessment of the slaughterhouse waste (blood and rumen) in Mauritania that could be used in a centralised biogas plant alongside manure.

3.5. Indirect outcomes of interventions

Table 2 summarises quantified positive indirect outcomes realised within each impact domain by interventions. The majority of these outcomes occur in the domains of economic & social wellbeing and the environment, as described in more detail below.

3.5.1. Economic & social wellbeing

In preventive studies economic outcomes were the most frequently described co-benefit of interventions. An increase in income was reported in nine cases (Rahman et al., 2018; Ansary et al., 2015; Maalekuu et al., 2014; Srinivasappa et al., 2015; Rosenthal, 2019; Cruz et al., 2019; Flores and Cruz, 2017; Rahman et al., 2020; Rasheed et al., 2016), increased profit in five cases (Kamrath et al., 2016; Ansary et al., 2015; Maalekuu et al., 2014; Amagloh et al., 2018; Shailza et al., 2020) and a higher product value in a single case (Shailza et al., 2020). One study mentioned enhanced household savings attributable to the intervention as reported by trial participants (Verploegen et al., 2019). Most economic benefits were not directly measured or quantified at the household or individual level but rather estimated for a representative scenario.

Mitigative studies mentioned economic outcomes in eight cases. These outcomes related to increased income (Kinyanjui and Noor, 2013; Weber et al., 2020; Fuller-Wimbush and Adebayo, 2014; Sarkar and Uddin, 2013; Ali et al., 2020) and savings (Abdallah et al., 2019), cost reduction in the diverted (non-food) supply chain (Ali et al., 2020; Tugiyono et al., 2020) and job creation (Kinyanjui and Noor, 2013; Sarkar and Uddin, 2013; Ali et al., 2020). Most of these economic benefits were calculated using the market price of the new output, such as organic fertiliser and biogas (Sarkar and Uddin, 2013), biodiesel (Wen et al., 2016) and distilled alcoholic beverages (Weber et al., 2020). One study described reusing of fishery waste for fish feed as a cost reduction strategy rather than a revenue enhancing strategy (Tugiyono et al., 2020). Two studies quantified the increase in income amongst the participating populations. Between them, crafts and soap from meat & meat product waste generated average weekly incomes between USD 45–50 for 14 female study participants in Somalia (Kinyanjui and Noor, 2013). On the other hand, additional income for cassava and goat farmers in Nigeria were considerably lower, at USD 384 and 198 per year, respectively (Fuller-Wimbush and Adebayo, 2014).

Four studies formally quantified the level of local energy demand that can be met through interventions (Masebinu et al., 2018; Marendra et al., 2020; Sarkar and Uddin, 2013; Babu and Kumar, 2017). Amongst them, one study concluded that the Gemah Ripah Market in Indonesia used food waste to produce its own electricity at the same quality as local electricity companies but in a more sustainable manner (Marendra et al., 2020). Another study showed that a Bangladeshi community-based biogas plant was able to provide electricity to 43 households and gas for cooking to 17 households, successfully providing energy to a decentralised rural community that lacked gas pipeline infrastructure (Sarkar and Uddin, 2013). A construction worker community in India followed the same principle and generated cooking energy from the waste collected in its canteens (Babu and Kumar, 2017). Time saved for women and children who would traditionally collect energy material for cooking was reported as an additional benefit (Sarkar and Uddin, 2013).

3.5.2. The environment

Environmental benefits were described in two preventive studies. One estimated the positive effect of improved shrimp trawling devices

Table 2
Overview of indirect outcomes quantified.

Impact domain	Outcome measure	References Preventive aim	Mitigative aim
Nutrition & health	Storage hygiene	Verploegen et al. (2018)	
	Improved vegetable availability	Verploegen et al. (2018)	
	Nutrient content		Mikhail et al. (2014)
Economic & social wellbeing	Profit	Amagloh et al. (2018), Ansary et al. (2015), Kamrath et al. (2016), Maalekuuu et al. (2014), Shailza et al. (2020)	Babu et al. (2017), Lalander et al. (2015), Wen et al. (2016)
	Income	Ansary et al. (2015), Cruz et al. (2019), Flores et al. (2017), Maalekuuu et al. (2014), Rahman et al. (2018), Rahman et al. (2020), Rosenthal et al. (2019)	Fuller-Wimbush et al. (2014), Kinyanjui et al. (2013), Masebinu et al. (2018), Sarkar et al. (2013), Weber et al. (2020), Rasheed et al. (2016)
	Economic savings	Srinivasappa et al. (2015), Verploegen et al. (2018)	Abdallah et al. (2019), Ali et al. (2020), Sarkar et al. (2013), Tugiyono et al. (2020)
	Time saving/ convenience	Srinivasappa et al. (2015), Verploegen et al. (2018)	
	Job creation		Kinyanjui et al. (2013)
Environment	Wild life	Eighani et al. (2019)	
	GHG emissions	Haass et al. (2015)	Abdallah et al. (2019), Ali et al. (2020), Alkaya et al. (2016), Lim et al. (2019), Marendra et al. (2020), Masebinu et al. (2018), Wen et al. (2016)
	Pollution		Marendra et al. (2020), Wen et al. (2016),
	Land use		Abdallah et al. (2019)
	Water use		Alkaya et al. (2016)
	Energy/fossil fuel use		Abdallah et al. (2019), Alkaya et al. (2016)
Food system	Compost quality		Adekunle et al. (2011), Babu et al. (2017), Jimenez-Antillon et al. (2018), Lalander et al. (2015), Palaniswamy et al. (2016)
	Plant growth		Adekunle et al. (2011)
	Feed quality		Tugiyono et al. (2020)
	Animal growth and health		Tugiyono et al. (2020)
Other	Product properties and quality		Claur et al. (2019)

on non-target fish populations (Eighani and Paighambari, 2019). Another estimated savings in greenhouse gas (GHG) emissions brought about by more efficient transatlantic banana shipping to reduce food waste (Haass et al., 2015).

Environmental benefits were evaluated more frequently amongst mitigative studies ($n = 6$) (Masebinu et al., 2018; Marendra et al., 2020; Abdallah et al., 2019; Wen et al., 2016; Lim et al., 2019; Alkaya and Demirer, 2016), with these benefits often linked to energy generation. A number of studies reported that interventions resulted in lower GHG emissions at waste management compared with landfill or open dumping (Abdallah et al., 2019; Lim et al., 2019), and at repurposing compared with use of freshly sourced input materials (Abdallah et al., 2019; Wen et al., 2016). In one example in Indonesia, a biogas plant is estimated to emit 250 tonnes less CO_2 compared to the use of fossil fuels. This benefit was in addition to 3650 tonnes of avoided fruit waste polluting the environment (Marendra et al., 2020). Another study in South Africa showed that, by switching to biogas production rather than disposing of market waste to landfill, up to 12,393 tonnes CO_2e of GHGs can be saved annually (Masebinu et al., 2018). Two studies reported non-GHG environmental co-benefits, namely savings of water (up to 77%) (Alkaya and Demirer, 2016), land (up to 1102 hectares) and fossil fuels (Abdallah et al., 2019) under more efficient waste management systems. Some studies that did not formally assess the reduced environmental burden provided qualitative discussions on indirect co-benefits, such as reduced pollution (Kinyanjui and Noor, 2013) and prevented deforestation (Sarkar and Uddin, 2013).

Several studies employed a modelling approach to map out the amount of energy that could be generated with the waste available in a specific region. Ali et al. (2020) determined geospatial availability and potential of meat & meat product waste to meet the energy demand in Mauritania and concluded that the proposed fixed dome digester had the potential to produce 326 million m^3 of biogas per year from slaughterhouse waste alone. When manure collected from farms was added to the calculation this figure increased to 2451 million m^3 of biogas per year or 4412 million kWh, meeting 43% of the energy demand for cooking in the country. A similar analysis was also conducted for the Middle East and North Africa region. Here, the authors mapped the energy consumption of nine countries against local data on municipal waste, of which food waste accounted for 60–66%. From an experiment in Egypt, it was further determined that 1772 kWh of 629 m^3 of methane was produced from one tonne of food waste through aerobic digestion (Abdallah et al., 2019). Local energy independence and a transition to a more sustainable energy source are two themes that emerged from all studies.

3.5.3. Nutrition & health

Only one identified study described co-benefits related to food security, which generally falls under the nutrition & health impact domain. Study participants in Mali who were provided with an evaporative cooling system for household food storage reported an increase in food availability and prolonged storage duration. They also reported additional benefits of convenience and time saved because of the reduced need for food purchases (Verploegen et al., 2019).

3.5.4. Other positive indirect outcomes

Seven studies evaluated additional outcomes within the food system itself. Amongst them, the quality of compost was assessed in terms of pH (Palaniswamy et al., 2016), nutrient composition (Jiménez-Antillón et al., 2018; Babu and Kumar, 2017), homogeneity (Lalander et al., 2015) and productivity as a growth medium (Adekunle et al., 2011), while food safety benefits were discussed in relation to heavy metal content, pathogen burden (Adekunle et al., 2011), and microbes and salmonella contaminations (Lalander et al., 2015). Of the two studies that piloted the conversion of food waste into animal feed, one measured subsequent animal (fish) growth performance and health outcomes (Tugiyono et al., 2020). The other study qualitatively observed that goats were "healthier and grow faster" after being fed with a feed made of cassava waste (Fuller-Wimbush and Adebayo, 2014). Elsewhere, the currently unrealised potential of reconverting worms used for vermicomposting to animal feed was discussed (Lalander et al., 2015). One further study noted a spillover effect onto communities that had not been directly targeted by the intervention. Here, non-target communities actually contributed to local innovation and improvisation, as they had to replicate the intervention strategy without any external material support (Rosenthal, 2019).

3.5.5. Unintended consequences & trade-offs

Alongside positive co-benefits, negative impacts of interventions were also highlighted in a number of studies. For example, interventions simultaneously targeting multiple value chain stakeholders were described to result in an unequal distribution of benefits between them (Dari et al., 2018; Plaisier et al., 2019). In an attempt to improve tomato value chains in Nigeria, farmers were not benefiting from the intervention because the losses were almost exclusively prevented at the transport stage of the value chain (Plaisier et al., 2019). Similarly, in Ghana, the price paid across local markets differed by 15% (Dari et al., 2018), and thus the intervention was shown to bear the risk of potentially amplifying the interregional income inequality. Preventive interventions could also result in unripe produce being brought to the wholesale market prematurely (Rahman et al., 2018).

A small number of studies examined various risks related to mitigative interventions which were often concluded to be negligible. The lack of air circulation at indoor spaces resulted in odour developing from compost boxes set up in Costa Rica (Jiménez-Antillón et al., 2018). Obeng et al. (2020) assessed the suitability of coconut waste as biochar and found that CO_2 emissions and Particulate Matter ($PM_{2.5}$) values both exceeded the World Health Organisation's indoor air quality recommendations. In another study, repurposed vegetable waste from local markets into briquettes generated excessive smoke due to the high moisture content in carrot and cabbage leaves used (Akande and Olorunnisola, 2018).

Trade-offs between positive and negative impacts are mentioned in several studies, often as a competition between direct and indirect outcomes. In preventive studies, a disconnect was observed between a material's capability to prevent waste and its overall cost-effectiveness (Anriquez et al., 2020; Amagloh et al., 2018). In mitigative studies, trade-offs were identified between GHG emissions, land requirement, energy potential and cost of interventions, which can potentially result in environmentally less favourable strategies to be recommended and adopted (Abdallah et al., 2019). Some studies provided a detailed list of advantages and disadvantages of each proposed intervention, including legal and social issues, technological viability, practical challenges and economic feasibility (Wen et al., 2016). For livestock agriculture, waste-based animal feeds were shown to be nominally cost reducing but associated with comparatively lower growth performance by animals (Tugiyono et al., 2020).

3.6. Context, barriers and enablers

3.6.1. Preventive interventions

3.6.1.1. Study motivation and design. The motivation for an intervention into a crop value chain varied across contexts and settings. For some authors, the identified need for an intervention was based on the extent of waste generated and the local significance of the particular crop (Rahman et al., 2018; Srinivasappa et al., 2015; Shailza et al., 2020). For example, Rahman et al. (2018) implemented an intervention in Chittagong because this was "the major commercial growing area of mango" in Bangladesh. Similarly, custard apples in Rajasthan, India were described as being crucial to local livelihoods by another study and as such selected as an intervention target (Shailza et al., 2020). The proximity to the main consumption areas were not explicitly considered in these cases. Contrarily, some other authors positioned food waste prevention as a means to meet national and international market demands (Rahman et al., 2018; Rahman et al., 2020; Nuevo et al., 2018) and to improve food availability (Plaisier et al., 2019). For example, a study in Visayas and Mindanao regions of the Philippines, major production areas of banana varieties for the Japanese market, was explicitly motivated by the need to meet the order and thereby increase the producers' income (Nuevo et al., 2018). As an outlier, one study specified cutting GHG emissions as a primary motivation for interventions on transatlantic refrigerated shipping (Haass et al., 2015).

For animal products, the most common justification for preventing losses was based around the social and economic dependence of local communities on the relevant value chain (Gromko and Abdurasalova, 2019; Rosenthal, 2019; Eighani and Paighambari, 2019). This was closely followed by the significance of animal products for adequate nutrition for local populations, alongside the importance of improving food safety (Gromko and Abdurasalova, 2019; Rosenthal, 2019). Eighani and Paighambari (2019) further aimed to improve shrimp trawling methods to support fishing communities' adherence to resource conservation regulations and policies.

A large number of studies identified one or several local practices along the food value chain as inadequate or problematic (Kinyanjui and Noor, 2013; Kamrath et al., 2016; Dari et al., 2018; Ansary et al., 2015; Maalekuu et al., 2014; Srinivasappa et al., 2015; Rosenthal, 2019; Rahman et al., 2020; Amagloh et al., 2018; Shailza et al., 2020; Nuevo et al., 2018). A typical solution to this situation was to directly substitute the current practice with a locally novel practice, for example, the replacement of a locally dominant packaging material (e.g. wooden boxes or raffia bags) with an alternative material (e.g. plastic crates) (Kamrath et al., 2016; Gromko and Abdurasalova, 2019; Dari et al., 2018). The origin of the replacement material was seldom disclosed, although two studies explicitly stated that the substitution materials had always been locally available but not traditionally used by local actors (Kamrath et al., 2016; Olatilewa et al., 2017). Several studies implemented an intervention at production and evaluated the effect at multiple stages of the food value chain (Gromko and Abdurasalova, 2019; Rahman et al., 2020; Amagloh et al., 2018; Shailza et al., 2020; Buntong et al., 2013; Hossain et al., 2016). In an eggplant value chain in Bangladesh, for example, the effect of improved sorting, grading and washing practices after harvest, was measured after transport, at wholesale and at retail (Rahman et al., 2020).

3.6.1.2. Inclusion of local actors. Frequently, the involvement of local value chain actors was limited to the production of food commodities used in intervention trials ($n = 50$). Several studies engaged local actors for additional roles with varying levels of responsibility, from simply observing the intervention and providing feedback to actively co-designing and co-creating the intervention. Amongst them, some collected qualitative data on people's willingness to adopt and perception of the proposed intervention while quantitatively evaluating its effectiveness without local participation (Kamrath et al., 2016; Srinivasappa et al., 2015; Cruz et al., 2019; Flores and Cruz, 2017). A number of studies invited local value chain actors to physical demonstrations of the proposed intervention, for example to showcase the workings of a mango harvesting tool (Srinivasappa et al., 2015). Onion storage structures trialled in two studies were installed in local farmers' fields for community awareness but then managed by the research staff (Ansary et al., 2015; Cruz et al., 2019). In some cases interventions were designed in response to farmers' needs (Srinivasappa et al., 2015; Verploegen et al., 2019; Amin et al., 2020). For example, the mechanical carrot washing machine in the Savar Union region of Bangladesh was developed upon farmers' request to provide a low-cost and movable processing option (Amin et al., 2020).

Only a small number of studies interviewed stakeholders across the value chain to understand causes and potential solutions to local food waste problems (Kamrath et al., 2016; Gromko and Abdurasalova, 2019; Maalekuu et al., 2014; Buntong et al., 2013). Amongst them, the majority of wholesalers and retailers in a Cambodian tomato value chain identified storage conditions as a main factor contributing to waste while listing inadequate transport as the second most important. Farmers, on the other hand, identified hot and humid weather conditions as the main reason for losses, revealing an important discrepancy between stakeholders depending on their roles (Buntong et al., 2013). Only one identified project, referred to in two studies, employed a genuinely co-creation approach to identify the most viable solutions to post-harvest losses across the food value chain, inviting local producers, transporters, traders and retailers to participate in workshops with the research team (Sibomana et al., 2019; Plaisier et al., 2019). During these meetings participants discussed both monetary and information flows along the value chain and thereby identified bottlenecks leading to waste. During the pilot phase of the intervention, participants then returned to their respective regions with an implementation plan detailing local responsibilities. Feedback was brought back to the final workshop (Plaisier et al., 2019).

3.6.1.3. Barriers and enablers. Both technical and practical limitations were mentioned as barriers to the success of interventions. These include the lack of sufficient space to build storage systems (Cruz et al., 2019), liquid leakage from household coolers (Verploegen et al., 2019) and conditions and practices at food value chain stages preceding the point of the intervention (Dari et al., 2018). Other barriers included organisational structures, concerns on practicality, long-standing beliefs about how the food system should work and lack of knowledge (Kamrath et al., 2016; Verploegen et al., 2019; Plaisier et al., 2019). In a value chain intervention, insufficient integration of all stakeholders and the lack of a common understanding of who owns and is responsible for maintenance and return of plastic crates used in the intervention were stated as a barrier to effectiveness. The intervention further resulted in an unequal distribution of benefits across the value chain. Farmers benefited least and retailers most, because product pricing and transaction took place before losses occurred (Plaisier et al., 2019).

Two studies formally tested and supported the long-standing belief in the programme evaluation literature that when local stakeholders perceive an intervention as beneficial *to them*, they are more likely to adopt it (Verploegen et al., 2019; Plaisier et al., 2019). Other factors identified to increase intervention uptake included local availability and affordability of materials needed (Verploegen et al., 2019) and the ease of adoption (Plaisier et al., 2019). Participants in a Nigerian tomato value chain project supported the transition to reusable plastic crates on the basis that it would improve the local handling system and market structures through standardisation (Plaisier et al., 2019). The presence of local organisations and the endorsement of influential local actors were also described as an important factor to successful implementation of and community-wide participation in a project (Kamrath et al., 2016).

3.6.2. Mitigative interventions

By and large, mitigative interventions identified in this review were conceived as a next-best option when preventive measures did not exist or had failed to preserve the quality of the food. The absence or inadequacy of local waste management systems was often described as a social problem because of the associated pollution (Kinyanjui and Noor, 2013; Akande and Olorunnisola, 2018; Masebinu et al., 2018; Babu and Kumar, 2017; Lalander et al., 2015; Palaniswamy et al., 2016) and health hazards (Kinyanjui and Noor, 2013; Palaniswamy et al., 2016). In these cases mitigative measures were primarily undertaken to address the relevant issue rather than increasing the food supply as such. One study was entirely motivated by the landfill capacities reaching the physical expansion limit (Masebinu et al., 2018). Two studies, on the other hand, were motivated by income generation (Kinyanjui and Noor, 2013; Sarkar and Uddin, 2013). Between them a study in Somaliland aimed at "deriving maximum benefit from livestock by-products" and thereby empower vulnerable groups in the region (Kinyanjui and Noor, 2013). In a Bangladeshi project a participation approach was used to integrate the local community into a biogas waste management system and generate additional income opportunities (Sarkar and Uddin, 2013).

Approximately one-third ($n = 8$) of mitigative studies measured the quantities and composition of food waste generated in the area of interest so that suitability of the proposed intervention could be evaluated (Kinyanjui and Noor, 2013; Akande and Olorunnisola, 2018; Masebinu et al., 2018; Abdallah et al., 2019; Sarkar and Uddin, 2013; Adekunle et al., 2011; Babu and Kumar, 2017; Palaniswamy et al., 2016). Three studies further employed geospatial mapping to plan the intervention with a geographical context (Weber et al., 2020; Ali et al., 2020; Brahma et al., 2016). Two interventions were explicitly designed to reduce the cost of animal production systems and increase the food supply by processing food waste into animal feed (Lalander et al., 2015; Tugiyono et al., 2020).

Amongst the included studies the most commonly reported barrier to effective mitigative interventions was issues related to participation (Fuller-Wimbush and Adebayo, 2014; Sarkar and Uddin, 2013; Palaniswamy et al., 2016), followed by food waste composition (Abdallah et al., 2019; Palaniswamy et al., 2016). In Bangladesh, the compost quality was highly variable because of participants' non-adherence to the predetermined composting schedule as a result of an odour issue. The absence of access to expertise during setbacks, especially in the initial phases of setting up an improved waste management system, was also mentioned as a barrier to successful implementation (Fuller-Wimbush and Adebayo, 2014; Sarkar and Uddin, 2013) as well as the general lack of funding for waste management projects (Fuller-Wimbush and Adebayo, 2014) and of political ambition to optimise food systems (Wen et al., 2016). A quantitative mismatch within the newly created (diverted) supply chain also posed a challenge in a number of projects. As a case example, an Indonesian biogas plant built for fruit waste had to operate at only 8% of its total capacity due to inadequate pre-processing capacity to crush the fruit in advance (Marendra et al., 2020).

3.7. Knowledge gaps identified across the literature

Geographically the largest number of studies were conducted in Asia, followed by sub-Saharan Africa and Central/South America. North Africa and the Middle East were the least represented regions in this sample of studies. The most common commodity groups studied were vegetables and fruits, while dairy, meat & meat products were least featured and eggs not at all. This can be seen as a major gap because, while livestock production and therefore associated waste levels are still low in some LMICs (Guo et al., 2020; Ritchie and Roser, 2017), from nutritional, economic, and environmental perspectives large benefits could be achieved by improving the value chain efficiency for these products. In particular, the potential of animal by-products and slaughterhouse waste is substantial both within and outside the food system (Jayathilakan et al., 2012). Amongst the eligible studies we observe a lack in diversity of interventions to capitalise on the multi-purpose nature of livestock. This disconnect is likely to be explained, at least in part, by the common distinction made between edible and inedible parts that prevents a full consideration of potential intervention gains (Chaboud and Daviron, 2017).

The preventive studies identified in this review most commonly employed material-based interventions during processing, storage and transport, followed by method- and machinery-based interventions at the same stages of the value chain. This finding indicates that these studies do not sufficiently acknowledge local food system structures and stakeholder relationships, with little focus given to interventions aiming to develop people's knowledge, skills and capacities (Stathers et al., 2020). Interventions to facilitate peer-to-peer support and participatory learning have long been shown to be effective in health sciences (Prost et al., 2013) and are now increasingly used in agri-food research as well (Kadiyala et al., 2021). Yet our Ishikawa Diagram indicates that the roll-out strategy underpinning a physical technology is rarely considered in the overall design of interventions. Only a small number of studies worked with value chain stakeholders at the design and evaluation of interventions. Even less attention was given to the environment in which interventions were implemented, with inadequate handling of food frequently identified as the primary cause of waste rather than the absence of knowledge, infrastructure and market incentives to prevent such handling. Furthermore, and despite the search criterion to only include studies involving local actors, most stakeholder participation was limited to providing the food produce used in the interventions. Evidence of the real-world effectiveness of interventions under non-controlled environments was rarely provided.

There is already a strong consensus that interventions that are embedded into the local context and relevant to local actors are more likely to be effective (Sethi et al., 2020; FAO 2019). Understanding the context also means that synergies and trade-offs can be anticipated rather than discovered unexpectedly (Cooper et al., 2021). In the context of food waste reduction, this necessitates a prior understanding of material flows across the value chain (and the diverted value chains), although in practice such effort is scarcely observed. An analysis of a traditional tomato value chain in Colombia provides a good example where, along the value chain, a proportion of damaged produce was gradually absorbed for other purposes, such as compost and animal feed (Chaboud, 2017). As the amount of waste decreases through preventive interventions, so does the supply of waste-derived products, forcing neighbouring farmers to find alternative sources of fertilisers and feed, likely at higher economic and environmental costs. Nonetheless, such knock-on effects were seldom considered amongst the eligible studies, all of which seem to assume either implicitly or explicitly that maximal waste prevention at an early stage of the supply chain is always socially most desirable. In order to design context-specific interventions in line with local priorities, linkages between the studied value chain and the rest of the economy must be more deeply understood.

Across the qualified publications, preventive studies dominated the upstream half of the food value chain from production to processing, while waste mitigation was more common at the downstream stages of retail and consumption. Few interventions were trialled to prevent food waste at retail and consumption despite strong evidence that a considerable proportion of loss occurs at these stages (Guo et al., 2020; Bilali and Hassen, 2020; UNEP 2021). Equally, there were few interventions to mitigate food waste at production, storage and transport stages, even though most preventive studies from these stages report that a substantial degree of losses still occur post-intervention. With no identified study covering both preventive and mitigative interventions, the disconnect between these mutually complementary strategies seems to represent an important missed opportunity. The imbalance in intervention effort between upstream and downstream also means that a locally effective intervention upstream is more likely to result in higher wastage downstream to offset the positive outcome (and vice versa). The ambiguity and inconsistency in study aims across the food waste literature (Chaboud and Daviron, 2017) is doubtlessly a strong contributing factor to this issue.

Of the studies that conducted a formal statistical test to evaluate the effectiveness of the studied intervention, the majority concluded that it contributed to the reduction of food waste. Notwithstanding, the size of the effect varied greatly across these studies and, perhaps more critically, a large proportion of the studies did not report sufficient data to allow a formal assessment at all. In particular, mitigative studies often lacked quantitative information regarding the amounts of waste in the control group. The pre-intervention flow of food waste was seldom clearly described, with the exception of a few studies that briefly defined the assumed baseline scenario (e.g. landfill, illegal dumping). While evaluation frameworks are reasonably well-established for preventive interventions (Laurentiis et al., 2020), the same is not true for mitigative interventions (Teigiserova et al., 2020). Common approaches are limited to the use of the waste hierarchy, which has been shown to be insufficient as a guide for intervention design and policy (Ewijk and Stegemann, 2016). This gap must be urgently filled, especially given the aforementioned need to optimise the effort between preventive and mitigative measures.

4. Conclusion

This review explored the trends and gaps of the current empirical evidence on the effectiveness of interventions aiming to either prevent or mitigate food waste in LMICs. We synthesised barriers, enablers and unintended consequences associated with these interventions and summarised their wider impacts for development and health. The majority of interventions represented immediate substitutes for materials or methods currently used along the value chain, with little support for local industrial structures and stakeholders to remove system-level drivers of food waste. We identified clear knowledge gaps in interventions targeting animal products, including eggs and dairy. There was a disconnect between preventive and mitigative studies, where the former was disproportionately concentrated from farm to retail stages and the latter from retail to consumption stages of the value chain. Few interventions were purposefully designed to create or evaluate indirect outcomes beyond immediate waste reduction, with none explicitly studying the impact on food security.

The FAO recommends that all agri-policy interventions be designed with food system efficiency, food security and environmental objectives in mind (FAO 2019). Amongst the qualified publications, mitigative studies seem to perform better in adhering to this principle, most commonly by reporting economic benefits of the intervention. On the other hand, preventive studies rarely measured economic co-benefits, possibly because they were too small to stimulate sizable stakeholder investments. This omission, however, means that the livelihood impacts of these interventions on smallholder households often remain unquantified. Furthermore, food security, nutrition and health outcomes barely featured in study justifications nor as indirect outcomes of the interventions evaluated. To elucidate whether, how and to what degree policy targeting food waste prevention can also deliver improved food security and human health is a priority for future studies. Most common justification for preventive studies relates to economic considerations. This presents a disconnect to the general discourse around food waste and underlines the single stage focus rather than a greater perspective on food system efficiency and sustainability.

Environmental benefits of food waste reduction were well-recognised, particularly amongst mitigative studies. In addition to reducing various forms of pollution, food waste was often considered a useful solution to localised energy shortages or dependence, and its reduction an effective measure to ease the land demand for both agriculture and landfill. However, synergies and trade-offs between food and energy solutions were seldom discussed within the qualified studies, leaving it unclear when it is socially more desirable to keep the unused commodity within the food system (e.g. as livestock feed) and when to transfer it to the energy sector. As many of the waste mitigation interventions have been shown to be effective only under a community approach, stronger integration of social science studies investigating behaviour change and technology adoption is recommended.

Finally, it is worth reiterating that the interlinkages between food waste reduction, food security, nutrition and health have predominantly been studied for grains and their supply chains. Yet, in order to meet the recommended consumption levels for protein, micronutrients, fruits and vegetables, preventing waste of perishable foods is as crucial, if not more crucial (Guo et al., 2020; Kuiper and Cui, 2020; Mason-D'Croz et al., 2019). This view is particularly pertinent in light that malnutrition in all its forms is prevalent across many LMICs, where obesity is increasingly co-existing alongside underweight and micronutrient deficiencies to create double and triple burdens (Micha et al., 2020). The excessive focus on calories, and by extension the weight of commodity lost, is therefore not always an adequate approach to assess the implications of waste on the overall society (Hiç et al., 2016). While experimental studies are likely to generate the most robust form of evidence to quantify the possible quantity-quality trade-off in this area, the use of non-experimental methods, metrics and tools can also provide important insights into the food waste and health linkages, provided that their findings are reported in the context of the full value chain upon which interventions carry a wide range of direct and indirect impacts.

Declaration of Competing Interest

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

Data availability

All data discussed are provided within the article.

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Appendix 1. Search results

CAB abstracts

Row	Search string	Results
1	((vegetabl* or fruit* or avocado* or apple* or banana* or berries or blackberr* or cherry or cherries or coconut* or jackfruit or mandarin* or melon* or grape* or plantain* or pineapple* or lemon* or lime* or citrus or grapefruit* or olive* or raspberr* or strawberr* or tomato* or kiwi* or orange* or plum* or pomegranate or peach* or papaya* or pumpkin* or piment* or spinach or lettuce or kale or garlic or sprout* or aubergine* or eggplant* or bean* or broccoli or cabbage* or carrot* or cassava or cauliflower or okra* or onion* or pepper* or potato* or peas or "sweet potato*" or yam or "leafy vegetable*" or "animal produc*" or meat* or diary or milk or egg* or fish* or shrimp or bycatch or "by-catch") adj3 ("food waste*" or "food loss*" or loss* or waste* or wastage or surplus or discard* or break* or bruis* or damage* or "by-product*" or byproduct* or carcas*)).mp.	63,319
2	((animal* or livestock* or poultr* or lamb or goat or mutton or chicken or duck or cattle or beef or goat or pork or swine) adj3 ("food waste*" or "food loss*" or waste or wastes or wastage or surplus or "by-product*" or byproduct*)).mp.	13,652
3	1 or 2	75,025
4	(("food waste*" or "food loss*" or loss* or wastes or waste or wastage or surplus or discard* or break* or bruis* or damage* or "by-product*" or byproduct* or carcas*) adj5 (avoid* or prevent* or reduc* or minimi* or decreas* or polic* or remov* or recycl* or reus* or conver* or digest* or diversion* or divert* or redistribut* or utilis* or utiliz* or valori* or recover*)).mp.	174,348
5	(waste adj2 (manage* or treat* or techn*)).mp.	1273,973
6	("circular econom*" or "circular bioeconom*").mp.	1099
7	4 or 5 or 6	279,047
8	3 and 7	21,071
9	exp postharvest losses/ or exp processing losses/ or exp storage losses/	2974
10	Exp food wastes/ or exp plate waste/ or exp kitchen waste/ or exp leftovers	5502
11	((food adj2 loss*) or (food adj2 waste*)).mp.	8,2801
12	9 or 10 or 11	11,862
13	(vegetabl* or fruit* or banana* or jackfruit or tomato* or orange* or mandarin* or apple* or grape* or plantain* or coconut* or pineapple* or lemon* or lime* or citrus or grapefruit* or olive* or berries or strawberr* or raspberr* or blackberr* or melon* or cherry or cherries or kiwi* or plum* or pomegranate or Peach* or avocado* or papaya* or pumpkin* or onion* or bean* or okra* or peas or pepper* or piment* or spinach or lettuce or kale or garlic or broccoli or sprout* or cauliflower or cabbage* or aubergine* or eggplant* or carrot* or potato* or "sweet potato*" or yam or cassava or "leafy vegetable*" or "animal produc*" or meat* or diary or milk or egg* or fish* or shrimp or bycatch or "by-catch").mp.	2,551,086
14	12 and 13	5102
15	14 or 8	25,217
16	exp developing countries/ or exp africa/ or exp agrarian countries/ or exp caribbean/ or exp central america/ or exp colonies/ or exp latin america/ or exp south america/	2332,232
17	(afghanistan or albania or algeria or american samoa or angola or antigua or barbuda or argentina or armenia or armenian or aruba or azerbaijan or bahrain or bangladesh or barbados or republic of belarus or belarus or byelarus or belorussia or byelorussian or belize or british honduras or benin or dahomey or bhutan or bolivia or bosnia or herzegovina or botswana or bechuanaland or brazil or brasil or burkina faso or burkina fasso or upper volta or burundi or urundi or cabo verde or cape verde or cambodia or kampuchea or khmer republic or cameroon or cameron or cameroun or central african republic or ubangi shari or chad or chile or china or colombia or comoros or comoro islands or iles comores or mayotte or democratic republic of the congo or democratic republic congo or congo or zaire or costa rica or cote divoire or cote d ivoire or ivory coast or croatia or cuba or cyprus or djibouti or french somaliland or dominica or dominican republic or ecuador or egypt or united arab republic or el salvador or equatorial guinea or spanish guinea or eritrea or eswatini or swaziland or ethiopia or fiji or gabon or gabonese republic or gambia or georgian or ghana or gold coast or gibraltar or greece or grenada or guam or guatemala or guinea or guinea bissau or guyana or british guiana or haiti or hispaniola or honduras or hungary or india or indonesia or timor or iran or iraq or isle of man or jamaica or jordan or kazakhstan or kazakh or kenya of north korea or kosovo or kyrgyzstan or kirghizia or kirgizstan or kyrgyz republic or kirghiz or laos or lao or lebanon or lebanese republic or lesotho or basutoland or liberia or libya or libyan arab jamahiriya or lithuania or macau or macao or republic of north macedonia or macedonia or madagascar or malagasy republic or malawi or nyasaland or malaysia or malay federation or malaya federation or maldives or indian ocean or mali or malta or micronesia or federated states of micronesia or kiribati or marshall islands or nauru or northern mariana islands or palau or tuvalu or mauritania or mauritius or mexico or moldova or moldovian or mongolia or montenegro or morocco or ifni or mozambique or portuguese east africa or myanmar or burma or namibia or nepal or netherlands antilles or nicaragua or niger or nigeria or oman or muscat or pakistan or panama or papua new guinea or new guinea or paraguay or peru or philippines or philipines or phillipines or phillippines or puerto rico or romania or russia or russian federation or ussr or soviet union or union of soviet socialist republics or rwanda or ruanda or samoa or pacific islands or polynesia or samoan islands or navigator island or navigator islands or saudi arabia or senegal or serbia or seychelles or sierra leone or melanesia or solomon island or solomon islands or norfolk island or norfolk islands or somalia or south africa or south sudan or sri lanka or ceylon or saint kitts or saint lucia or saint vincent or grenadines or sudan or suriname or surinam or dutch guiana or netherlands guiana or syria or syrian arab republic or tajikistan or tadjikistan or tadzhikistan or tadzhik or tanzania or tanganyika or thailand or siam or timor leste or east timor or togo or togolese republic or tonga or trinidad or tobago or tunisia or turkey or turkmenistan or turkmen	2727,445

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Row	Search string	Results
	or uganda or ukraine or uruguay or uzbekistan or uzbek or vanuatu or new hebrides or venezuela or vietnam or viet nam or middle east or west bank or gaza or palestine or yemen or yugoslavia or zambia or Zimbabwe).mp.	
18	(developing nation* or developing population* or developing world or less developed countr* or less developed nation* or less developed world or lesser developed countr* or lesser developed nation? or lesser developed population? or lesser developed world or under developed countr* or under developed nation? or under developed population? or under developed world or underdeveloped countr* or underdeveloped nation? or underdeveloped population? or underdeveloped world or middle income countr* or middle income nation? or middle income population? or low income countr* or low income nation? or low income population? or lower income countr* or lower income nation? or lower income population? or underserved countr* or underserved nation? or underserved population? or underserved world or under served countr* or under served nation? or under served population? or under served world or deprived countr* or deprived nation? or deprived population? or deprived world or poor countr* or poor nation? or poor population? or poor world or poorer countr* or poorer nation? or poorer population? or poorer world or developing econom* or less developed econom* or lesser developed econom* or under developed econom* or underdeveloped econom* or middle income econom* or low income econom* or lower income econom* or low gdp or low gnp or low gross domestic or low gross national or lower gdp or lower gnp or lower gross domestic or lower gross national or lmic or lmics or third world or lami countr* or transitional countr* or emerging economies or emerging nation).mp.	68,246
19	16 or 17 or 18	2887,086
20	19 and 15	5976
21	limit 20 to yr="2011 -Current"	3119

EconLit

Row	Search string	Result
1	((vegetabl* OR fruit* OR banana* OR jackfruit* OR tomato* OR orange* OR mandarin* OR apple* OR grape* OR plantain* OR coconut* OR pineapple* OR lemon* OR lime* OR citrus OR grapefruit* OR olive* OR berries OR strawberr* OR raspberr* OR blackberr* OR melon* OR cherry OR cherries OR kiwi* OR plum* OR Pomegranate OR Peach* OR avocado* OR papaya* OR pumpkin* OR onion* OR bean* OR okra* OR peas OR pepper* OR piment* OR spinach OR lettuce OR kale OR garlic OR broccoli OR sprout* OR cauliflower OR eggplant* OR aubergine* OR cabbage* OR eggplant* OR aubergine* OR carrot* OR potato* OR "sweet potato*" OR yam OR cassava OR "Leafy vegetable*" OR "animal produc*" OR meat* OR diary OR milk OR egg* OR fish* OR shrimp OR bycatch OR "by-catch") N3("food waste*" OR "food loss*" OR loss* OR wastes OR waste OR wastage OR surplus OR discard* OR break* OR bruis* OR damage* OR "by-product*" OR byproduct*))	3161
2	((animal* or livestock* or poultr* or lamb or goat or mutton or chicken or duck or cattle or beef or goat or pork or swine) N3 ("food waste*" or "food loss*" or waste or wastes or wastage or surplus or "by-product*" or byproduct*)).	2018
3	1 or 2	4832
	(("food waste*" or "food loss*" or loss* or waste or wastes or wastage or surplus or discard* or break* or bruis* or damage* or "by-product*" or byproduct* or carcas*) N5 (avoid* or prevent* or reduc* or minimi* or decreas* or polic* or remov* or recycl* or reus* or conver* or digest* or diversion* or divert* or redistribut* or utilis* or utiliz* or valori* or recover*))	69,974
	(waste N2 (manage* or treat* or techn*))	1231
	("circular econom*" or "circular bioeconom*")	172
4	4 or 5 or 6	70,647
5	3 and 4	810
	("postharvest loss*" OR "processing loss*" OR "storage loss*")	
	("food waste*" OR "plate waste*" OR "kitchen waste*" OR leftovers)	
	((food N2 loss*) or (food N2 waste*))	
6	or	273
7	(vegetabl* OR fruit* OR banana* OR jackfruit* OR tomato* OR orange* OR mandarin* OR apple* OR grape* OR plantain* OR coconut* OR pineapple* OR lemon* OR lime* OR citrus OR grapefruit* OR olive* OR berries OR strawberr* OR raspberr* OR blackberr* OR melon* OR cherry OR cherries OR kiwi* OR plum* OR Pomegranate OR Peach* OR avocado* OR papaya* OR pumpkin* OR onion* OR bean* OR okra* OR peas OR pepper* OR piment* OR spinach OR lettuce OR kale OR garlic OR broccoli OR sprout* OR cauliflower OR eggplant* OR aubergine* OR cabbage* OR eggplant* OR aubergine* OR carrot* OR potato* OR "sweet potato*" OR yam OR cassava OR "Leafy vegetable*" OR "animal produc*" OR meat* OR diary OR milk OR egg* OR fish* OR shrimp OR bycatch OR "by-catch")	41,562
8	6 AND 7	55
9	8 OR 5	849
10	"developing countr*" OR africa OR "agrarian countr*" OR Caribbean OR "central America" or "colonies" or "latin america" OR "south America"	150,513
11	(afghanistan OR albania OR algeria OR "american samoa" OR angola OR "antigua and barbuda" OR antigua OR barbuda OR argentina OR armenia OR armenian OR aruba OR azerbaijan OR bahrain OR bangladesh OR barbados OR "republic of belarus" OR belarus OR byelarus OR belorussia OR byelorussian OR belize OR honduras OR benin OR dahomey OR bhutan OR bolivia OR " OR botswana OR bechuanaland OR brazil OR brasil OR bulgaria OR "burkina faso" OR "burkina fasso" OR "upper volta" OR burundi OR urundi OR "cabo verde" OR "cape verde" OR cambodia OR kampuchea OR "khmer republic" OR cameroon OR cameron OR cameroun OR "central african republic" OR "ubangi shari" OR chad OR chile OR china OR colombia OR comoros OR "comoro islands" OR "iles comores" OR mayotte OR "democratic republic of the congo" OR "democratic republic congo" OR congo OR zaire OR "costa rica" OR "cote d'ivoire" OR "cote d' ivoire" OR "cote divoire" OR "cote d ivoire" OR "ivory coast" OR croatia OR cuba OR djibouti OR "french Somaliland" OR dominica OR "dominican republic" OR ecuador OR egypt OR "united arab republic" OR "el Salvador" OR "equatorial guinea" OR "spanish guinea" OR eritrea OR eswatini OR swaziland OR ethiopia OR fiji OR gabon OR "gabonese republic" OR gambia OR "georgia (republic)" OR georgian OR ghana OR "gold coast" OR gibraltar OR grenada OR guam OR guatemala OR guinea OR "guinea Bissau" OR guyana OR "british Guiana" OR haiti OR hispaniola OR honduras OR india OR indonesia OR timor OR iran OR iraq OR "isle of man" OR jamaica OR jordan OR kazakhstan OR kazakh OR kenya OR "north korea" OR kosovo OR kyrgyzstan OR kirghizia OR kirgizstan OR "kyrgyz republic" OR kirghiz OR laos OR "lao pdr" OR "lao people's democratic republic" OR lebanon OR "lebanese republic" OR lesotho OR basutoland OR liberia OR libya OR "libyan arab Jamahiriya" OR lithuania OR macau OR macao OR "republic of north Macedonia" OR macedonia OR madagascar OR "malagasy republic" OR malawi OR nyasaland OR malaysia OR "malay federation" OR "malaya federation" OR maldives OR "indian ocean islands" OR "indian ocean" OR mali OR micronesia OR "federated states of Micronesia" OR kiribati OR "marshall islands" OR nauru OR "northern mariana islands" OR palau OR tuvalu OR mauritania OR mauritius OR mexico OR moldova OR moldovian OR mongolia OR montenegro OR morocco OR ifni OR mozambique OR "portuguese east Africa" OR myanmar OR burma OR namibia OR nepal OR "netherlands Antilles" OR nicaragua OR niger OR nigeria OR oman OR muscat OR pakistan OR panama OR "papua new guinea" OR "new guinea" OR paraguay OR peru OR philippines OR philipines OR phillipines OR phillippines OR puerto rico OR romania OR russia OR "russian federation" OR ussr OR "soviet union" OR "union of soviet socialist republics" OR rwanda OR ruanda OR samoa OR "pacific islands" OR polynesia OR "samoan islands" OR "navigator island" OR "navigator islands" OR "sao tome and principe" OR "saudi	19,825

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Row	Search string	Result
	arabia" OR senegal OR seychelles OR "sierra leone" OR melanesia OR "solomon island" OR "solomon islands" OR "norfolk island" OR "norfolk islands" OR somalia OR "south Africa" OR "south sudan" OR "sri lanka" OR ceylon OR "saint kitts and nevis" OR "st. kitts and nevis" OR "saint lucia" OR "st. lucia" OR "saint vincent and the grenadines" OR "saint Vincent" OR "st. vincent" OR grenadines OR sudan OR suriname OR surinam OR "dutch Guiana" OR "netherlands Guiana" OR syria OR "syrian arab republic" OR tajikistan OR tadjikistan OR tadzhikistan OR tadzhik OR tanzania OR tanganyika OR thailand OR siam OR "timor leste" OR "east timor" OR togo OR "togolese republic" OR tonga OR "trinidad and tobago" OR trinidad OR tobago OR tunisia OR turkey OR turkmenistan OR turkmen OR uganda OR ukraine OR uruguay OR uzbekistan OR uzbek OR vanuatu OR "new Hebrides" OR venezuela OR vietnam OR "viet nam" OR "middle east" OR "west bank" OR gaza OR palestine OR yemen OR zambia OR zimbabwe OR "northern Rhodesia"	
12	(developing nation* or developing population* or developing world or less developed countr* or less developed nation* or less developed world or lesser developed countr* or lesser developed nation? or lesser developed population? or lesser developed world or under developed countr* or under developed nation? or under developed population? or under developed world or underdeveloped countr* or underdeveloped nation? or underdeveloped population? or underdeveloped world or middle income countr* or middle income nation? or middle income population? or low income countr* or low income nation? or low income population? or lower income countr* or lower income nation? or lower income population? or underserved countr* or underserved nation? or underserved population? or underserved world or under served countr* or under served nation? or under served population? or under served world or deprived countr* or deprived nation? or deprived population? or deprived world or poor countr* or poor nation? or poor population? or poor world or poorer countr* or poorer nation? or poorer population? or poorer world or developing econom* or less developed econom* or lesser developed econom* or under developed econom* or underdeveloped econom* or middle income econom* or low income econom* or lower income econom* or low gdp or low gnp or low gross domestic or low gross national or lower gdp or lower gnp or lower gross domestic or lower gross national or lmic or lmics or third world or lami countr* or transitional countr* or emerging economies or emerging nation)	
13	10 OR 11 OR 12	187,293
14	13 AND 9	185
	Publications after 1.1.2011	110

Web of Science

Row	Search string	Result
1	TS=((vegetabl* or fruit* or banana* or jackfruit or tomato* or orange* or mandarin* or apple* or grape* or plantain* or coconut* or pineapple* or lemon* or lime* or citrus or grapefruit* or olive* or berries or strawberr* or raspberr* or blackberr* or melon* or cherry or cherries or kiwi* or plum* or pomegranate or Peach* or avocado* or papaya* or pumpkin* or onion* or bean* or okra* or peas or pepper* or piment* or spinach or lettuce or kale or garlic or broccoli or sprout* or cauliflower or cabbage* or aubergine* or eggplant* or carrot* or potato* or "sweet potato*" or yam or cassava or "leafy vegetable*" or "animal produc*" or meat* or diary or milk or egg* or fish* or shrimp or bycatch or "by-catch") NEAR/3("food waste*" or "food loss*" or loss* or waste* or wastage or surplus or discard* or break* or bruis* or damage* or "by-product*" or byproduct* or carcas*))	56,569
2	TS=((animal* or livestock* or poultr* or lamb or goat or mutton or chicken or duck or cattle or beef or goat or pork or swine) NEAR/3("food waste*" or "food loss*" or waste or wastes or wastage or surplus or "by-product*" or byproduct*)).	10,071
3	1 OR 2	63,395
4	TS=(("food waste*" OR "food loss*" OR loss* OR wastes OR waste OR wastage OR surplus OR discard* OR break* OR bruis* OR damage* OR "by-product*" OR byproduct* OR carcas*) NEAR/5(avoid* OR prevent* OR reduc* OR minimi* OR decreas* OR polic* OR remov* OR recycl* OR reus* OR conver* OR digest* OR diversion* OR divert* OR redistribut* OR utilis* OR utiliz* OR valori* OR recover*))	493,9337
5	TS=(waste NEAR/2 (manage* OR treat* OR techn*))	69,289
6	TS=("circular econom*" OR "circular bioeconom*")	7032
7	4 OR 5 OR 6	550,728
8	3 AND 4	3429
9	TS=("postharvest loss*" OR "processing loss*" OR "storage loss*")	1582
10	TS=("food waste*" OR "plate waste*" OR "kitchen waste*" OR leftovers)	12,824
11	TS=((food NEAR/2 loss*) or (food NEAR/2 waste*))	13,661
12	9 or 10 or 11	18,633
13	TS=(vegetabl* OR fruit* OR banana* OR jackfruit* OR tomato* OR orange* OR mandarin* OR apple* OR grape* OR plantain* OR coconut* OR pineapple* OR lemon* OR lime* OR citrus OR grapefruit* OR olive* OR berries OR strawberr* OR raspberr* OR blackberr* OR melon* OR cherry OR cherries OR kiwi* OR plum* OR Pomegranate OR Peach* OR avocado* OR papaya* OR pumpkin* OR onion* OR bean* OR okra* OR peas OR pepper* OR piment* OR spinach OR lettuce OR kale OR garlic OR broccoli OR sprout* OR cauliflower OR eggplant* OR aubergine* OR cabbage* OR eggplant* OR aubergine* OR carrot* OR potato* OR "sweet potato*" OR yam OR cassava OR "Leafy vegetable*" OR "animal produc*" OR meat* OR diary OR milk OR egg* OR fish* OR shrimp OR bycatch OR "by-catch")	2405,197
14	13 and 12	5117
15	14 or 8	8418
16	TS=("developing countr*" OR africa OR "agrarian countr*" OR Caribbean OR "central America" or "colonies" or "latin america" OR "south America")	652,395
	TS=(afghanistan OR albania OR algeria OR "american samoa" OR angola OR "antigua and barbuda" OR antigua OR barbuda OR argentina OR armenia OR armenian OR aruba OR azerbaijan OR bahrain OR bangladesh OR barbados OR "republic of belarus" OR belarus OR byelarus OR belorussia OR byelorussian OR belize OR honduras OR benin OR dahomey OR bhutan OR bolivia OR botswana OR bechuanaland OR brazil OR brasil OR bulgaria OR "burkina faso" OR "burkina fasso" OR "upper volta" OR burundi OR urundi OR "cabo verde" OR "cape verde" OR cambodia OR kampuchea OR "khmer republic" OR cameroon OR cameron OR cameroun OR "central african republic" OR "ubangi shari" OR chad OR chile OR china OR colombia OR comoros OR "comoro islands" OR "iles comores" OR mayotte OR "democratic republic of the congo" OR "democratic republic congo" OR congo OR zaire OR "costa rica" OR "cote divoire" OR "cote d ivoire" OR "cote divoire" OR "cote d ivoire" OR "ivory coast" OR croatia OR cuba OR djibouti OR "french Somaliland" OR dominica OR "dominican republic" OR ecuador OR egypt OR "united arab republic" OR "el Salvador" OR "equatorial guinea" OR "spanish guinea" OR eritrea OR eswatini OR swaziland OR ethiopia OR fiji OR gabon OR "gabonese republic" OR gambia OR "georgia (republic)" OR georgian OR ghana OR "gold coast" OR gibraltar OR grenada OR guam OR guatemala OR guinea OR "guinea Bissau" OR guyana OR "british Guiana" OR haiti OR hispaniola OR honduras OR india OR indonesia OR timor OR iran OR iraq OR "isle of man" OR jamaica OR jordan OR kazakhstan OR kazakh OR kenya OR "north korea" OR kosovo OR kyrgyzstan OR kirghizia OR kirgizstan OR "kyrgyz republic" OR kirghiz OR laos OR "lao pdr" OR "lao people's democratic republic" OR lebanon OR "lebanese republic" OR lesotho OR basutoland OR liberia OR libya OR "libyan arab Jamahiriya" OR lithuania OR macau OR macao OR "republic of north Macedonia" OR macedonia OR madagascar OR "malagasy republic" OR malawi OR nyasaland OR malaysia OR "malay federation" OR "malaya federation" OR maldives OR "indian ocean islands" OR "indian ocean" OR mali OR micronesia OR "federated states of Micronesia" OR kiribati OR "marshall islands" OR nauru OR "northern mariana islands" OR palau OR tuvalu OR mauritania OR mauritius OR mexico OR moldova OR moldovian OR mongolia OR montenegro OR morocco OR ifni OR mozambique OR "portuguese east Africa" OR myanmar OR burma OR	3333,319

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Row	Search string	Result
	namibia OR nepal OR "netherlands Antilles" OR nicaragua OR niger OR nigeria OR oman OR muscat OR pakistan OR panama OR "papua new guinea" OR "new guinea" OR paraguay OR peru OR philippines OR philipines OR phillipines OR phillippines OR puerto rico OR romania OR russia OR "russian federation" OR ussr OR "soviet union" OR "union of soviet socialist republics" OR rwanda OR ruanda OR samoa OR "pacific islands" OR polynesia OR "samoan islands" OR "navigator island" OR "navigator islands" OR "sao tome and principe" OR "saudi arabia" OR senegal OR seychelles OR "sierra leone" OR melanesia OR "solomon island" OR "solomon islands" OR "norfolk island" OR "norfolk islands" OR somalia OR "south Africa" OR "south sudan" OR "sri lanka" OR ceylon OR "saint kitts and nevis" OR "st. kitts and nevis" OR "saint lucia" OR "st. lucia" OR "saint vincent and the grenadines" OR "saint Vincent" OR "st. vincent" OR grenadines OR sudan OR suriname OR surinam OR "dutch Guiana" OR "netherlands Guiana" OR syria OR "syrian arab republic" OR tajikistan OR tadjikistan OR tadzhikistan OR tadzhik OR tanzania OR tanganyika OR thailand OR siam OR "timor leste" OR "east timor" OR togo OR "togolese republic" OR tonga OR "trinidad and tobago" OR trinidad OR tobago OR tunisia OR turkey OR turkmenistan OR turkmen OR uganda OR ukraine OR uruguay OR uzbekistan OR uzbek OR vanuatu OR "new Hebrides" OR venezuela OR vietnam OR "viet nam" OR "middle east" OR "west bank" OR gaza OR palestine OR yemen OR zambia OR zimbabwe OR "northern Rhodesia")	
	TS=("developing nation?" OR "developing population?" OR "developing world" OR "less developed countr*" OR "less developed nation?" OR "less developed population?" OR "less developed world" OR "lesser developed countr*" OR "lesser developed nation?" OR "lesser developed population?" OR "lesser developed world" OR "under developed countr*" OR "under developed nation?" OR "under developed population?" OR "under developed world" OR "underdeveloped countr*" OR "underdeveloped nation?" OR "underdeveloped population?" OR "underdeveloped world" OR "middle income countr*" OR "middle income nation?" OR "middle income population?" OR "low income countr*" OR "low income nation?" OR "low income population?" OR "lower income countr*" OR "lower income nation?" OR "lower income population?" OR "underserved countr*" OR "underserved nation?" OR "underserved population?" OR "underserved world" OR "under served countr*" OR "under served nation?" OR "under served population?" OR "under served world" OR "deprived countr*" OR "deprived nation?" OR "deprived population?" OR "deprived world" OR "poor countr*" OR "poor nation?" OR "poor population?" OR "poor world" OR "poorer countr*" OR "poorer nation?" OR "poorer population?" OR "poorer world" OR "developing econom*" OR "less developed econom*" OR "lesser developed econom*" OR "under developed econom*" OR "underdeveloped econom*" OR "middle income econom*" OR "low income econom*" OR "lower income econom*" OR "low gdp" OR "low gnp" OR "low gross domestic" OR "low gross national" OR "lower gdp" OR "lower gnp" OR "lower gross domestic" OR "lower gross national" OR lmic OR lmics OR "third world" OR "lami countr*" OR "transitional countr*" OR "emerging economie" OR "emerging nation?")	83,616
19	18 or 17 or 16	3681,066
20	19 and 15	1359
21	D #15	1088
	Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2011–2020	

Scopus

Row	Search string	Result
1	TITLE-ABS-KEY((vegetabl* or fruit* or banana* or jackfruit or tomato* or orange* or mandarin* or apple* or grape* or plantain* or coconut* or pineapple* or lemon* or lime* or citrus or grapefruit* or olive* or berries or strawberr* or raspberr* or blackberr* or melon* or cherry or cherries or kiwi* or plum* or pomegranate or Peach* or avocado* or papaya* or pumpkin* or onion* or bean* or okra* or peas or pepper* or piment* or spinach or lettuce or kale or garlic or broccoli or sprout* or cauliflower or cabbage* or aubergine* or eggplant* or carrot* or potato* or "sweet potato*" or yam or cassava or "leafy vegetable*" or "animal produc*" or meat* or diary or milk or egg* or fish* or shrimp or bycatch or "by-catch") W/3("food waste*" or "food loss*" or loss* or waste* or wastage or surplus or discard* or break* or bruis* or damage* or "by-product*" or byproduct* or carcas*))	68,496
2	TITLE-ABS-KEY ((animal* OR livestock* OR poultr* OR lamb OR goat OR chicken OR cattle OR beef OR goat OR pork OR swine) W/3("food waste*" OR "food loss*" OR loss* OR waste* OR wastage OR surplus OR "by-product*" OR byproduct *))	12,086
3	#1 OR #2	79,054
4	TITLE-ABS-KEY (("food waste*" OR "food loss*" OR wastes OR waste OR wastage OR surplus OR discard* OR break* OR bruis* OR damage* OR "by-product*" OR byproduct* OR carcas*) W/5(avoid* OR prevent* OR reduc* OR minimi* OR decreas* OR polic* OR remov* OR recycl* OR reus* OR conver* OR digest* OR diversion* OR divert* OR redistribut* OR utilis* OR utiliz* OR valori* OR recover*))	742,929
5	TITLE-ABS-KEY (waste W/2 (manage* OR treat* OR techn*))	202,973
6	TITLE-ABS-KEY ("circular econom*" OR "circular bioeconom*")	8533
7	#4 OR #5 OR #6	899,283
8	#3 AND #7	22,657
9	TITLE-ABS-KEY("postharvest loss*" OR "processing loss*" OR "storage loss*")	2148
10	TITLE-ABS-KEY ("food waste*" OR "plate waste*" OR "kitchen waste*" OR leftovers)	14,447
11	TITLE-ABS-KEY((food W/2 loss*) or (food W/2 waste*))	16,155
12	#9 OR #10 OR #11	22,755
13	TITLE-ABS-KEY (vegetabl* OR fruit* OR banana* OR jackfruit* OR tomato* OR orange* OR mandarin* OR apple* OR grape* OR plantain* OR coconut* OR pineapple* OR lemon* OR lime* OR citrus OR grapefruit* OR olive* OR berries OR strawberr* OR raspberr* OR blackberr* OR melon* OR cherry OR cherries OR kiwi* OR plum* OR pomegranate OR peach* OR avocado* OR papaya* OR pumpkin* OR onion* OR bean* OR okra* OR peas OR pepper* OR piment* OR spinach OR lettuce OR kale OR garlic OR broccoli OR sprout* OR cauliflower OR eggplant* OR aubergine* OR cabbage* OR eggplant* OR aubergine* OR carrot* OR potato* OR "sweet potato*" OR yam OR cassava OR "Leafy vegetable*" OR "animal produc*" OR meat* OR diary OR milk OR egg* OR fish* OR shrimp OR bycatch OR "by-catch")	2852,501
14	#12 AND #13	6210
15	#14 OR #8	27,392
16	ALL("developing countr*" OR africa OR "agrarian countr*" OR Caribbean OR "central America" or "colonies" or "latin america" OR "south America")	3616,732
17	ALL (afghanistan OR albania OR algeria OR "american samoa" OR angola OR "antigua and barbuda" OR antigua OR barbuda OR argentina OR armenia OR armenian OR aruba OR azerbaijan OR bahrain OR bangladesh OR barbados OR "republic of belarus" OR belarus OR byelarus OR belorussia OR byelorussian OR belize OR honduras OR benin OR dahomey OR bhutan OR bolivia OR botswana OR bechuanaland OR brazil OR brasil OR bulgaria OR "burkina faso" OR "burkina fasso" OR "upper volta" OR burundi OR urundi OR "cabo verde" OR "cape verde" OR cambodia OR kampuchea OR "khmer republic" OR cameroon OR cameron OR cameroun OR "central african republic" OR "ubangi shari" OR chad OR chile OR china OR colombia OR comoros OR "comoro islands" OR "iles comores" OR mayotte OR "democratic republic of the congo" OR "democratic republic congo" OR congo OR zaire OR "costa rica" OR "cote divoire" OR "cote d ivoire" OR "cote divoire" OR "cote d ivoire" OR "ivory coast" OR croatia OR cuba OR djibouti OR "french Somaliland" OR dominica OR "dominican republic" OR ecuador OR egypt OR "united arab republic" OR "el Salvador" OR "equatorial guinea" OR "spanish guinea" OR eritrea OR eswatini OR swaziland OR ethiopia OR fiji OR gabon OR "gabonese republic" OR gambia OR "georgia (republic)" OR georgian OR ghana OR "gold coast" OR gibraltar OR grenada OR guam OR guatemala OR guinea OR "guinea Bissau" OR guyana OR "british Guiana" OR haiti OR hispaniola OR honduras OR india OR indonesia OR timor OR iran OR iraq OR "isle of man" OR jamaica OR jordan OR kazakhstan OR kazakh	3422,926

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Row	Search string	Result
	OR kenya OR "north korea" OR kosovo OR kyrgyzstan OR kirghizia OR kirgizstan OR "kyrgyz republic" OR kirghiz OR laos OR "lao pdr" OR "lao people's democratic republic" OR lebanon OR "lebanese republic" OR lesotho OR basutoland OR liberia OR libya OR "libyan arab Jamahiriya" OR lithuania OR macau OR macao OR "republic of north Macedonia" OR macedonia OR madagascar OR "malagasy republic" OR malawi OR nyasaland OR malaysia OR "malay federation" OR "malaya federation" OR maldives OR "indian ocean islands" OR "indian ocean" OR mali OR micronesia OR "federated states of Micronesia" OR kiribati OR "marshall islands" OR nauru OR "northern mariana islands" OR palau OR tuvalu OR mauritania OR mauritius OR mexico OR moldova OR moldovian OR mongolia OR montenegro OR morocco OR ifni OR mozambique OR "portuguese east Africa" OR myanmar OR burma OR namibia OR nepal OR "netherlands Antilles" OR nicaragua OR niger OR nigeria OR oman OR muscat OR pakistan OR panama OR "papua new guinea" OR "new guinea" OR paraguay OR peru OR philippines OR philipines OR phillipines OR phillippines OR puerto AND rico OR romania OR russia OR "russian federation" OR ussr OR "soviet union" OR "union of soviet socialist republics" OR rwanda OR ruanda OR samoa OR "pacific islands" OR polynesia OR "samoan islands" OR "navigator island" OR "navigator islands" OR "sao tome and principe" OR "saudi arabia" OR senegal OR seychelles OR "sierra leone" OR melanesia OR "solomon island" OR "solomon islands" OR "norfolk island" OR "norfolk islands" OR somalia OR "south Africa" OR "south sudan" OR "sri lanka" OR ceylon OR "saint kitts and nevis" OR "st. kitts and nevis" OR "saint lucia" OR "st. lucia" OR "saint vincent and the grenadines" OR "saint Vincent" OR "st. vincent" OR grenadines OR sudan OR suriname OR surinam OR "dutch Guiana" OR "netherlands Guiana" OR syria OR "syrian arab republic" OR tajikistan OR tadjikistan OR tadzhikistan OR tadzhik OR tanzania OR tanganyika OR thailand OR siam OR "timor leste" OR "east timor" OR togo OR "togolese republic" OR tonga OR "trinidad and tobago" OR trinidad OR tobago OR tunisia OR turkey OR turkmenistan OR turkmen OR uganda OR ukraine OR uruguay OR uzbekistan OR uzbek OR vanuatu OR "new Hebrides" OR venezuela OR vietnam OR "viet nam" OR "middle east" OR "west bank" OR gaza OR palestine OR yemen OR zambia OR zimbabwe OR "northern Rhodesia")	
18	ALL("developing nation?" OR "developing population?" OR "developing world" OR "less developed countr*" OR "less developed nation?" OR "less developed population?" OR "less developed world" OR "lesser developed countr*" OR "lesser developed nation?" OR "lesser developed population?" OR "lesser developed world" OR "under developed countr*" OR "under developed nation?" OR "under developed population?" OR "under developed world" OR "underdeveloped countr*" OR "underdeveloped nation?" OR "underdeveloped population?" OR "underdeveloped world" OR "middle income countr*" OR "middle income nation?" OR "middle income population?" OR "low income countr*" OR "low income nation?" OR "low income population?" OR "lower income countr*" OR "lower income nation?" OR "lower income population?" OR "underserved countr*" OR "underserved nation?" OR "underserved population?" OR "underserved world" OR "under served countr*" OR "under served nation?" OR "under served population?" OR "under served world" OR "deprived countr*" OR "deprived nation?" OR "deprived population?" OR "deprived world" OR "poor countr*" OR "poor nation?" OR "poor population?" OR "poor world" OR "poorer countr*" OR "poorer nation?" OR "poorer population?" OR "poorer world" OR "developing econom*" OR "less developed econom*" OR "lesser developed econom*" OR "under developed econom*" OR "underdeveloped econom*" OR "middle income econom*" OR "low income econom*" OR "lower income econom*" OR "low gdp" OR "low gnp" OR "low gross domestic" OR "low gross national" OR "lower gdp" OR "lower gnp" OR "lower gross domestic" OR "lower gross national" OR lmic OR lmics OR "third world" OR "lami countr*" OR "transitional countr*" OR "emerging economie" OR "emerging nation?")	521,463
19	#16 OR #17 OR #18	6006,253
20	#19 AND #15	5599
21	PUBYR AFT 2010	3770

Appendix 2. Quality appraisal

The quality of each study was evaluated against the following criteria, where the possible outcomes were "1″ (yes), "0″ (no), and "NA" (not applicable). The total score represents the number of "1″ across the 11 questions.

1. Is there a clear description of the food commodity of interest?
2. Is the choice of study area clearly justified?
3. Does the intervention directly target and involve local value chain actors?
4. Were human participants or food commodities randomly assigned to the interventions and comparison arms or were adequate methods used to minimize bias (i.e. propensity score matching, difference-in-differences)?
5. Are the intervention design and implementation methods clearly described?
6. Was the intervention compared to an appropriate and comparable intervention or control situation (i.e. different treatments, control group, pre-post testing)?
7. Were baseline characteristics of the commodity clearly described and are they similar across intervention groups?
8. Are the outcome assessments methods and measures clearly justified?
9. Were the effects of the intervention reported comprehensively?
10. Are sufficient data presented to support the findings, including the precision of the estimate?
11. Does the study consider unintended consequences, availability of inputs required, upkeep or sustainability?

	Author	Year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q 8	Q9	Q10	Q11	Total score
1	Abdallah et al.	2019	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	Adekunle	2011	0	1	1	1	0	1	0	0	1	0	1	6
3	Akande et al.	2018	1	0	0	1	0	1	NA	1	1	0	1	6
4	Ali et al.	2020	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	Alkaya et al.	2016	1	1	0	1	1	1	1	1	0	0	1	8
6	Alvarez et al.	2016	1	1	0	1	1	1	1	1	0	0	1	8
7	Amagloh et al.	2018	1	1	0	1	0	1	1	0	1	1	0	7
8	Amin et al.	2020	1	0	0	1	1	1	1	1	1	1	0	8
9	Anriquez et al.	2020	0	1	NA	1	1	1	1	0	1	1	1	8
10	Ansary et al.	2015	1	1	0	1	1	1	1	0	1	1	0	8
11	Asses et al.	2019	1	0	0	0	1	1	NA	1	0	0	0	4
12	Babu et al.	2017	1	NA	0	1	1	1	0	1	0	0	1	6
13	Bayogan et al.	2018	1	0	0	1	1	0	1	0	0	1	0	5

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	Author	Year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q 8	Q9	Q10	Q11	Total score
14	Bihon et al.	2020	1	0	0	1	0	1	0	1	0	0	1	5
15	Bishop et al.	2012	1	0	NA	1	0	1	1	NA	0	0	0	4
16	Bonicet et al.	2012	1	0	1	1	1	1	1	0	1	0	0	7
17	Brahma et al.	2016	1	1	0	1	1	1	1	1	0	0	1	8
18	Buntong et al.	2013	1	1	NA	1	1	1	1	NA	0	1	0	7
19	Carella et al.	2021	1	0	0	1	1	0	NA	0	NA	NA	1	4
20	Chauhan et al.	2013	0	NA	0	0	1	1	1	0	1	1	0	5
21	Cherono	2020	1	NA	0	1	1	1	1	1	0	1	0	7
22	Claur et al. .	2019	1	0	0	0	1	1	NA	0	1	1	0	5
23	Cruz et al.	2019	1	1	1	1	1	1	1	1	0	1	1	10
24	Dari et al.	2018	0	1	1	0	0	0	1	1	0	0	0	4
25	Eighani et al.	2019	1	NA	0	1	1	1	1	NA	1	1	0	7
26	Endalew	2014	1	NA	1	1	1	1	1	NA	0	1	1	8
27	Flores et al.	2017	0	1	0	1	1	1	1	1	0	0	NA	6
28	Fuller-Wimbush et al.	2014	1	1	0	1	0	1	1	0	0	1	1	7
29	Gautam et al.	2017	1	0	NA	1	1	NA	NA	0	NA	NA	0	3
30	Gautam et al.	2017	1	NA	0	0	1	1	1	0	0	1	0	5
31	Glivin et al.	2016	1	1	0	1	1	1	0	1	0	0	0	6
32	Grasso	2014	1	NA	1	1	0	0	1	1	0	0	0	5
33	Gromko et al.	2019	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
34	Haass et al.	2015	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
35	Hossain et al.	2016	1	0	0	1	1	1	0	NA	0	1	0	5
36	Jimenez-Antillon et al.	2018	1	1	0	1	1	1	1	0	1	0	0	7
37	Jolayemi et al.	2018	1	NA	1	1	1	1	1	NA	1	0	0	7
38	Kamrath et al.	2016	1	1	0	1	1	1	1	1	0	0	1	8
39	Karuppasamy et al.	2016	1	0	0	1	1	0	1	0	0	0	0	4
40	Kinyanjui et al.	2013	0	1	0	1	0	1	NA	0	1	NA	1	5
41	Korir et al.	2017	1	0	0	0	1	1	1	1	1	1	0	7
42	Kuo et al.	2016	1	1	0	0	1	1	1	0	0	1	1	7
43	Kuyu et al.	2019	1	1	0	1	1	1	0	1	1	1	0	8
44	Lalander et al.	2015	0	NA	0	1	1	1	0	0	0	1	1	5
45	Lim et al.	2019	1	0	0	1	1	1	1	0	0	1	1	7
46	Lofthouse et al.	2020	0	1	0	1	1	1	1	0	0	0	1	6
47	Ma'arif et al.	2019	1	0	0	1	1	1	1	1	0	Na	1	7
48	Maalekuu et al.	2014	1	1	0	1	0	0	1	1	0	1	0	6
49	Mai et al.	2016	1	0	0	0	1	0	0	1	0	0	0	3
50	Mani et al.	2011	0	1	0	1	0	1	0	0	0	0	0	3
51	Marendra et al.	2020	0	0	0	1	1	1	0	0	0	0	0	3
52	Masebinu et al.	2018	0	NA	1	1	1	1	1	1	0	0	1	7
53	Mehta et al.	2014	1	0	0	0	1	1	1	1	0	1	0	6
54	Mikhail et al.	2014	1	0	0	0	1	0	1	1	0	0	0	4
55	Milani et al.	2020	0	0	0	1	0	0	1	0	1	1	0	4
56	Msogoya et al.	2011	1	0	NA	0	1	0	1	0	1	1	0	5
57	Muñoz et al.	2020	1	0	0	0	1	1	1	1	1	1	0	7
58	Mwatawala	2018	1	0	NA	0	0	1	1	0	0	1	0	4
59	Nenguwo et al.	2017	1	NA	1	1	1	0	1	NA	0	1	0	6
60	Nkolisa et al.	2018	1	1	1	1	1	1	1	1	1	1	1	11
61	Nuevo et al.	2018	1	1	0	1	1	0	1	0	0	1	0	6
62	Obeng et al.	2020	1	0	1	1	1	1	1	0	1	0	1	8
63	Olatilewa et al.	2017	1	0	1	1	1	1	1	1	0	1	0	8
64	Palaniswamy et al.	2016	0	1	1	1	1	1	1	1	0	0	1	8
65	Philip et al.	2017	0	1	1	1	0	1	1	0	0	0	1	6
66	Plaisier et al.	2019	1	1	0	1	1	0	0	1	0	0	1	6
67	Putra et al.	2017	1	0	0	0	1	0	1	1	0	0	0	4
68	Rahman et al.	2018	1	0	0	0	1	1	1	0	1	1	1	7
69	Rahman et al.	2020	1	0	1	1	1	0	1	1	0	0	0	6
70	Rasheed et al.	2016	0	1	0	1	1	1	1	0	0	0	1	6
71	Rosenthal, I. (1)	2019	0	1	NA	1	0	NA	NA	0	NA	NA	0	2
72	Rosenthal, I. (2)	2019	0	1	NA	1	0	0	NA	0	0	0	0	2
73	Sarkar et al.	2013	0	1	1	1	0	1	1	0	0	0	1	6
74	Shah	2015	1	0	0	1	1	1	1	1	1	1	0	8
75	Shailza et al.	2020	0	1	0	1	0	0	0	NA	0	0	0	2
76	Sharma et al.	2017	1	0	0	1	1	1	1	0	0	0	0	5
77	Sibomana et al.	2019	1	1	0	1	1	1	1	1	0	0	1	8
78	Srinivasappa et al.	2015	0	1	NA	1	0	1	1	1	0	0	1	6
79	Tarabay et al.	2018	1	0	0	0	1	1	1	0	1	1	0	6
80	Tugiyono et al.	2020	0	0	0	1	0	0	1	1	0	0	0	3
81	Venugopal et al.	2017	0	0	NA	1	1	1	1	1	0	1	0	6
82	Verploegen et al.	2019	1	1	0	1	1	0	1	0	0	0	1	6
83	Weber et al.	2020	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
84	Wen et al.	2016	1	1	0	1	1	1	0	1	0	0	1	7
85	Wijewardhane et al.	2020	1	1	1	0	1	1	1	0	0	1	0	7
86	Woldemariam et al.	2014	0	0	NA	0	1	1	1	1	1	1	0	6
87	Yalch et al.	2017	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
88	Zohaib et al.	2019	1	0	0	1	1	1	1	0	1	1	0	7

References

Abdallah, M., et al., 2019. Waste to energy potential in middle income countries of MENA region based on multi-scenario analysis for Kafr El-Sheikh Governorate, Egypt. J. Environ. Manage. 232, 58–65.

Adekunle, I.M., Adekunle, A.A., Akintokun, A.K., Akintokun, P.O., Arowolo, T.A., 2011. Recycling of organic wastes through composting for land applications: a Nigerian experience. Waste Manag. Res. 29, 582–593.

Adhikari, B.K., Barrington, S., Martinez, J., 2006. Predicted growth of world urban food waste and methane production. Waste Manag. Res. 24, 421–433.

Affognon, H., Mutungi, C., Sanginga, P., Borgemeister, C., 2015. Unpacking postharvest losses in Sub-Saharan Africa: a meta-analysis. World Dev. 66, 49–68.

Ahmed, S., et al., 2021. Systematic review on effects of bioenergy from edible versus inedible feedstocks on food security. npj Sci.Food 5, 9.

Akande, O.M., Olorunnisola, A.O., 2018. Potential of briquetting as a waste-management option for handling market-generated vegetable waste in Port Harcourt, Nigeria. Recycling 3, 11.

Alexander, P., et al., 2017. Losses, inefficiencies and waste in the global food system. Agric. Syst. 153, 190–200.

Ali, M.M., et al., 2020. Mapping of biogas production potential from livestock manures and slaughterhouse waste: a case study for African countries. J. Clean. Prod. 256, 120499.

Alkaya, E., Demirer, G.N., 2016. Minimizing and adding value to seafood processing wastes. Food Bioprod. Process. 100, 195–202.

Alvarez, R.E.A., et al., 2016. Technical and economic feasibility of a solar-bio-powered waste utilization and treatment system in Central America. J. Environ. Manage. 184, 371–379.

Amagloh, F.K., et al., 2018. Packaging containers for long-distance transport of sweetpotato [Ipomoea batatas (L) Lam] storage roots in Ghana. Open Agric. 3, 596–608.

Amin, Md.N., et al., 2020. Use of non-chlorine sanitizer and low-cost packages enhancing microbial safety and quality of commercial cold-stored carrots. J. Food Process. Preserv. 45, e15065.

Anriquez, G., Foster, W., Ortega, J., Rocha, J.S., 2020. In search of economically significant food losses: evidence from Tunisia and Egypt. Food Policy 98, 101912.

Ansary, S.H., Mudi, N., Chowdhury, A.K., Gayen, N., Barui, K., 2015. Comparative studies of different pre harvest practices and economic analysis of different low cost storage structures for reduction of storage losses of onion (Allium cepa L.) in West Bengal condition. Int. J. Tropic. Agric. 33, 333–337.

Asses, N., Farhat, W., Hamdi, M., Bouallagui, H., 2019. Large scale composting of poultry slaughterhouse processing waste: microbial removal and agricultural biofertilizer application. Process Saf. Environ. Prot. 124, 128–136.

Babu, G.R., Kumar, G.M., 2017. An eco friendly solution to the food waste disposal. AIP Conf. Proc. 1859, 020068.

Barrera, E.L., Hertel, T., 2021. Global food waste across the income spectrum: implications for food prices, production and resource use. Food Policy 98, 101874.

Bilali, H.E., Hassen, T.B., 2020. Food Waste in the Countries of the Gulf Cooperation Council: a Systematic Review. Foods 9, 463.

Bilska, B., Wrzosek, M., Kołożyn-Krajewska, D., Krajewski, K., 2016. Risk of food losses and potential of food recovery for social purposes. Waste Manage. (Oxford) 52, 269–277.

Bonicet, A.J., Sargent, S.A., Teixeira, A., 2012. Adoption of plastic field crates to reduce mechanical injuries in postharvest handling of Haitian mango. Proceedings of the Florida State Horticultural Society 125, 260–263.

Brahma, A., Saikia, K., Hiloidhari, M., Baruah, D.C., 2016. GIS based planning of a biomethanation power plant in Assam, India. Renew. Sustain. Energy Rev. 62, 596–608.

Buntong, B., Srilaong, V., Wasusri, T., Kanlayanarat, S., Acedo, A.L., 2013. Reducing postharvest losses of tomato in traditional and modern supply chains in Cambodia. Int. Food Res. J. 20, 233–238.

Carella, F., et al., 2021. Thermal conversion of fish bones into fertilizers and biostimulants for plant growth – a low tech valorization process for the development of circular economy in least developed countries. J. Environ. Chem. Eng. 9, 104815.

CASP, 2019. CASP Randomised Controlled Trials Standard Checklist. Critical Appraisal Skills Programme.

Cattaneo, A., Sánchez, M.V., Torero, M., Vos, R., 2021. Reducing food loss and waste: five challenges for policy and research. Food Policy 98, 101974.

Chaboud, G., 2017. Assessing food losses and waste with a methodological framework: insights from a case study. Resour. Conserv. Recycl. 125, 188–197.

Chaboud, G., Daviron, B., 2017. Food losses and waste: navigating the inconsistencies. Glob. Food Sec. 12, 1–7.

Cherono, K., Workneh, T.S., 2020. Effect of packing units during long distance transportation on the quality and shelf-life of tomatoes under commercial supply conditions. Acta Hortic. 1292, 165–173.

Cooper, G.S., et al., 2021. Identifying 'win-win-win' futures from inequitable value chain trade-offs: a system dynamics approach. Agric. Syst. 190, 103096.

Craig, P., et al., 2013. Developing and evaluating complex interventions: the new Medical Research Council guidance. Int. J. Nurs. Stud. 50, 587–592.

Crippa, M., et al., 2021. Food systems are responsible for a third of global anthropogenic GHG emissions. Nat. Food 2, 198–209.

Cruz, R.S.M.D., Flores, E.D., Galapon, M.A.F, 2019. Adaptation of high-temperature storage for multiplier bulb sets under Philippine condition. Agric. Eng. Int. CIGR J. 21, 177–183.

Dari, L., Nenguwo, N., Afari-Sefa, V., 2018. Evaluation of packaging liners in wooden and plastic crates for handling tomatoes. J. Postharvest Technol. 6, 36–40.

Dora, M., Biswas, S., Choudhary, S., Nayak, R., Irani, Z., 2021. A system-wide interdisciplinary conceptual framework for food loss and waste mitigation strategies in the supply chain. Ind. Market. Manag. 93, 492–508.

Eighani, M., Paighambari, S.Y., 2019. Performance of bycatch reduction devices in the small-scale shrimp trawl fishery of the Persian Gulf. Thalassas: An Int. J. Marine Sci. 35, 229–238.

Endalew, W., Getahun, A., Demissew, A., Ambaye, T., 2014. Storage performance of naturally ventilated structure for onion bulbs. Agric. Eng. Int. CIGR J. 16, 97–101.

European Parliament, 2008. Directive 2008/98/EC Of The European Parliament And Of The Council. European Parliament.

Ewijk, S.V., Stegemann, J.A., 2016. Limitations of the waste hierarchy for achieving absolute reductions in material throughput. J. Clean. Prod. 132, 122–128.

FAO, 2011. Global Food Losses and Food Waste: Extent, causes and prevention. Food and Agricultural Organization.

FAO, 2019. The State of Food and Agriculture 2019: Moving forward on food loss and waste reduction. Food and Agricultural Organization.

FAO, 2022. Sustainable Development Goal: Indicator 12.3.1 Global food losses. Food and Agricultural Organization.

Flores, E.D., Cruz, R.S.M.D, 2017. Value chain improvement of fresh sweet potato through the utilization of mechanical harvester. Agric. Eng. Int. CIGR J. 19, 159–169.

Fuller-Wimbush, D., Adebayo, K., 2014. Lessons of endogenous leadership in Nigeria: innovating to reduce waste and raise incomes in the cassava processing and goat-keeping systems. Dev. Pract. 24, 693–698.

Gautam, D.M., et al., 2017. Effectiveness of non-chlorine sanitizers in enhancing quality and shelf life of tomato in Bangladesh, Cambodia and Nepal. Acta Hortic. 1179, 149–156.

Glivin, G., Sekhar, S.J., 2016. Experimental and analytical studies on the utilization of biowastes available in an educational institution in India. Sustainability 8, 1128.

Goossens, Y., Wegner, A., Schmidt, T., 2019. Sustainability assessment of food waste prevention measures: review of existing evaluation practices. Front. Sustain. Food Syst. 3, 90.

Gromko, D., Abdurasalova, G., 2019. Climate Change Mitigation and Food Loss and Waste Reduction: Exploring the business case. CGIAR Research Program on Climate Change. Agriculture and Food Security.

Guo, X., Broeze, J., Groot, J.J., Axmann, H., Vollebregt, M., 2020. A worldwide hotspot analysis on food loss and waste, associated greenhouse gas emissions, and protein losses. Sustainability 12, 7488.

Haass, R., Dittmer, P., Veigt, M., Lütjen, M., 2015. Reducing food losses and carbon emission by using autonomous control – A simulation study of the intelligent container. Int. J. Prod. Econ. 164, 400–408.

Hanson, C., et al., 2016. Food Loss and Waste Accounting and Reporting Standard. World Resources Institute.

Harris, F., et al., 2019. The water footprint of diets: a global systematic review and meta-analysis. Adv. Nutr. 11, 375–386.

Hiç, C., Pradhan, P., Rybski, D., Kropp, J.P., 2016. Food Surplus and Its Climate Burdens. Environ. Sci. Technol. 50, 4269–4277.

Higgins, J., et al., 2021. Cochrane Handbook for Systematic Reviews of Interventions. The Cochrane Collaboration.

Hossain, M.A., et al., 2016. Survey on postharvest losses of vegetables in two selected areas of Bangladesh. Acta Hortic. 1128, 237–242.

Hwang, S., Birken, S.A., Melvin, C.L., Rohweder, C.L., Smith, J.D., 2020. Designs and methods for implementation research: advancing the mission of the CTSA program. J. Clin.d Transl. Sci. 4, 159–167.

HLPE, 2020. Food Security and Nutrition: Building a global narrative towards 2030. High Level Panel of Experts on Food. Security and Nutrition.

Ingram, J., Zurek, M., 2019. Food systems approaches for the future. In: Serraj, R., Pingali, P. (Eds.), Agriculture & Food Systems to 2050: Global trends, challenges and opportunities. World Scientific, pp. 547–567.

Jayathilakan, K., Sultana, K., Radhakrishna, K., Bawa, A.S., 2012. Utilization of byproducts and waste materials from meat, poultry and fish processing industries: a review. J. Food Sci. Technol. 49, 278–293.

Jiménez-Antillón, J., Calleja-Amador, C., Romero-Esquivel, L.G., 2018. Food waste recovery with takakura portable compost boxes in offices and working places. Resources 7, 84.

Kadiyala, S., et al., 2021. Effect of nutrition-sensitive agriculture interventions with participatory videos and women's group meetings on maternal and child nutritional outcomes in rural Odisha, India (UPAVAN trial): a four-arm, observer-blind, cluster-randomised controlled trial. Lancet Planetary Health 5, E263–E276.

Kamrath, C., Rajendran, S., Nenguwo, N., Afari-Sefa, V., 2016. Traders' perceptions and acceptability on use of linings for improving tomato packaging in wooden crates. Int. J. Vegetable Sci. 22, 1–11.

Karuppasamy, G., D'Couto, M.A., Achary, A, 2016. Bioconversion of non edible vegetables from market into biofertilizer for crop improvement. J. Agric. Sci. 8, 71.

Kasavan, S., Siron, R., Yusoff, S., Fakri, M.F.R., 2022. Drivers of food waste generation and best practice towards sustainable food waste management in the hotel sector: a systematic review. Environ. Sci. Pollut. Res. 29, 48152–48167.

Kinyanjui, W., Noor, M.S., 2013. From waste to employment opportunities and wealth creation: a case study of utilization of livestock by-products in Hargeisa, Somaliland. J. Nutr. Food Sci. 3, 1000224.

Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: an analysis of 114 definitions. Resour. Conserv. Recycl. 127, 221–232.

Korir, M.K., Mutwiwa, U.N., Kituu, G.M., Sila, D.N., 2017. Effect of near infrared reflection and evaporative cooling on quality of mangoes. Agric. Eng. Int. CIGR J. 19, 162–168.

Kruijssen, F., et al., 2020. Loss and waste in fish value chains: a review of the evidence from low and middle-income countries. Glob. Food Sec. 26, 100434.
Kuiper, M., Cui, H.D., 2020. Using food loss reduction to reach food security and environmental objectives – A search for promising leverage points. Food Policy 98, 101915.
Kuo, C., Shih, Y., 2016. Gender differences in the effects of education and coercion on reducing buffet plate waste. J. Foodservice Bus. Res. 19, 1–13.
Lalander, C.H., Komakech, A.J., Vinnerås, B., 2015. Vermicomposting as manure management strategy for urban small-holder animal farms – Kampala case study. Waste Manage. (Oxford) 39, 96–103.
Laurentiis, V.D., Caldeira, C., Sala, S., 2020. No time to waste: assessing the performance of food waste prevention actions. Resour. Conserv. Recycl. 161, 104946.
Lim, L.Y., Lee, C.T., Bong, C.P.C., Lim, J.S., Klemeš, J.J., 2019. Environmental and economic feasibility of an integrated community composting plant and organic farm in Malaysia. J. Environ. Manage. 244, 431–439.
Maalekuu, B.K., Saajah, J.K., Addae, A.K., 2014. Effect of three storage methods on the quality and shelf-life of white yam (dioscorea rotundata) cultivars Pona and Tela. J. Agric. Sci. 6.
Ma'arif, S., Widyawidura, W., Aridito, M.N., Kurniasari, H.D., Kismurtono, M., 2019. Error! Hyperlink reference not valid. Int. J. Renew. Energy Res. 9, 354–362.
Mani, L., Kumar, D., 2011. Study of onion storages structure in Etawah district of UP. New Agriculturist 22, 175–178.
Marendra, F., et al., 2020. Biogas production for electricity from fruit waste: a case study of Gemah Ripah biogas plant, Yogyakarta. IOP Conf. Series: Mater. Sci. Eng. 736, 022058.
Masebinu, S.O., Akinlabi, E.T., Muzenda, E., Aboyade, A.O., Mbohwa, C., 2018. Experimental and feasibility assessment of biogas production by anaerobic digestion of fruit and vegetable waste from Joburg Market. Waste Manage. (Oxford) 75, 236–250.
Mason-D'Croz, D., et al., 2019. Gaps between fruit and vegetable production, demand, and recommended consumption at global and national levels: an integrated modelling study. Lancet Planet. Health 3, e318–e329.
Mehta, A., et al., 2014. On-farm heap storage of potatoes: evaluation in north-eastern plains of India. Potato J. 41, 68–75.
Messner, R., Richards, C., Johnson, H., 2020. The "Prevention Paradox": food waste prevention and the quandary of systemic surplus production. Agric Human Values 37, 805–817.
Micha, R., et al., 2020. Global Nutrition Report: Action on equity to end malnutrition. Developmemt Initiatives.
Mikhail, W.Z.A., et al., 2014. Suggested treatments for processing high nutritive value chicken burger. Annal. Agric. Sci. 59, 41–45.
Milani, M.D.Y., Samarawickrama, D.S., Perera, P.S.D., Wijeratnam, R.S.W., Hewajulige, I.G.N, 2020. Eco friendly packaging material from banana pseudo stem for transportation of fruits and vegetables. Acta Hortic. 1278, 59–64.
Moraes, C.C.de, Costa, F.H.de O., Pereira, C.R., Silva, A.L.da, Delai, I., 2020. Retail food waste: mapping causes and reduction practices. J. Clean. Prod. 256, 120124.
Moss, C., et al., 2019. The effects of crop diversity and crop type on biological diversity in agricultural landscapes: a systematic review protocol. Wellcome Open Res. 4, 101.
Msgoya, T.J., Kimaro, E.S., 2011. Assessment and management of post harvest losses of fresh mango under small-scale business in Morogoro, Tanzania. J. Anim. Plant Sci. 11, 1358–1363.
Nicholes, M.J., Quested, T.E., Reynolds, C., Gillick, S., Parry, A.D., 2019. Surely you don't eat parsnip skins? Categorising the edibility of food waste. Resour. Conserv. Recycl. 147, 179–188.
Nkolisa, N., Magwaza, L.S., Workneh, T.S., Chimpango, A., 2018. Evaluating evaporative cooling system as an energy- free and cost- effective method for postharvest storage of tomatoes (Solanum lycopersicum L.) for smallholder farmers. Sci. Hortic. 241, 131–143.
Nuevo, P.A., Maunahan, M.V., Resorez, J.M., 2018. Minimizing losses in the postharvest handling of export 'Bungulan' (Musa genome AAA) banana grown by small farmers in the Philippines. Acta Hortic. 1210, 13–20.
Obeng, G.Y., et al., 2020. Coconut wastes as bioresource for sustainable energy: quantifying wastes, calorific values and emissions in Ghana. Energies 13, 2178.
Olatilewa, M.O., Omotesho, O.A., Mohammad-Lawal, A.-.A., 2017. Evaluation of the sustainability of sweet orange postharvest handling technologies in Oyo and Osun States, Nigeria. J. Sustain. Develop. Africa 37–50.
Ouzzani, M., Hammady, H., Fedorowicz, Z., Elmagarmid, A., 2016. Rayyan: A web and mobile app for systematic reviews. Rayyan.
Page, M.J., et al., 2021. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ 372, n160.
Palaniswamy, U.R., Uddin, N., Islam, F., 2016. Kitchen waste as organic matter for composting in Bangladesh. Acta Hortic. 1112, 349–356.
Papargyropoulou, E., Lozano, R., Steinberger, J.K., Wright, N., Ujang, Z.bin, 2014. The food waste hierarchy as a framework for the management of food surplus and food waste. J. Clean. Prod. 76, 106–115.
Parfitt, J., Croker, T., Brockhaus, A., 2021. Global food loss and waste in primary production: a reassessment of its scale and significance. Sustainability 13, 12087.
Philip, D., Hod-Ovadia, S., Troen, A.M., 2017. A Technical and policy case study of large-scale rescue and redistribution of perishable foods by the 'Leket Israel' Food Bank. Food Nutr. Bull. 38, 226–239.
Plaisier, C., et al., 2019. Approach for designing context-specific, locally owned interventions to reduce postharvest losses: case study on tomato value chains in Nigeria. Sustainability 11, 247.
Porter, S.D., Reay, D.S., Higgins, P., Bomberg, E., 2016. A half-century of production-phase greenhouse gas emissions from food loss & waste in the global food supply chain. Sci. Total Environ. 571, 721–729.
Prost, A., et al., 2013. Women's groups practising participatory learning and action to improve maternal and newborn health in low-resource settings: a systematic review and meta-analysis. Lancet North Am. Ed. 381, 1736–1746.
Rahman, M., Islam, M., Begum, M., Arfin, S., 2020. Technical and economic feasibility of improved postharvest management practices in enhancing the eggplant value chain of Bangladesh. Int. J. Agric. Res. Innov. Technol. 9, 35–41.
R Core Team, 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing.
Rahman, M.A., Esguerra, E.B., Saha, M.G., Rolle, R., 2018. Managing quality and reducing postharvest losses in the mango value chain. Acta Hortic. 1210, 1–12.
Rasheed, R., Khan, N., Yasar, A., Su, Y., Tabinda, A.B., 2016. Design and cost-benefit analysis of a novel anaerobic industrial bioenergy plant in Pakistan. Renew. Energy 90, 242–247.
Redlingshöfer, B., Barles, S., Weisz, H., 2020. Are waste hierarchies effective in reducing environmental impacts from food waste? A systematic review for OECD countries. Resour. Conserv. Recycl. 156, 104723.
Ritchie, H., Roser, M., 2017. Our World in Data: Meat and dairy production. Our World in Data.
Rolker, H.B., Cardenas, L., Takahashi, T., Deeney, M., Eisler, M., 2021. Interventions to Reduce Perishable Food Waste in Low-and-middle-income Countries: A systematic literature review protocol. University of Bristol.
Rosenthal, I., 2019. Improving Rural Services for Small-scale Fisheries Using a Technological Platform Approach. Food and Agriculture Organization.
Rosenzweig, C., et al., 2020. Climate change responses benefit from a global food system approach. Nat. Food 1, 94–97.
Salemdeeb, R., Vivanco, D.F., Al-Tabbaa, A., Ermgassen, E.K.H.J.Zu., 2017. A holistic approach to the environmental evaluation of food waste prevention. Waste Manage. (Oxford) 59, 442–450.
Sarkar, S., Uddin, M., 2013. Community based waste management and its utilization for sustainable environment. Bangladesh J. Animal Sci. 42, 165–173.
Sethi, G., et al., 2020. Addressing Food Loss and Waste: A global problem with local solutions. World Bank.
Shailza, Sharma, L., Burark, S., Kaushik, R., Meena, G, 2020. Prospects of custard apple value chain development in Rajasthan. Econ. Affairs 65, 207–212.
Sibomana, M., Clercx, L., Waal, J.W.H.van der, 2019. An integrated analysis of tomato supply networks in Nigeria to improve efficiency and quality. Acta Hortic. 1258, 171–182.
Springmann, M., et al., 2018. Options for keeping the food system within environmental limits. Nature 562, 519–525.
Srinivasappa, K.N., Savita, S.M., Rajanna, N., 2015. Evaluation on efficacy of farmer friendly mango harvesters. Mysore J. Agric. Sci. 49, 484–491.
Stathers, T., et al., 2020. A scoping review of interventions for crop postharvest loss reduction in sub-Saharan Africa and South Asia. Nature Sustain. 3, 821–835.
Teigiserova, D.A., Hamelin, L., Thomsen, M., 2020. Towards transparent valorization of food surplus, waste and loss: clarifying definitions, food waste hierarchy, and role in the circular economy. Sci. Total Environ. 706, 136033.
Tugiyono, Febr, I.G., Puja, Y., Suharso, 2020. Utilization of fish waste as fish feed material as an alternative effort to reduce and use waste. Pak. J. Biol. Sci. 23, 701–707.
World Bank, 2022. World Bank Country and Lending Groups – Historical Classification by Income.
UNEP, 2021. UNEP Food Waste Index Report 2021. UN Environment Programme.
Venugopal, A.P., Viswanath, A., Ganapthy, S., 2017. Development of night time on-farm ventilated potato storage system in Nilgiri Hills of Southern India. Int. J. Process. Post Harvest Technol. 8, 37–43.
Verploegen, E., Sanogo, O., Chagomoka, T., 2019. Evaluation of low-cost evaporative cooling technologies for improved vegetable storage in Mali. 2018 IEEE Global Humanit. Technol. Conf.
Weber, C.T., Trierweiler, L.F., Trierweiler, J.O., 2020. Food waste biorefinery advocating circular economy: bioethanol and distilled beverage from sweet potato. J. Clean. Prod. 268, 121788.
Wen, Z., Wang, Y., Clercq, D.D., 2016. What is the true value of food waste? A case study of technology integration in urban food waste treatment in Suzhou City, China. J. Clean. Prod. 118, 88–96.
Woldemariam, H.W., Abera, B.D., 2014. Development and evaluation of low cost evaporative cooling systems to minimise postharvest losses of tomatoes (Roma vf) around Woreta, Ethiopia. Int. J. Postharvest Technol. Innov. 4, 69.
Xue, L., et al., 2017. Missing Food, Missing Data? A Critical Review of Global Food Losses and Food Waste Data. Environ. Sci. Technol. 51, 6618–6633.
Zohaib, A., Malik, A.U., Khan, A.S., Muhammad, A., Abdul, R., 2019. Effect of modified atmosphere packaging on the postharvest life and quality of mango cv. Samar Bahisat Chaunsa stored at chilling temperature. Pakistan J. Agric. Sci. 4, 847–856.
Zurek, M., Hebinck, A., Selomane, O., 2021. Looking across diverse food system futures: implications for climate change and the environment. Q Open 1, qoaa001.