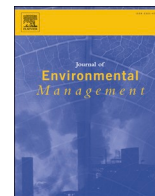




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## A systematic review of food loss and waste in China: Quantity, impacts and mediators

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### ABSTRACT

Although food loss and waste (FL&W) is high on China's national policy agenda, there is still little scientific information published about how much FL&W exists in China, what its impacts are, and what needs to be done to reduce it. Furthermore, what is known about FL&W across the various hotspots of China's food supply chain is not accessible in one place due to the tendency of scholars to focus on one part of the food chain depending on their disciplinary backgrounds, thereby making it difficult to obtain a 'comprehensive whole supply chain perspective'. Thus, this review provides an interdisciplinary collation of what is already known about FL&W in China. A systematic review of both English and Chinese databases followed PRISMA guidelines further complemented with a qualitative content analysis process uncovered 57 articles. The view revealed confounding factors such as an inconsistency of the definitions and calculation methods used to measure FL&W, and research gaps such as a lack of focus on the behavioral factors pertaining to waste, and the limited range of social innovations studied to reduce it. Thus, this review will help in the development of research agendas designed to advance efforts in this field.

### 1. Introduction

The United Nation's Food and Agriculture Organization (FAO) estimates that approximately one-third of the food produced in the world (or 1.3 billion tons) each year does not reach the consumer (Gustavsson et al., 2011). As Food loss (FL) and food waste (FW) significantly contribute to food insecurity and reduced sustainability, many governmental and non-governmental organizations at international, regional and national levels are increasing their efforts to analyze and reduce FL&W.

During the past decade, several international and regional initiatives efforts have started to define and measure food loss and waste (FL&W) along food supply chains (FSC) (Fabi et al., 2020). Since the first global assessment attempted by FAO in 2011 (Gustavsson et al., 2011), many researchers have provided quantitative FL&W estimates in different ways for different geographic regions. For example, Nahman and de

Lange (2013) estimated the costs of FW throughout the FSC in South Africa; van der Werf and Gilliland (2017) estimated FL&W throughout the FSC from developed countries (USA, Canada, UK, some EU countries, and Japan, etc.) and Xue et al. (2017) estimated FL&W at a global level for major commodity groups. Unfortunately, owing to differences in definitions and measurement frameworks used by various researchers, the available data on FL&W is disjointed and heterogeneous.

In 2015, the 193 Member States of the United Nations adopted the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development. SDG Target 12.3 specified that 'By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.'

For Target 12.3 there was, however, no clear agreement on the definition of 'food loss' or 'food waste': this omission was rectified in November 2018, when the FAO published the guide 'SDG 12.3.1 - Global

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Food Loss Index' which provided an operational definition (Fabi and English, 2018) and split Target 12.3 into two stages: 1) Supply oriented: 'reduction of losses along the food production and supply chains' and 2) Demand oriented: 'halving per capita global food waste at the retail and consumer level'. The scope of the two stages can be summarized by a simplified FSC in which the loss indicator covers losses from the farm up to, but not including, the retail sector and FW covers retail and public consumption (Fig. 1). In this review, we have used the Target SDG 12.3.1 guide to define the boundaries of FL&W in relation to the FSC.

Within the operational framework of SDG 12.3.1, food losses are all the crop and livestock human-edible commodity quantities that, directly or indirectly, completely exit the post-harvest/slaughter production/supply chain by being discarded, incinerated or otherwise, and do not re-enter in any other utilization (such as animal feed, industrial use, etc.), up to, and excluding, the retail level. Losses that occur during storage, transportation and processing, including for imported products, are therefore all included. FW within the SDG 12.3.1 framework is focused on the consumption end of the FSC and occurs from retail through to the final consumption/demand stages. A separate Food Waste Index (FWI) is being developed to cover FW at the retail and consumption level (Fabi and English, 2018).

The boundaries of this study do not include destinations of post-consumption food waste which later might be collected and processed for further utilization, such as for animal feed, productive composting, biogas production or insect or fish farming. The waste flows into those processes are not well-documented and are highly variable, as municipalities experiment with a wide range of possible post-consumption processes and related infrastructures. However, we do note that in recent years some very significant advances have been made in Nanjing (Li et al., 2021; Li et al., 2017) and Shanghai (Chen, 2020), where over 9600 tons per day of clean post-consumer food waste is now being diverted into an growing infrastructure producing biogas.

The extant literature examining FL&W worldwide focuses on a diversity of topics, such as: the quantification of FL&W; the composition of FW and waste management; the development of quantification methodologies; the assessment of consumers attitudes/behaviors on FL&W; and on understanding the drivers/interventions that cause stakeholders (growers, processors, retailers and consumers) to increase or reduce their FL&W. However, overall, these studies remain in different silos, lack generalizability, have a narrow focus and scale, and a limited geographical scope. For example, recent reviews which have outlined empirical studies on food waste and loss prevention and discussed worldwide minimization methods have revealed a wide gap between Europe, United States and the other continents with a dearth of studies conducted in the Asia region (Moraes et al., 2021; Xue et al., 2017). Such a limited global focus is quite concerning since there is an established linkage between the reduction of FL&W and an enhancement of food sustainability and natural resource utilization (Wunderlich and Martinez, 2018), which would suggest that academic research on FL&W in developing economies should be prioritized.

As the world's largest emerging economy, China's food security is of special concern, particularly because while it contains approximately 20% of the world's population, China only encompasses 7% of the world's arable land (Larson, 2013) which is decreasing in area due to industrialization and urbanization (Zhang et al., 2020). Further, while China has recently demonstrated remarkable success in increasing agricultural production (Gong, 2018), increasing affluence and a booming catering sector has resulted in a dramatic rise in FW (Cheng et al., 2018). Given this context, and with growing media, public and governmental interest (Du, 2016; Yu and Li, 2013), it seemed timely to produce an up-to-date review bringing together the fragmented findings on FL&W in China, as a foundation for further systematic work.

To achieve this goal, we used a systematic review method to address four research questions: 1. 'What is the research profile of the selected studies in terms of summary statistics?'; 2. 'What are the overall quantities of FL&W?'; 3. 'What are the impacts overall of this FL&W?'; and 4. 'What mediators (drivers and possible interventions) affect FL&W?'

## 2. Methods

To interrogate the extant literature in this area in a comprehensive manner, a systematic review was conducted following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Petticrew and Roberts, 2008; Tranfield et al., 2003). Systematic reviews are recommended to be used when there is a need to summarize existing information about a topic in order to draw a conclusion about a specific phenomenon (Kitchenham, 2004). The approach used to search for data and to synthesis and conceptualize the data from relevant studies was based on the process outlined by Petticrew and Roberts (2008), complemented by the qualitative content analysis process suggested by Hsieh and Shannon (2005). The literature review process was accomplished by the authors collaboratively developing all search terms, identifying databases to be used and inclusion/exclusion criteria in advance of starting data collection.

### 2.1. Search strategy

The search for relevant articles pertaining to FL&W at least along a part of the FSC in China was limited to peer-reviewed journal articles published in English or Chinese, with grey literature such as research reports, books or conference proceedings being consciously omitted. Studies were identified through searching on-line electronic English (SCOPUS, Web of Science) and Chinese (China National Knowledge Infrastructure (CNKI), Wanfang and Chongqing Weipu (VIP)) databases. The search terms used are shown in Table 1, applied to the field, "Topic", in all databases except VIP due to a lack of this option, where "Title or keywords" was used instead. The search was conducted in July 2020 and was not date restricted as this is commonly the case for PRISMA (Abiad and Meho, 2018; De Steur et al., 2016; Schanes et al., 2018).

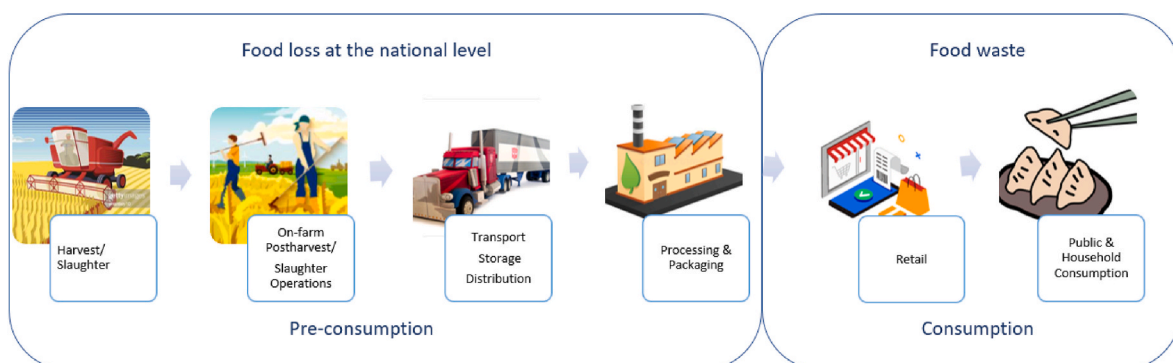


Fig. 1. Definition of FL&W along FSC derived from SDG 12.3.1 (Fabi and English, 2018).

**Table 1**  
Search terms used for system review.

Databases	Term 1	AND	Term 2	AND	Term 3
English	food waste		quant*		Chin*
	food waste		/		
	food loss*		/		
Chinese	食物浪费		/		/
	食物损失				

\* Note: The asterisk serves as the truncation (or wildcard) operator which means that the ending can be replaced in multiple ways. e.g., quant\* means either quantity or quantities.

## 2.2. Study selection

The search identified 1217 papers obtained from the database. As outlined in Fig. 2, the analysis of the papers started with the removal of duplicates. Next, relevant studies were identified first through title screening and then by assessing the abstracts of papers that passed title screening. Studies remaining after abstract screening were subject to full-text screening and a final decision was made on their relevance for inclusion in the review. Paper relevance was determined through the application of the inclusion/exclusion criteria outlined in Table S1. Quality appraisal of the studies was then performed by adapting a validated methodological scoring system developed for the assessment of qualitative, quantitative and mixed methods studies as outlined in Table S2. The most recent review was found to be in 2016, therefore the snowballing technique was applied to any papers published after 2016 to check for otherwise uncaptured papers. The final decision on if a paper was suitable for inclusion or not was based on the opinion of at least three of the authors.

Relevant information was extracted from each study including general information (title, author, publication details), study features and specific information (Tranfield et al., 2003). NVivo software was used to code for the amount of FL&W, the environmental impact of FL&W

occurring at each stage of the FSC, and the possible drivers for or interventions to prevent FL&W. When analyzing mediators of FL&W, variables that affected consumer behavior and contributed to food consumption and waste were also coded, such as age, educational level, annual income, and household size. The codes were then clustered for similar meanings or representations of similar phases of food consumption. For example, although the sentences of “woman mainly responsible for preparing food would increase household FW” and “female students wasted more food than males when eating in the school canteens” discuss FW in different scenarios such as households and dining out of home, they can both be coded into the same demographic mediator category: “gender”.

## 3. Results

Fig. 2 shows the PRISMA flow of the systematic search results which initially identified 1217 papers of potential relevance across the English (791) and Chinese (426) databases. It is important to note that as expected English and Chinese databases had very few (five) papers in common. After the removal of duplicates, most of the papers were rejected at the title and abstract screening stage owing to the fact that they were about the characterization of food waste at a municipal solid waste level, or the treatment of food waste, such as recycling or energy potential. Then the full text of the papers that passed the title and abstract screening were assessed for their quality. At this step a further 21 papers were excluded for failing quality assessment due mainly to a poor sampling approach and/or poor data analysis. The final pool contained 57 relevant, quality-assured papers. The relevant articles retained in the final pool as a percentage of the initially identified papers was between 4 and 5% which is within the usual value range reported by other systematic studies (Abiad and Meho, 2018; De Steur et al., 2016; Schanes et al., 2018; van der Werf and Gilliland, 2017).

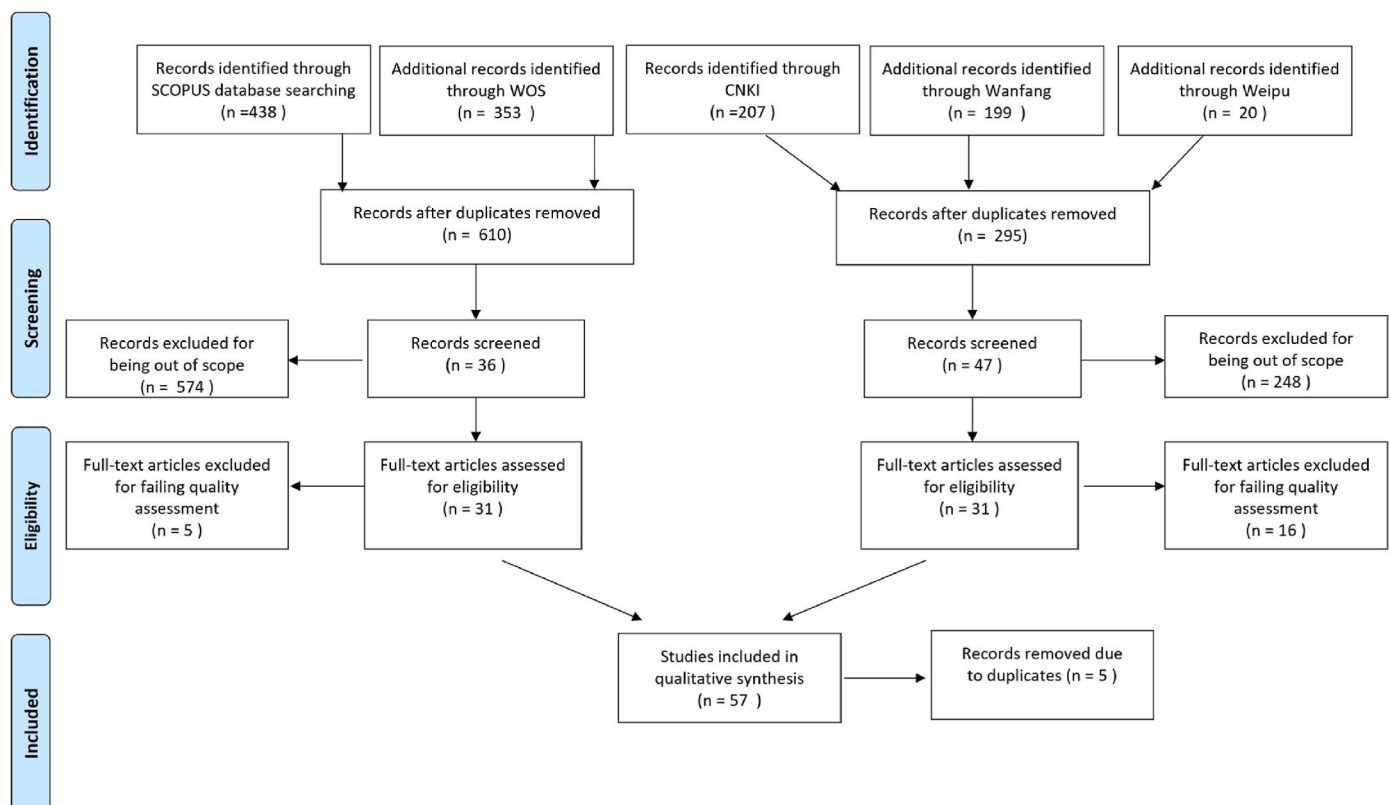


Fig. 2. PRISMA Flow chart of the systematic review on “food loss” and “food waste” in China.

### 3.1. Profiles of papers selected (question 1)

The 57 eligible publications came from 39 different journals, with Resources, Conservation and Recycling (4 papers) and the Journal of Cleaner Production (3 papers) having the most articles in English, and the Journal of Natural Resources (4 papers) and Resources Science (4 papers) the most in Chinese. Note that the search criteria used was designed for studies within a broader FL&W context, and consequently did not select a number of published papers that were focused specifically on production losses associated with Chinese staple crops - as discussed in more detail later.

Very few papers included applied theories. The theory of planned behavior (TPB) was used in three papers, for analyzing the pro-environmental behavior of students and green consumers (Liao et al., 2020; Wang, 2016; Wu et al., 2019). Other theories used once each were cue utilization theory (Loebnitz and Grunert, 2014), the elaboration likelihood model (ELM) (Liao et al., 2018), the communicative ecology theory (Miroso et al., 2018) and the household production theory (Min et al., 2020). In addition, Liao et al. (2018) used an integrated behavioral intention model combining the TPB model and Lee's modified Fishbein model to verify a useful framework for predicting consumer behavior in a Confucian culture context.

### 3.2. Review of FL&W quantities reported (question 2)

#### 3.2.1. Quantities of food losses (FL) reported

During the first round of keywords searching, only nine papers were found which contained relevant FL data and they included the three reviews (Gao et al., 2016; Liu, 2014; Liu et al., 2013) published over the last 8 years. These three reviews effectively summarized the information within earlier articles (from 1950 to 2016) on FL associated with staple crops. Liu et al. (2013) reviewed information from 1987 to 2011 on grain losses and waste along the entire FSC and provided a framework of FL&W in terms of quantities and implications of FL&W for water and land. Subsequently, Liu (2014) published a review of FL&W for a wider range of food commodities (grain, meat and fruit & vegetable) from 1950 to 2011 along the entire FSC and Gao et al. (2016) reviewed publications from 1979 to 2016 concerning postharvest losses of three major crops (rice, wheat and maize) in China. As these reviews have been widely cited, we decided to include the results from them in the current review rather than incorporating all of earlier papers they cited. Note that as these three review papers were published before SDG 12.3, the boundaries they used for the FSC differed from those used in SDG 12.3, especially for the FL&W associated with agricultural production or the retail stage. For example, in the 'SDG 12.3.1: Global Food Loss Index', FL at the agricultural production stage solely refers to on-farm losses, which is the timeframe between maturity and harvesting. However, in the review by Liu (2014), agricultural loss was considered as being preharvest farm-level loss which was mainly caused by microbial infections (e.g. fungal), damage by pests (e.g. insects) or natural disasters (e.g. drought). Note that such losses are not covered under SDG 12.3.1 in order to avoid double-counting of pre-harvest losses due to extreme events and environmental disasters which are captured by another SDG 1.5 (SDG 1.5: "By, 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters") (Fabi and English, 2018). Further, in the review by Liu (2014) and in a paper by Lu et al. (2019), retail loss was considered to be a part of distribution, while in SDG 12.3.1, retail has been clearly moved from the distribution sector to consumption.

In general, when analyzing the earlier papers, it was extremely difficult to integrate the FL data provided into the stages stated in SDG 12.3 owing to inconsistencies in the way the data reported. We therefore made the decision to report the data in its original format as either: Postharvest handling and storage; Processing; or Distribution (Table 2).

FL during these stages has traditionally been measured by assessing the loss rate, which is the ratio of food loss to the total amount of food production (Bellemare et al., 2017) as reported in Table 2. While the FWI is still under development, we consider it will be important to use the SDG 12.3.1 framework to define the stages in future reviews and studies and to consider FW during retail as a separate sector from distribution.

The three major crops in China are rice, wheat and corn and FL in these crops has been well-researched. Note that 'Liangshi', which can be translated from Chinese to mean in English "staple food", usually covers rice, wheat, corn, and sometimes potatoes and soybean, was kept in a separate category. There was limited data on FL in the processing and distribution sectors in China. Further challenges in integrating and simply expressing earlier FL data, included the aggregation of data into different stages by the different authors. For example, there were three different criteria to measure FL during storage, such as household traditional storage, household scientific storage, and depot storage (either by government or enterprises) (Table 2).

We only found two papers which mentioned FL associated with meat at the post-harvest stage. In the review by Liu (2014) the loss rate for meat (types of meat not specified) were postharvest handling (1.4–2.1%), storage (2.5–3.7%), processing (1.1%) and transportation (3%, retail included), while in a paper by Zhou et al. (2019) in 2019, losses for meat were defined as postharvest handling including pre-cooling, storage including frozen and processing including cutting, transport were supplied for pork (6.64%), chicken (5.43–9.68%), beef (8.34%) and mutton (4.18%). The data of FL of fruits and vegetables was also scarce with only one review paper reporting FL rates in storage and distribution as being 15% and 10%, respectively (Liu, 2014).

In summary, FL in the processing and distribution sectors has not been well studied in China. In general, to be more useful, the boundaries of FL&W along FSC needs to be more clearly stated in future studies by using the definition of SDG 12.3.1. Most research so far has focused on the staple foods, meaning that in order to develop a more holistic picture of FL in China more research is required pertaining to fruit, vegetables, meat and aquatic products.

#### 3.2.2. Quantities of food waste (FW) reported

Only one paper mentioned FW in relation to meat at the retail stage, which cited post-harvest loss for 4 types of meat (Zhou et al., 2019) and also provided retail/wholesale FW estimates for pork (1.46%), chicken (2%–3.17%), beef (3.13%) and mutton (3.27%).

In total 23 papers (Table 3) published data on FW quantities pertaining to public or household consumption and they covered a variety of food service sectors, including Horeca (hotels, restaurants and cafés), households, and school canteens<sup>1</sup> (Fig. 3). These studies were mainly focused on Horeca (10), rather than households (7), or school canteens (5), and were carried out in major cities including Beijing (9), Lhasa (4), Shanghai (3), Chengdu (2) and Shenzhen (1).

Of the 23 papers which discussed the amount FW generated, 13 used direct weighing and questionnaires for restaurants and school canteens (Huang et al., 2017; Liu et al., 2016; Qian et al., 2019; Wang et al., 2016; Wang et al., 2017; Wang et al., 2018; Wu et al., 2019; Zhang et al., 2016a; Zhang et al., 2016b; Zhang et al., 2016c; Zhang et al., 2017; Zhang et al., 2018b; Zhu et al., 2020) and one other asked participants from rural households to weigh and report their FW quantities (Li et al., 2017). In these studies, the quantities of FW reported varied depending

<sup>1</sup> Canteens, similar to "cafeterias" in the US, are food service systems provided in almost all schools, universities, and many workplaces throughout China. They differ from typical restaurants in that people serve themselves at the counter from a selection of food. After eating, the consumers are normally asked to take their plate with any food leftovers to a sorting area where staff will help to dispose of the wasted food and collect the plates and cutlery for cleaning.

Table 2

A summary of key data collated concerning FL in postharvest handling and storage, processing &amp; distribution.

Crop	Postharvest handling and storage %				Processing %	Distribution %	Total Postharvest loss % <sup>a</sup>	Ref		
	Harvesting <sup>b</sup>	Transport <sup>c</sup>	Drying	Storage <sup>d</sup>						
Rice	2.7	0.9	1.4	2.0	1.73	0.79	6.9	Gao et al. (2016) Lu et al. (2019) Huang et al. (2018) Qu et al. (2019)		
	2.84 <sup>e</sup>		1.85 <sup>f</sup>	1.21 <sup>g</sup>						
	3.02									
	3.92									
Wheat	2.3	0.9	1.4	1.75–2.00 <sup>h</sup>			7.8	Luo et al. (2020) Gao et al. (2016) Cao et al. (2018)		
	4.715			1.867						
Maize/corn	2.3	0.9	1.4	4.5			9.0	Luo et al. (2020) Gao et al. (2016) Guo et al. (2019)		
	2.74			2.41 <sup>g</sup>						
Grain (Liangshi)	2.5	0.9	1.4	3.2	2.2–3.3	1–1.5	7.9	Gao et al. (2016) Liu (2014)		
	4–6 <sup>i</sup>			5.7–8.6					3.1 ± 1.1	1.2 ± 1.2 <sup>j</sup>
	3.5 ± 2.6			5.5 ± 3.4						

<sup>a</sup> The number indicated in this column came from the original papers (Gao et al., 2016) and (Lu et al., 2019).

<sup>b</sup> Indicates combine harvesting and segment harvesting together if there is no further specification.

<sup>c</sup> Indicates the transport from field to household.

<sup>d</sup> Indicates the all the possible ways of storage, such as household traditional storage, household scientific storage, and depot storage (either of government or enterprises).

<sup>e</sup> Indicates the process is basically fully mechanized. Harvesting loss indicates loss during harvesting and threshing.

<sup>f</sup> Indicates the transport-drying and temporary storage-transport.

<sup>g</sup> Indicates the grain depots storage.

<sup>h</sup> Indicates the household storage.

<sup>i</sup> Indicates the postharvest handling as a whole process.

<sup>j</sup> Indicates the transport only.

on the year, region, school type and food supply patterns. The amount of FW per person in school canteens (buffet meal<sup>2</sup>) was reported to range from 61 to 74 g/meal (Liu et al., 2016; Qian et al., 2019; Wu et al., 2019; Zhu et al., 2020), which was less than that reported for restaurants, which ranged from 74 to 144 g/meal (Wang et al., 2016; Wang et al., 2017; Wang et al., 2018; Zhang et al., 2017; Zhang et al., 2018b). However, even at a school canteen, food supply patterns were shown to significantly influence FW, with packed meals<sup>3</sup> (216 g/meal) being more wasteful than set<sup>4</sup> (109 g/meal) or buffet meals (63 g/meal) (Liu et al., 2016).

Four studies (Jiang et al., 2018; Qi et al., 2020; Song et al., 2015, 2018) reported on household FW quantities from data obtained from the China Health and Nutrition Survey (CHNS). CHNS is the name of a largescale longitudinal household-based survey conducted by the Population Centre at the University of North Carolina and the National Institute of Nutrition and Food Safety at the Chinese Centre for Disease Control and Prevention (CCDCP). To date nine survey rounds (i.e., 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011), covering 12 provinces have been reported. CHNS used the income-stratified multi-stage cluster sampling method, with detailed information summarized by Popkin et al. (2009). Two papers studied the CHNS data from 1991 to 2009 and found that household FW per person had declined from nearly 52 g/day in the early 1990s to less than 41 g/day by 2009, (an approximate 20% decrease) (Jiang et al., 2018; Qi et al., 2020). Using a Bayesian belief network modelling approach, Song et al. (2018) also found that both household waste and catering service waste was declining, but that FW still accounted for 4.5–5.2% of China's yearly total grain output (Jiang et al., 2018).

Although the data presented above indicates that substantial reductions in household FW have occurred over time, it is important to

<sup>2</sup> Buffet meal: individual dishes can be chosen; people pay according to the individual price of each dish.

<sup>3</sup> Packed meal: delivered from food supply companies to schools, the variety and weight of meal are pre-ordered.

<sup>4</sup> Set meal: provided by a school kitchen, generally comprised of grains, vegetables, and meat.

consider that households represent only one possible source of consumer-level FW. As disposable incomes have increased over time, so have tendencies for people to eat at restaurants and other food services, a trend which may be simply shifting where the FW is being generated. Indeed as previously mentioned, the observed FW per person in restaurants at 74–144 g/meal (Wang, L.E. et al., 2016; Wang et al., 2017; Wang, L.E. et al., 2018; Zhang et al., 2017; Zhang, P.P. et al., 2018b) is two-to-three times higher than the FW generated for an entire day (41 g) per person reported in the CHNS survey in 2009 (Jiang et al., 2018; Qi et al., 2020).

Public data available from sources such as the China Statistical Yearbook, the China Agriculture Yearbook, FAO food balance sheet, or the 12th Five-year Plan (2011–2015) for National Economic and Social Development in China has also been used to build models to estimate FW on a national, city or prefecture-level. In these studies, FW is always presented in units of 'ton/year'. For example, China's consumption stage FW was modeled at 62.8 million tons in 2010 (Sun et al., 2018) and in 2015 two different groups reported FW in China as being 53.7 (Li et al., 2020) and 55.7 million tons (Yang et al., 2020). These values of FW are broadly comparable with the FW amounts extrapolated from direct weighing. For example, on a smaller city-based scale, total restaurant FW in Beijing in 2015 was estimated to be 956,300 tons (De Clercq et al., 2016), which is of the same magnitude as the figure of 398,600 to 399,700 tons calculated for 2013 by extrapolating direct weighing data (Zhang et al., 2016b, 2016c), although comparisons between studies carried out at different times, locations, and using different methodologies are challenging and generalizations must be made with caution.

Studies on FW composition showed that the most commonly-consumed foods generate the most waste (p-value 0.87) (Song et al., 2015). This is consistent with widespread findings that vegetable and staple foods make up the majority of FW in China (Huang et al., 2017; Li et al., 2020; Liu et al., 2016; Qi et al., 2020; Song et al., 2015; Song et al., 2018; Sun et al., 2018; Wang et al., 2017; Zhang et al., 2016b; Zhang et al., 2016c; Zhang et al., 2017; Zhang et al., 2018; Zhu et al., 2020), albeit with variation between provinces (Song et al., 2018), for example, as meat is more readily available in Lhasa, the meat FW in this province is higher than reported for other provinces (Wang et al., 2016).

In the newly developed catering industry associated with online food

Table 3

Summary of systematic review papers selected which relate to FW quantities in public and household consumption.

Service sectors	Year data based/collected	Region	Scope	Data collection method	Amount or characteristic of FW	Ref
University canteens	2018	Beijing	Quantify the plate waste and identify key influencing factors, also evaluate the environmental impacts from the perspective of nitrogen, phosphorus, carbon, and ecological footprints	Direct weighing, questionnaire surveys, and regression analysis of 551 observations from 6 universities	73.7 g/cap/meal	Wu et al. (2019)
Primary, middle, and high school canteens	2015	Shanghai	Evaluate the intake of food and nutrients among students and provide recommendations for amendments in new local school lunch standards	Physical measurement of plate waste and conduct questionnaire survey among 5389 students of 20 schools in seven districts	Most wasted by percentage: vegetables (primary school 53%, middle school 42%, and high school 31%)	Huang et al. (2017)
Middle and high school canteens	2014	Beijing	Investigate the patterns and causes of plate waste in school lunch programs and find out the reasons and to explore feasible countermeasures	Applying physical weighing, questionnaire survey, and semi-structured interview approaches to quantify the FW	Packed meals waste: 216 g/cap/meal (1/3 of the food served) Set meal waste: 109 g/cap/meal Buffet meals waste: 63 g/cap/meal Average: 130 g/cap/meal Most wasted: staple food (43%) and vegetables (42%)	Liu et al. (2016)
University canteens	2017–2018	30 provinces	Estimate the FW of university canteens and its carbon footprint	Direct weighing and questionnaires of 9660 students in 30 national universities in 30 provinces	67.55 g/cap/meal (waste rate 14.54%) Most wasted by percentage: Vegetables 16.79%, rice products 14.54% and bean products 13.25% Most wasted by weight: Pasta 43.03 g, rice product 33.99 g and vegetable 31.7 g	Zhu et al. (2020)
University canteens	2017–2018	29 provinces	Estimate the FW and to reveal the drivers of FW for college students	Direct weighing method and questionnaire of 9192 students in 29 universities in 29 provinces	61.03 g/cap/meal FW rate per person per meal is 12.13% Up to 74% of students waste food	Qian et al. (2019)
Hotels, restaurants, and cafés	2011 and 2015	Lhasa	Quantify the amount of Horeca (hotels, restaurants, and cafés) FW and its ecological footprint	Direct-weighing and questionnaire of 1162 consumers (232 tourists and 930 residents) of 460 tables in 27 restaurants in 2015 and 2947 consumers (1189 tourists and 1758 residents) of 318 tables in the 8 restaurants in 2011	128 ± 3 g/cap/meal in 2011 98 ± 2 g/cap/meal in 2015	(Wang et al., 2018)
Restaurants	2011 and 2012	Lhasa	Calculate the total amount of catering food consumption in Lhasa and the resources and environment cost through constructing ecological footprint model	Direct weighing of 443 tables in 9 restaurants and questionnaire	143.4 g/cap/meal most wasted: mutton (25.6%), followed by staple (24.8%), the least was fruit (5.7%)	(Wang, L.E. et al., 2016)
Restaurants	2015	Beijing, Shanghai, Chengdu and Lhasa	Determine scales and patterns of restaurant FW in 4 Chinese cities	Direct weighing method and a survey of 3557 tables in 195 restaurants	93 g/cap/meal Most wasted: vegetables (29%), rice (14%), aquatic products (11%), wheat (10%) Total estimated FW 1.3 Mt (Shanghai 0.59, Beijing 0.42, Chengdu 0.31, and Lhasa 0.02 Mt)	Wang et al. (2017)
Restaurants	2013	Beijing	Investigate the total amount of FW generated by the catering industry and calculate the greenhouse gas and carbon emissions	Direct weighing method and consumer questionnaire of 2564 tables in 124 restaurants.	398,600 tons (half of the total weight of food consumed in Beijing) The most wasted by weight: vegetables (43.16%), followed by aquatic products (10.51%), pork (8.79%), wheat flour (7.35%)	Zhang et al. (2016b)

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Table 3 (continued)

Service sectors	Year data based/collected	Region	Scope	Data collection method	Amount or characteristic of FW	Ref
Restaurants	2013	Beijing	Investigate the volume of catering FW generated and calculated its nitrogen footprint	Direct weighing method and a consumer questionnaire of 2564 tables in 124 restaurants.	74.39 g/cap/meal Large restaurants 99.34 g/cap/meal fast food restaurants:30.27 g/cap/meal Most wasted by weight: vegetables (44.18%), followed by aquatic products (12.04%)	Zhang et al. (2017)
Restaurants	2013	Beijing	Study the phosphors footprint using restaurant FW	Direct weighing and questionnaire to investigate the catering FW of 2564 samples in 124 restaurants	399, 700 tons Plant-based FW 26.82 × 10 <sup>4</sup> t/a Animal-based FW 13.15 × 10 <sup>4</sup> t/a	Zhang et al. (2016c)
Restaurants	2013	Beijing	Study the ecological footprint related to restaurants FW	Direct weighing and questionnaire to investigate the catering FW of 2564 samples in 124 restaurants	399, 700 tons Urban inhabitant FW: 27.82 × 10 <sup>4</sup> t/a Tourism population FW: 12.15 × 10 <sup>4</sup> t/a Most wasted: Vegetables 43.03%, followed by meat 20.54%, and staple food 16.61%	Zhang et al. (2016a)
Restaurants	2015	Beijing, Shanghai, Chengdu, and Lhasa	characteristics of FW behavior, especially differences in the FW behavior of tourists and non-tourists	field survey of 2293 samples in 159 catering companies	79.52 g/cap/meal Tourists waste 96.54 g/cap/meal Non-tourists 73.79 g/cap/meal	(Zhang et al., 2018b)
Households	2016	25 provinces	Estimate the quantity of FW of rural households and its causes	Using accounting survey to obtain the FW data of 1596 samples and applying statistical analysis method and Tobit model to analyze the causes	Average FW rate: 2.4% regionally, highest at 3.69% (middle reaches of the Yangtze river) vs lowest at 0.14% (Beijing and Tianjin) food type: highest at 3.92% (potato) vs lowest at 1.29% (egg)	(Li et al., 2017)
Households	1991–2009 (1991,1993,1997,2000,2004,2006 and 2009)	China	Describe FW patterns and trends within households	Analysis of physical measurements of discarded food from more than 37,000 households enrolled in the China Health and Nutrition Survey (CHNS)	52 g/cap/day (18.8 kg/person/year) in 1991 41 g/cap/day (14.9 kg/person/year) in 2009 Most wasted: vegetables and fruits, followed by cereal and then animal proteins	Qi et al. (2020)
Households	1991–2009 (1991,1993,1997,2000,2004,2006 and 2009)	China	Study the FW quantity within households and discuss the associated micro-level determinants	Analysis of physical measurements of discarded food from more than 37,000 households enrolled in the China Health and Nutrition Survey (CHNS)	15.91(1991), 17.78 (1993), 16.76(1997), 16.74(2000), 13.74 (2004), 10.71(2006), 10.76(2009) kg/cap/year. Simulated FW: 7.63–10.76 kg/person/year (10.6–15.0 million tons) in 2016	Jiang et al. (2018)
Households	1991, 1993, 1997, 2000, 2004, 2006 and 2009	9 provinces	Quantify FW in Chinese typical provinces, and develop a Bayesian Belief Network (BBN) model to reveal the mechanism of household FW generations	Link CHNS household survey data and review life-cycle-assessment dataset to estimate FW about 7091 households and 31,161 individuals	average FW: 12–33 kg/cap/year (varies among provinces) most wasted by weight: plant-derived food (80–93%) in all provinces, the animal-derived food 5–18%	Song et al. (2018)
Households	2004, 2006 and 2009	China	Summarize the patterns of both food consumption and waste generation and analyze the factors influencing the observed trends, and quantify the carbon, water, and ecological footprints of Chinese households	Combine survey data of CHNS database with available life-cycle assessment data sets to calculate FW and related ecological footprints about one million food records obtained from 17,110 family members	average food consumption (waste): 1498 kg (58 kg)/household/year and 415 kg (16 kg)/cap/year most consumed/wasted: Vegetables 31% (54%) followed by rice at 22% (13%)	Song et al. (2015)
Consumption stage	2010	China	Evaluate the impacts of food wastage in the consumption stage on water resources and the environment	Calculation	62.8 million tons (Mt) (14.5% of total food production) Most wasted by weight:	Sun et al. (2018)

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Table 3 (continued)

Service sectors	Year data based/collected	Region	Scope	Data collection method	Amount or characteristic of FW	Ref
At the table	2015	China	Quantify FW at the provincial level by considering both at-home and away-from-home consumption, and estimate phosphorus loss along the FSC using phosphorus loss factor derived from substance flow analysis	Calculation Based on China Statistical Yearbook, the China Agriculture Yearbook and the United States Geological Survey database	plant food (Cereals 29.00 Mt and vegetables 20.63 Mt) Most wasted by percentage: Cereals 20%, followed by vegetables of 15%, and dairy products 5%. 53.7 million tons (Mt) (39.2 kg/cap/y) embedded phosphorus: 86,300 tons vegetable 24.5, cereal 9.6, fruits 8.0, pork 2.1 and poultry 1.7 Mt	(Li et al., 2020)
Restaurants and households	2015	China	Systematic estimation and analysis of municipal FW produced in administrative divisions at the prefecture-level and above and estimate the resource utilization potential	Modelling and Calculation	55.7 million tons (Mt) Shanghai 1.4, Beijing 1.2, Chongqing 0.9, Tianjin 0.8, Guangzhou 0.8 Mt	Yang et al. (2020)
Restaurant	2015	Beijing	Calculate the theoretical biomethane potential of restaurant FW in megacity case study, and evaluate project-level bottlenecks in anaerobic digestion facilities	Calculation	956,300 tons	De Clercq et al. (2016)
Households	2015/2017	Shenzhen	Estimate the quantity and composition of avoidable household FW in Shenzhen, and identify the driving forces to further explored potential means of reducing household FW	Using questionnaires of 418 households in Shenzhen to estimate and calculate the quantity of avoidable household FW	549,000 tons in 2001 1,673,000 tons in 2015 Most wasted by weight: cereal products: 0.51, fruits: 0.38, vegetable: 0.27 and animal-derived food: 0.26 Mt	(Zhang et al., 2018)

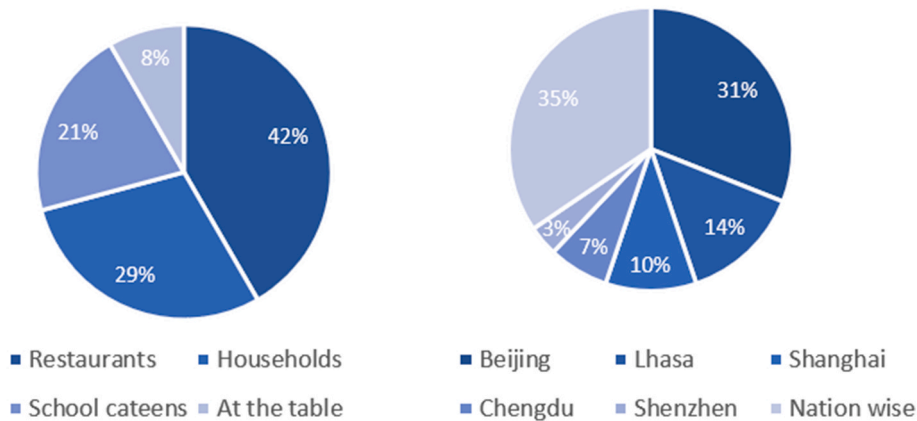


Fig. 3. Distributions of published articles about consumption FW, by food service sectors and geographic locations.

delivery (OFD) which is mainly used by students and white-collar workers, issues around FW are postulated to be occurring. With OFD, although the food is consumed at home or in the office, it is prepared in food service sector kitchens, including restaurants. While data on the quantity of FW from OFD has not been directly reported, a 2018 study at Jilin University reported that almost half of the students (43.6%) surveyed wasted *half or more* of their delivered food (Lin et al., 2018, 2019).

In summary, the data on FW quantities is patchy. CHNS data has been the source for most of the household FW studies. Restaurant FW has been well researched by the Chinese Academy of Science (CAS) team using direct weighing and questionnaires but such research has only been reported for the major cities. People who eat at restaurants tend to

order more food than they need, which might be influenced by Mianzi culture (also known as Face culture and can be interpreted as pride and self-esteem).<sup>5</sup> FW in non-school canteens rather than school canteens, and OFD, are not well reported. Students waste less food when they make more-active decisions on the food they ordered and paid for, suggesting buffet rather than set meals might reduce their FW. Finally, data from retail stages of FSC was scarce.

<sup>5</sup> Mianzi culture is further described and discussed in Section 3.4.2.1 culture factors.



### 3.3. FL&W impacts reported (question 3)

FL&W is a huge waste of resources, including land use, water and fertilizers. Applying an FAO food balance sheet and GTAP model, it was estimated that 276 million mu (18.4 million hectares (ha)) of sown area, 4.6 million tons of chemical fertilizer, and 31.6 billion m<sup>3</sup> of agricultural water were used in vain in China in 2009 (Hu et al., 2013). Across the whole country, the loss of water associated with FW reached 60.5 billion m<sup>3</sup> in 2010, which is more than 10% of China's total water usage (Sun et al., 2018). This estimate of water loss is broadly in line with another study estimating the loss to 135 ± 60 billion m<sup>3</sup> for 2010, which at the time was equivalent to the water footprint of Canada (Liu et al., 2013). The latter study also estimated that this level of FL&W was equivalent to 26 ± 11 million ha of wasted agricultural land use, or the total arable land of Mexico (Liu et al., 2013). Additionally, total phosphorus loss caused by FL&W along the entire FSC was estimated to be 424,400 tons in 2010, which was equivalent to 16.4% of the total mineral phosphate fertilizer consumption in China (Li, B. et al., 2020). It has been estimated that if the rice harvesting process loss rate dropped to 2.76% (from 3.02% in 2015) nationally, 78.41 thousand ha of arable land and 26.1 thousand tons (kt) of standardized fertilizer could be saved (Huang et al., 2018).

FL&W causes other serious environmental impacts, which can be assessed by its carbon footprint (CF), nitrogen footprint (NF), phosphorus footprint (PF), water footprint (WF) and ecological footprint (EF). For example, based on a lifecycle assessment of CHNS data, the environmental impacts of household FW were estimated for CF (40 kg CO<sub>2</sub>e/capita/year), WF (18 m<sup>3</sup>/capita/year) and EF (173 gm<sup>2</sup>/capita/year) (Song et al., 2015). Although the CF varied among provinces (from 30 to 96 kg CO<sub>2</sub>e/capita/year), animal derived food accounted for 18–40% of the CF, which was disproportionately high as it only accounted for 5–18% of the FW in weight (Song et al., 2018). On a city scale, in Shenzhen in 2015, avoidable household FW produced 1378 kt CO<sub>2</sub>e (Zhang, H. et al., 2018).

The environmental impacts of FW from university canteens and restaurants in Beijing, have been extensively studied. The data suggested that in terms of environmental impacts, restaurant generated FW was a more significant concern than FW from university canteens. For example, the annual FW in university canteens in 2018 caused up to 98.3 kt CO<sub>2</sub> eq CF, 7.72 kt NF, 0.85 kt PF and 46.4 km<sup>2</sup> EF, meaning 2.1% of all arable farmland in Beijing was used in vain (Wu et al., 2019). In comparison, four studies on the environmental impacts of FW from restaurants in Beijing (2013), used direct weighing and questionnaire data of 2564 tables in 124 restaurants to calculate values of 1925–2085 kt CO<sub>2</sub> eq CF, 0.22 g N/g NF, 40.56 g P/kg PF and 294.7 k nhm<sup>2</sup> EF (Zhang et al., 2016a, 2016b, 2016c, 2017).

For a special case like Lhasa, whose food supply is dependent on imports from other parts of China due to its plateau climate and less developed infrastructure, the total EF caused by Horeca FW was 50,556 ± 5208 ha in 2011, which increased by 41.5% to 71,516 ± 7705 ha in 2015 which is almost two times the arable land area of Lhasa (36,000 ha) (Wang, L.E. et al., 2018).

In addition, there is of course indirect economic savings associated with reducing FL&W. For example, it has been calculated that if FL&W (weight) in China was decreased by 1% the value of the increased food available for consumption would result in the CPI (consumer price index) reducing by 0.82% (Hu et al., 2013). Further, these authors postulate that owing to the fact that a decrease in FL&W will increase the availability of domestically produced food, reducing FL&W will help to decrease China's increasing reliance on imported food and hence indirectly benefit food security.

### 3.4. FL&W mediators reported (question 4)

#### 3.4.1. FL mediators

In the reported papers, the mediators for FL could mainly be

categorized as technological factors along the FSC (harvesting, post-harvest handling, storage and processing) such as the level of mechanization, the equipment availability, and the management practices used.

**Harvesting.** The amount of grain loss during harvesting was influenced by natural conditions such as the occurrence of abnormal weather, the number of insects present and the humidity in the field (Cao et al., 2018; Huang et al., 2018; Wu et al., 2017) and technological factors such as planting scale or the varieties planted (Cao et al., 2018; Huang et al., 2018; Wu et al., 2017). For example, wheat varieties with traits such as drought resistance or lodging resistance were less influenced by bad weather so their loss during harvesting was less (Cao et al., 2018). Operational factors such as low staffing levels during harvest could also significantly increase rice harvest losses (Wu et al., 2017).

Although 80.4% of rice throughout China was harvested by machine in 2014 (Huang et al., 2018), whether mechanical harvesting reduces the loss rate or not is still a matter of debate. A field study of 25 plots from six experiments conducted in five provinces in China in 2014 reported that combine harvesting (cutting and threshing by machine) had a significantly higher loss rates (1.18%–6.55%) than segmented harvesting (cutting by hand and threshing by machine) (<2%) (Huang et al., 2018). The high losses were attributed to local topography and the occurrence of typhoons. In contrast, another study investigated 1032 farmlets (households) in 20 provinces in 2016 and concluded that the use of machines in harvesting and transportation can reduce the loss rate (Qu et al., 2019). However, this result is seen as controversial and Gao et al. (2016) suggested that although harvesting was the second-largest contributor to postharvest loss (31.4%) there was not much potential for loss reduction by changing harvesting methods from segment to combined harvesting.

**Post-harvest handling.** Poor weather and inadequate grain drying facilities were the major reasons for FL during post-harvest handling. Indica rice which is produced in southern China where the weather is hot and humid, had nearly a 1.5 times higher loss rate (2.2%) than Japonica rice (1.27%) during post-harvest handling processes. This occurred because Japonica rice is mainly grown in the North which has a dry, cool climate, which means that FL during storage caused by spoilage is dramatically reduced (Lu et al., 2019).

**Storage.** Natural conditions such as humidity, or the presence of rodents, insect pests or mildew can increase FL. For example, based on research carried out on 1608 households in 28 provinces in 2015, the comprehensive loss rate was highest in the Southwest at 2.57% due to these regions having a more humid climate and a lower level of economic development. In China, the FL rate caused by the actions of rodents, insects and mildew varied between 1.75 and 2.41% for different crops (Luo et al., 2020).

The quality of storage facilities plays an important role in FL. Traditionally, when farmers stored grain in cabinets without any protection, the household storage loss of grains has been estimated to be in the range of 8–10% (He et al., 2013). Hence storage was historically the largest contributor to postharvest loss (40.3%), and by changing from traditional to scientific or depot storage, a large reduction in FL was possible (Gao et al., 2016). Owing to the establishment of the China National Grain Reserve Corporation in 2006, grain storage facilities and technologies have been continuously improved, and losses from storage have been effectively controlled (Luo et al., 2020). For example, zero loss rate can be achieved by nitrogen storage (Zheng, 2009). Research in 2019 reported that across 413 households in four major rice production provinces, all the rice produced by these households were stored in grain depots rather than in their own households (Lu et al., 2019).

**Processing.** Data on FL associated with industrially processed food is limited (Liu, 2014). Only one paper discussed the reason for rice loss during the initial processing owing to the technical inefficiency of equipment (Lu et al., 2019) and this paper reported that the total rice loss rate during processing in China was 1.84% in 2017, of which 1.17% was lost during the initial processing steps (paddy to rice), while 0.67%

was lost during secondary processing (rice to rice products like noodles etc.).

What's more, farmers' management practices such as ensuring a timely harvest, and operational meticulousness reduced grain harvest losses (Cao et al., 2018; Wu et al., 2017), while a rush to plant the next batch of crops increased the harvest losses (Cao et al., 2018). The excessive polishing of rice due to consumers' preference for 'fine and white' rice also caused more FL during processing (Lu et al., 2019).

In summary, some factors mediating FL such as the weather cannot be controlled but others such as the provision of secure storage facilities can be used to reduce FL. Whether machine harvesting can help to reduce FL further is still controversial, as this could be location dependent. In general, more data is required on the amount of FL during the initial processing stages. The management skills of farmers and manufacturers can also influence the FL amount being generated and hence this is also an area which requires additional research.

### 3.4.2. FW mediators

Mediating factors can affect FW by either increasing (+) it, reducing (-) it, or in some circumstances their impacts can be unclear to variables ( $\pm$ ). Stangherlin and de Barcellos (2018) classified mediating factors on FW as either societal factors (external context of influence, with socio-cultural factors that influence the individual, having both direct and indirect effect); personal factors (households characteristics and psychological influences, particularly from individuals); or behavioral factors (the behavior, habits and routines related to food provisioning) (Fig. 4). As consumers' behavior is influenced by the predominant culture, this was presented as an integrated variable affecting all of the dimensions analyzed.

**3.4.2.1. Culture factors.** Face culture (Mianzi) has a profound impact on traditional Chinese behavior, attitudes and social norms. It is interpreted as pride and self-esteem. An example of this is the presenting of an excessive number of dishes of food when entertaining guests as a means of showing great hospitality. This occurs because if all of the food presented is consumed during the meal, there is concern that this could be interpreted that the host had not prepared or ordered enough food. It is therefore not surprising that "Mianzi" has been shown to influence FW. For example, business banquets or gatherings of friends at large restaurants have been reported to generate more FW than generated during routine work meals or at private meals in small restaurants or snack bars (Wang et al., 2017; Wang et al., 2018; Xu et al., 2020; Zhang et al.,

2018b). Similarly, being seen to take food home from a restaurant in order to avoid wasting it could result in a loss of face (Liao et al., 2018). Consequently, it has been reported that people were more willing to take leftovers home if they had been dining in more-relaxed situations such as with their families, friends, classmates, or colleagues than with their business partners (Wang et al., 2016).

The cultural differences within China at different geographical locations also affects both the occurrence and the amount of FW. More household FW is reported to be produced in the Southern provinces than the Northern provinces (Jiang et al., 2018). This geographical difference was also observed in university canteens where students wasted more food in the Southern provinces than in the Northern ones (Qian et al., 2019). Similarly, FW patterns differ according to dietary habits, with consumers in Shanghai wasting more aquatic products than consumers in Lhasa, because Shanghai is a coastal city with a long history of consuming aquatic products while Lhasa is far inland and fish is rarely available at local restaurants (Wang et al., 2017).

FW was seen to be more common when people perceived that the wasted food came at no extra cost to them. Based on observations, casual conversation and in-depth interviews with 76 Chinese respondents on three international cruise ships, food abundance and the all-inclusive nature of the cruise packages were demonstrated to contribute to FW (Li and Wang, 2020). This finding was consistent with the results from a Western study where international tourists wasted food in a hotel in Slovenia because the breakfast was included in the room rate (Juvan et al., 2017).

In summary, Mianzi requires people to order large amounts of food as a show of hospitality and wealth, but at the same time wasteful spending and food waste are culturally viewed as being negative behaviors. How these two opposing cultural norms impact on the amount of FW generated in different settings has yet to be fully investigated.

**3.4.2.2. Societal factors.** There are two subgroups of societal factors that can influence FW at the consumer level: supply chain factors and regulatory factors.

**Supply chain factors.** Campaigns to raise awareness and to educate consumers of the adverse impacts of FW have targeted activities all along the FSC (Stangherlin and de Barcellos, 2018). "Clean Your Plate" is an example of an initiative first launched in January 2013 nationally in China. In 2015, 2016, the awareness of FW among university students in Changsha and Beijing was found to have slightly increased, although their willingness to "clean my plate" was still relatively low for reasons

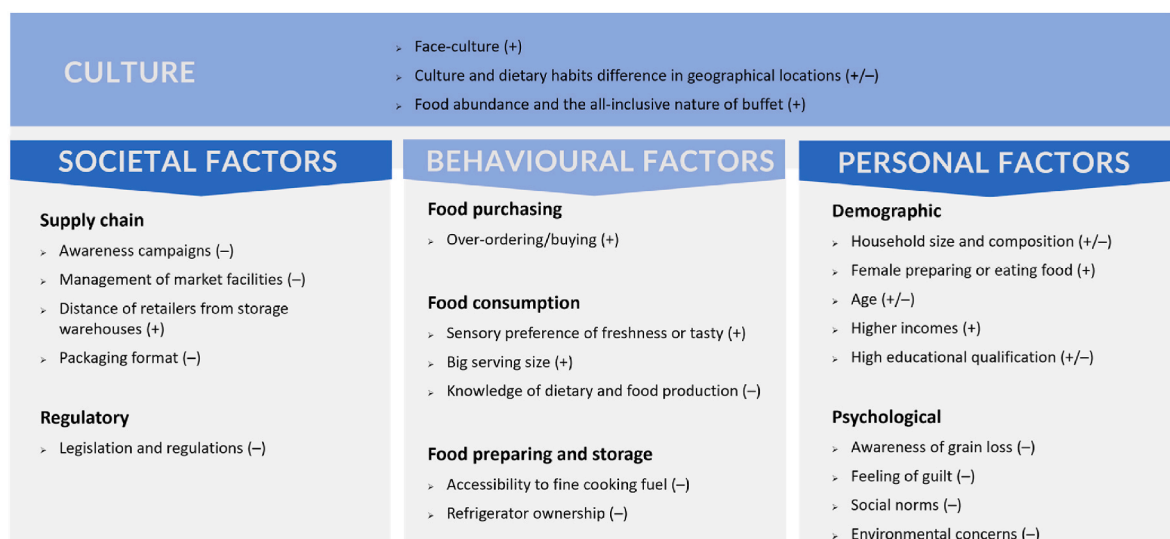


Fig. 4. Mediators of FW of FSC found in our review selection of papers, classified according to the scheme outlined in Stangherlin and de Barcellos (2018). ("+" indicates an increasing effect on FW, "-" indicates a reducing effect, while "+/-" means the effect is uncertain or unclear).

such as the poor taste of the food, serving sizes being too big, or concerns about gaining weight (Wang, Z.G. et al., 2018; Yang, 2017). In contrast, a 2017 study of 624 university students reported that as FW awareness increased, waste from poultry decreased (Li and Qian, 2018).

Many approaches to raise consumers awareness of the adverse impacts of FW have been reported: 237 university students in Beijing reported gaining information about FW from “slogans inside the canteen (77.49%)”, “media messages including TV and internet (53.25%)”, “slogans outside the canteen (48.92%)” or “word of mouth (25.74%)” (Wang, Z.G. et al., 2018). The effectiveness of different promotions has also been investigated in various settings. For example, in 2013, Zhang et al., 2018a placed leaflets inside menus or on tables to determine their influence of the FW behavior of restaurant customers in Beijing and Lhasa. It was found that more than 41.38% of consumers did not notice these leaflets and those who did had either a higher education, farming experience, or thrifty minds while in general people who did not notice them were aged over 40, or on higher incomes (Zhang et al., 2018a). In China, online information sources like Sina Weibo have been reported to be an effective vehicle for promoting FW reduction (Miroso et al., 2018). A study of 208 university students in Jilin, found that a 21-day intervention which involved the students receiving leaflets on a weekly basis and occasional posts to their WeChat accounts, resulted in a significant decrease in the frequency and volume of FW from OFD (Lin et al., 2019). Another study showed that putting the information into terms that people could better relate to such as “one third of food never reaches a human stomach” was more effective than general phrases such as “love food, hate waste” (Liao, F. et al., 2018).

*Management of market facilities and distance of retailers.* Based on a survey of 1890 grain sellers across 54 regions in 9 provinces, the quality of the grain storage options and the effectiveness of the supply and management of public market facilities (e.g., shops and warehouses, water, electricity, and roads to carry out sales and business activities) were correlated with the amount of grain loss during the sales (Chen et al., 2018). The same study also found that grain loss was higher in autumn and that loss was greater the further the retailers were from the warehouse.

*Packaging format.* The packaging format used for the selling of grain has also been reported to impact on the amount of retail FW. For example, vacuum packaging has reduced FL during grain distribution compared with the sacks and woven bags used in the 1990s (Wu, 1998). In addition, the loss rate of bulk rice has been reported to be 3.5 times higher than that of bagged rice, due to the spilling of it by consumers weighing out the amount they require and children playing with it (Lu et al., 2019).

*Regulatory factors.* Regulations, policies and strategies are important drivers for FW reduction in China. The implementation of the government’s “Eight Rules” in 2012 and social campaigns in Lhasa is believed to have been partly responsible for a decrease in FW from 128 g/capita/meal in 2011 to 98 g/capita/meal in 2015 (Wang, L.E. et al., 2018). This top-down initiative also targeted publicly-funded official, traditional governmental food extravagance which in 2015 resulted in a significant decrease in FW at large and medium-sized restaurants (219.61, 152.27 and 145.67 g/cap/meal in 2011, 2013 and 2015 respectively in large restaurants; 136.48, 96.14 and 62.41 g/cap/meal in 2011, 2013 and 2015 respectively in medium-sized restaurants) in Lhasa (Gao et al., 2017).

In summary, although there is a range of studies which have investigated the factors influencing consumer awareness of FW, their generalizability is not yet clear. Further these studies have mainly focused on understanding diners’ behavior in restaurants or cafeterias, rather than explicitly studying FW behaviors at home, which would be useful information to obtain. Studies have also not been reported on who maybe the most effective promoters of FW reduction e.g., celebrities versus senior politicians, understanding who are the most compelling advocates for FW reduction in China is of critical importance to encourage consumers to reduce their FW as are studies to assess the effectiveness of

multi-faceted media messaging (Xu et al., 2016). Future advances in FW prevention rely on central management through the provision/implementation of governmental policies relating to the quality of market facilities and regulations such as the 2021 law against FW (Anti-food Waste Law of the People’s Republic of China).

*3.4.2.3. Personal factors. Demographic factors.* Demographic factors that can impact on FW were associated with household characteristics and family composition. For example, larger households were reported to produce more FW than smaller households (Jiang et al., 2018; Zhang, H. et al., 2018) though people living alone were reported to generate more FW per capita (Song et al., 2015). Households with non-working members (e.g., children), adolescents (20–25 years) and older members (55–60 years) also generated more FW (Song et al., 2015). However, the number of children and adolescents in a household was not correlated to the occurrence or the amount of FW (Jiang et al., 2018). Interestingly, households with members engaged in intense physical activity such as loading, logging, mining, or stonecutting, consumed less food but generated more waste (Qi et al., 2020; Song et al., 2015).

In relation to gender, females tend to produce more waste than males, either when preparing food, eating in a canteen, or using OFD (Huang et al., 2017; Li, F. et al., 2017; Li and Qian, 2018; Lin et al., 2018; Qian et al., 2019; Wang et al., 2019; Wang, 2016; Wu et al., 2019).

Correlations with age differed with context. Based on a survey of 1890 grain sellers across 54 regions in 9 provinces found that as a grain seller’s age increased, the amount of grain loss increased (Chen et al., 2018). The age of the dominant family female has also been positively correlated to the household FW per capita, with FW increasing as age increased (Jiang et al., 2018). Interesting with restaurant dining, an “inverted U” relationship was reported between the amount and occurrence of FW against age (Wang, Y. et al., 2018; Zhang, P.P. et al., 2018b), in which FW was lowest for people under 30 or over 60.

Many empirical studies carried out in households, school canteens and restaurants have reported that higher disposable incomes correlate with increases in FW (Jiang et al., 2018; Li, F. et al., 2017; Qian et al., 2019; Wang et al., 2019; Wang, 2016; Wu et al., 2019; Xu et al., 2020; Zhang, H. et al., 2018; Zhang, P.P. et al., 2018b). On a national scale, both FW per capita and total FW were higher in the more economically-developed Eastern and Southern regions of China than elsewhere (Sun et al., 2018). In addition, rice harvest losses were reported to be significantly lower for those holdings where the family income was more dependent on the rice harvest compared to families that had other sources of income (such as being a migrant worker) (Wu et al., 2017).

A higher education levels has been reported to reduce FW in retail settings (Chen et al., 2018), households and canteens (Huang et al., 2017; Li and Qian, 2018; Qian et al., 2019; Song et al., 2015; Wu et al., 2019). It is generally assumed that urban residents are better-educated than their rural counterparts and they consequently generate less FW even though they consume more food (Qi et al., 2020; Song et al., 2015). However, Jiang et al. (2018) found that there was no significant difference in the occurrence or amount of FW between urban and rural families. However, it has been reported that students from an urban background waste more when dining in canteens than students from a rural background (Wang et al., 2019; Wang, 2016), possibly due to them having a higher disposable income. However, an “inverted U” relationship was reported by Zhang, P.P. et al. (2018b) who in 2015, investigated FW from 2293 tables in 159 catering companies across Beijing, Shanghai, Chengdu and Lhasa and reported that the amount of FW generated was the lowest for consumers who either only had a primary school education or for those that had a PhD.

*Psychological factors.* Psychological factors are intrinsic factors associated with each individual. For example, as a farmers’ awareness of grain loss increased, their loss rate decreased (Cao et al., 2018). In addition, a feelings of guilt about throwing food away and a belief that

saving food is the right thing to do have been reported as being key factors in preventing FW (Wang et al., 2019; Wang et al., 2018; Wang et al., 2018; Wu et al., 2019). Some university students have reported that they wasted food because they thought “others are all wasting food”. Therefore, developing social norms to reduce FW has been shown to influence individual behavior and to encourage them to reduce their FW regardless of if they are eating in a canteen or ordering food online (Lin et al., 2018; Wang et al., 2018; Wang, 2016). Moreover, individuals who stated that they had high environmental-protection awareness and concerns about resource utilization produce less FW and tended to behave in a more responsible way, such as taking leftovers home or purchasing abnormally-shaped vegetables (Loebnitz and Grunert, 2014; Wang, Y. et al., 2018; Wang, Y. et al., 2016).

The TPB is an appropriate theory to explain consumers' FW behavior (Liao, C. et al., 2018; Liao et al., 2020; Wang, 2016; Wu et al., 2019). Based on a survey of 961 consumers, their environmental attitude had the most significant impact on their willingness to reduce FW. Further, a willingness to reduce FW significantly decreased consumers' FW behaviors (Liao et al., 2020).

In summary, as the disposable income of China's population increases, it is likely that dietary choices will increasingly shift towards higher protein diets and the use of more OFD. These factors coupled with an increase in the number of elderly family members supported remotely by children with higher incomes may cause increases in FW unless suitable mitigation strategies are implemented. For example, social norms could be used to decrease FW by highlighting the shameful aspects of FW, thereby utilizing Mianzi culture as a mediator.

**3.4.2.4. Behavioral factors. Food purchasing.** The over-buying or over-ordering of food, caused by a lack of awareness of the portion size frequently occurs among people visiting a place that is new to them (Li et al., 2019; Wang et al., 2017; Xu et al., 2020; Zhang, P.P. et al., 2018b). In a study carried out in 2015 in 159 catering companies across Beijing, Shanghai, Chengdu, and Lhasa, tourists' FW (96.54 g/capita/meal) was 1.3 times higher than generated by residents (73.79 g/capita/meal) due to their unfamiliarity with the local food and a willingness to try more food (Zhang, P.P. et al., 2018b).

**Food consumption.** Sensory preferences such as a desire for fresh and tasty food is a significant reason for FW in household, canteens or online settings. A study of rural households in 25 provinces reported FW increased with family members' preferences for freshness, as they perceived leftovers as not being fresh and were unwilling to consume them (Li, F. et al., 2017). Students rated “unpalatable or unhygienic food” together with “large serving size” as their main reason for leaving food on their plate in canteens (Huang et al., 2017; Qian et al., 2019; Wang, Z.G. et al., 2018). Also, a study of 884 university students from Changchun, Jilin in 2018, reported that food ordered online was being wasted because it didn't meet taste expectations (Lin et al., 2018).

An individual's dietary knowledge has been reported to play an important role in reducing FW both in households and canteens (Liu et al., 2016). For example, based on the CHNS data for 2004, 2006 and 2009, it has been reported that improving dietary knowledge of the household food decision maker will help reduce food waste overall (Min et al., 2020). A lack of knowledge about food production has been reported to increase plate waste in middle and high school canteens in Beijing (Liu et al., 2016), a result which was consistent with the findings reported from school canteens in Spain (Derqui et al., 2018).

**Food preparing and storage.** In rural areas the accessibility of energy alternatives such as electricity or gas rather than firewood or coal for cooking and good storage conditions have been reported to significantly reduce FW (Li, F. et al., 2017). In addition, perhaps as could be expected refrigerator ownership has been reported to be the most important factor in reducing FW in Chinese households, presumably owing to less food waste occurring owing to a reduction in food spoilage and increased confidence in the safety of the food (Qi et al., 2020; Song et al., 2018) as

reported for other countries (Evans, 2012). However, education about how to use of the fridge correctly is required to ensure the quality and safety of food during storage.

In summary, providing better indications of portion sizes and food taste in restaurants, especially in tourist areas may reduce FW. The preference in China for fresh food is very strong, more research is required to better understand its influence on FW. Future changes could be influenced by central management through government initiatives such as increasing the availability of quality fuel and refrigeration.

## 4. Discussion

### 4.1. Current research gaps

In China, the published data of FL of the FSC is relatively incomplete and quite limited, with most of the research being limited to staple foods such as rice, wheat, and maize. Future studies could investigate the processing and distribution sector, especially at the retailer and wholesaler level, as per the SDG 12.3.1 guidelines.

Over the last few decades FL during grain storage has been the area most extensively research owing to the high level of FL associated with traditional household storage practices. This research has effectively helped to control FL during storage (Lu et al., 2019; Luo et al., 2020) and further technological and infrastructural improvements are continuing to reduce the postharvest FL of rice.

Direct weighing methods and questionnaires have been widely used in studies on FW at the consumption stage by CAS researchers (FW data collected in HORECA in cities), and the Nanjing University of Finance and Economics (FW data collected in 30 university canteens nationwide), followed by the calculation and estimation of FW based on modelling (De Clercq et al., 2016; Li, B. et al., 2020; Yang et al., 2020). More robust and representative measures of FW are still required for restaurants, canteens and other food service outlets in urban and a range of rural areas of China from, and the tracking of FW trends needs to be improved.

While the out-of-home FW has been measured using direct weighing and questionnaires, most data on household FW data has relied on the CHNS surveys (Jiang et al., 2018; Qi et al., 2020; Song et al., 2015, 2018). Other methods used have included weighing and reporting on FW quantities by the participants from rural households (Li, F. et al., 2017) and estimating the household FW in Shenzhen using survey questionnaires and data from the China statistical yearbook (Zhang, H. et al., 2018). Admittedly, the household is considered as a more private place, so the collecting of data is relatively more difficult than in the out-of-home scenario. However, in addition to the measurement methods used to date in China, other methods such as the use of a FW diary are suggested as a means to obtain a deeper and clearer view of household FW amounts and composition.

Restaurants and canteens are two major generators of out-of-home FW, as people who eat at restaurants (Wang, L.E. et al., 2016; Wang et al., 2017; Wang, L.E. et al., 2018; Zhang et al., 2017; Zhang, P.P. et al., 2018b) tend to waste more than those who eat in canteens (Liu et al., 2016; Qian et al., 2019; Wu et al., 2019; Zhu et al., 2020). This result indicates that people are likely to order more food than they need when they eat in a restaurant. This could be explained by the Mianzi culture because social event like gathering of friends or at business banquet were more likely to happen in the restaurants and people don't want to lose face by not ordering sufficient food or by taking leftovers home. However, in a canteen, most people are there for the sole purpose of eating and they are less likely to order more than they can consume. Admittedly, currently available canteen data has all been collected in schools, hence one of the possible reasons for a lower level of FW be reported for canteens could also be the lower disposable income of students. The widespread occurrence of canteens is somewhat unique to the culture in China, hence it would be interesting to study FW in canteens of companies, office buildings and governmental bodies.

Consumer FW in China has been reported to be higher in restaurants and canteens than in households, which appears to be a different result that reported for Western countries (Katajajuuri et al., 2014). For example, 74 g/meal/capita (Wu et al., 2019) in university canteens, which increased to 130 g/meal/capita (around 21% of total food served) for middle/high schools canteens in Beijing (Liu et al., 2016). In restaurants in four major cities (Beijing, Shanghai, Chengdu and Lhasa) the average FW was 93 g/meal/capita which is close to Western values, although the per capita GDP of China is still much lower (Wang et al., 2017). Recent data on household-level FW indicates it has declined from nearly 52 g/capita/day in the early 1990s to less than 41 g/capita/day in 2009 (Qi et al., 2020). However, this result may simply suggest that due to increases in disposable income and consumer consequently eating out, where the FW is being generated has simply moved from the home to the restaurant.

Only two papers have been published about more contemporary pathways for obtaining food such as through OFD, and although they included attitudes, they did not quantify the FW (Lin et al., 2018, 2019).

During the reviewing process of this paper, it became apparent that a number of relevant papers had been published since the systematic search and the manuscript's submission. While we have not included these recent papers in our analyses we believe it is important to acknowledge that FL&W is a rapidly growing research area in China and the number and range of papers being published is increasing, including papers by Qu et al. (2021), Xue et al. (2021) and Qian et al. (2021).

The data presented in this systematic review has captured a range of important mediators of FL&W. Some factors such as the impact of household size and composition on FW are now better understood, which may be important as China's population profile changes with increased urbanization and an ageing population. Technological and behavioral factors, encompassing storage conditions and food handling still have room for improvements. However, it is apparent in the international consumer FW literature that a much wider range of mediators exist that have not yet been discussed in the context of China. Whether this is because they simply do not exist due to cultural and contextual differences, or they have not been yet been revealed because the relevant literature is still in its infancy, remains to be seen. As previously signaled, to-date only a handful of theoretical frameworks have been used to support the studies examining Chinese FW behavior. A rich range of behavioral theories exist which have been shown to offer interesting insights in consumer FW in other countries. Broadly speaking, these contributions can be categorized into two social ontologies which offer different conceptualizations of behavior and change: socio-psychology-oriented approaches, and social practice theory (Schanes et al., 2018). Socio-psychological-oriented approaches come from the fields of consumer behavior and environmental psychology and aim to measure specific intra-personal factors and processes influencing FW behaviors such attitudes, concerns, personal norms, intentions, and motivations. The most common of these approaches to study FW is the theory of planned behavior which can help establish causal relationships between attitudes, norms, knowledge, and intentions to reduce FW. The other group of theories, rooted in sociology, evolve around social practice theory. These practice approaches differ from the psychology approaches in that they acknowledge that FW behavior is often influenced by wider factors deemed beyond control of individuals who are embedded in wider social, economic, and cultural facets of everyday life. Studies taking this approach have offered useful insights in relation to daily FW-related procedures and processes at the household level. Both strands of psychology-orientated and social practice theory approaches have contributed significantly to a better understanding of the complex phenomena of FW and moving forward, the Chinese-focused literature would benefit from the integration of these different disciplinary perspectives.

Efforts to move consumers closer to an anti-FL&W behavior require macro-environmental change, restaurants' engagement, increased awareness of the issues, and the creation of new social norms. Different

actors of the FSC must collaborate to move into anti-FL&W patterns of behavior.

Finally, the gaps identified in the literature also serve as the basis for managerial implications, as summarized in Table 4.

#### 4.2. Potential new research areas

Our systematic review of the literature has provided insights into the complex nature of the prior research on FL&W along the FSC in China, and has enabled us to identify several research gaps (Table 5), such as in robustness of the methods used; the geographic coverage; demographic factors; behavioral manifestations and the relevant lack of studies grounded with a theoretical framework. The extensive analysis of the selected studies resulted in the development of a framework for research and provides useful inferences for practice.

### 5. Conclusion

Our systematic review methodology only produced a few empirical studies about FL at the pre-consumption stage in China, because of the difference in the search terms used in English and Chinese databases. As we had anticipated, the standard terminology did not capture the diversity of terms used in China, which may have resulted in some relevant research not being included. Future researchers may need to further specify the search terms in Chinese to include more relevant studies and to address in more detail other types of food commodities such as fruit and vegetables, aquatic products and meat.

Although we have applied the Target SDG 12.3.1 guide to define the boundaries of FL&W in relation to the FSC, the data was difficult to disaggregate from previous articles due to the different definitions of boundaries in various former frameworks. We suggest the use of SDG 12.3.1 in future empirical studies and reviews, especially clear delineation of different stages of FSC.

Dining modes that are becoming increasingly popular such as OFD have to date been mostly overlooked for research on FL&W. Owing to the development of E-commerce and the increasing fast pace of life in the big cities in China, OFD is a rapidly growing segment in the dining industry (Li et al., 2020). This is an interesting research area because food is prepared in the catering sectors such as restaurants and cafés but consumed in a more private condition like households or offices. Do people waste food when they eat a delivered meal? How much do they throw away? Are the factors driving FW in restaurants different from

**Table 4**  
Research gaps identified, and their managerial implications.

Research gaps	Managerial Implications
Data-related issues (e.g., sample size, lack of theory, representativeness)	The available research findings are not robust and generalizable, in order to provide more robust and international comparable data, SDG indicator 12.3.1 b, also referred to as the FWI should be used when measuring FL&W at national level in China. The use of both psychological-oriented and social practice approaches to enhance understanding of FW
Lack of comprehensive and simultaneous testing of various nudges and interventions to reduce FW at both the restaurant staff and consumer levels	Knowing the kind of nudging measures that are effective for their type of establishment means managers can successfully apply these to encourage customers to select products and make behavioral choices that lead to less FW
A limited number of behavioral variables and FW hot spots have been explored	Knowledge about satiety, food choices, health-related food preferences, personal factors, and the variety of FW hot spots can help managers in developing menus more effectively and determining portion sizes to reduce FW

**Table 5**  
Setting a future research agenda.

Thematic Foci	Potential Research Questions (RQs)
Causes of FL&W	What theories could be used to explain FL&W behavior of Chinese consumers? How can a better understanding of the causes of FL&W help to reduce FL&W?
Culture and demographic factors	What does the role of Mianzi culture play in FW when dining with different people, such as families, friends, colleagues and guests? Is there a cultural aspect that influences the FW in different regions? Does the composition of FW change with age and gender? Should different menus be developed based on demographic factors to reduce FW?
Stages of FL&W generation	What is the amount of FL in fruit and vegetables in the pre-consumption stage? What is the FL in meat and aquatic products in the pre-consumption stage? What is the FL in processing stage? What is the FL in retail sector, such as wholesale and supermarket?
FW by the type of establishment	How much FW is generated in canteens of companies, office buildings and government bodies? How can school lunch programs help to reduce FW among children? What would be the outcome of offering buffets in schools instead of set meal? Is the variation in FW in different types of restaurants related to menu choices and the profile of the diners?
Impact of FL&W	What is the level of awareness among consumers about the link between FW and nutritional loss? Are the consumers aware of the impact of FL on food security?
“Nudges” to reduce FL&W	What is the role of government intervention on FW, such as legal requirement? Can the same nudges be introduced at different types of food service establishments to reduce FW? What is the efficacy of awareness campaigns in reducing FW at different food service establishments?
Handling of “wasted” food	What are the challenges and opportunities of running food banks in China? What are the issues in donating food to charity?
FL&W control practices	Is it worthwhile to expend effort in undertaking composition analysis of the waste collected? Can the knowledge of FW hot spots aid in developing a better menu and portion size to reduce FW?

those driving FW in OFD? i.e. do they still consider ‘Mianzi’ as they order food online? These are promising avenues to explore in the future.

#### Author contributions

Conceptualization, P.B. and M.M.; Methodology, M.M., P.B. and C.L.; Data collection and analysis, C.L.; Writing—original draft preparation, C.L.; Writing—review and editing, M.M., P.B., M.K.H., M.S.W., K.P., and E.G.; Supervision, M.M. and P.B.; Project administration, M.M. and P.B.; Funding acquisition, M.M., P.B., M.K.H., M.S.W., K.P., and E.G.; . All authors have read and agreed to the published version of the manuscript.

#### 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.

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#### Appendix A. Supplementary data

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