Food losses and food waste in China: a first estimate

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Executive summary

Reducing food losses and food waste is attracting growing public attention at the international, regional, and national levels, and is widely acknowledged to contribute to abating interlinked sustainability challenges such as food security, climate change, and water shortage. However, the pattern and scale of food waste throughout the supply chain remains poorly understood for developing countries such as China, despite growing media coverage and public concerns in recent years. The data in the literature are either out of date or fragmented. This report aims at a first crude estimate of food losses and food waste in China, based on literature data, informed estimates, and other public available information.

The main conclusions are as follows: (i) Information on the quantity of food loss and waste along the various stages of food value chain is deficient and rarely complete, with most of the previous estimates found to be relatively limited to staple food such as rice, wheat, and maize (or *liangshi* in Chinese). (ii) Storage contributes the most to postharvest losses for all types of food (e.g., 5.7-8.6% for grain, 2.5-3.7% for meats, and 10-15% for perishable food). One notable reason behind this is the decentralized agricultural system in China. (iii) Technological and infrastructural change in the past decades are likely to have reduced the postharvest food losses, while consumer food waste is expected to have ballooned due to growing affluence and escalating urbanization. (iv)The majority of consumer food waste is found in the catering and restaurant sector rather than at the household level, which appears the opposite of that in western countries. (v) China has established a decent regulatory framework dealing with waste in general, however, this framework is not specifically adapted to food loss and waste, and the relevant government ministries and agencies are currently working rather independently.

Since there are seldom official statistics, the presented data have to be interpreted tentatively. However, it provides an order of magnitude estimate and can help inform the public and policy-makers how serious the problem is and where actions are urgently needed.

1. Introduction

1.1 Food supply, demand, and security in China

Food security has been one of the top priorities and challenges for human societies, particularly for large developing countries like China. It remains a critical challenge and a global concern if China could feed roughly 20% of the world's population with only 7% of its arable land (Brown 1994; Smil 1995; Larson 2013). The country has demonstrated a remarkable success in increasing agricultural production and in feeding better its growing population in the past several decades. As shown in Figure 1, for example, its annual grain production has increased from 113 Mt in 1949 to a level of approximately 500 Mt in recent years and has kept an increasing trend for nine consecutive years since 2004. Consequently, the number of undernourished people has been reduced from 21% in 1990 to 12% today (OECD and FAO 2013). The self-sufficiency ratio of grain stabilized above 95% in most of the years, and fell below 95% only after 2007 because of the sharp rise of China's soybean import (which ballooned from near negligible before 1995 to 54.8 Mt in 2010 and reflects China's exponential growth of trade of certain agricultural commodities after its WTO accession) for feed grain and edible oil.

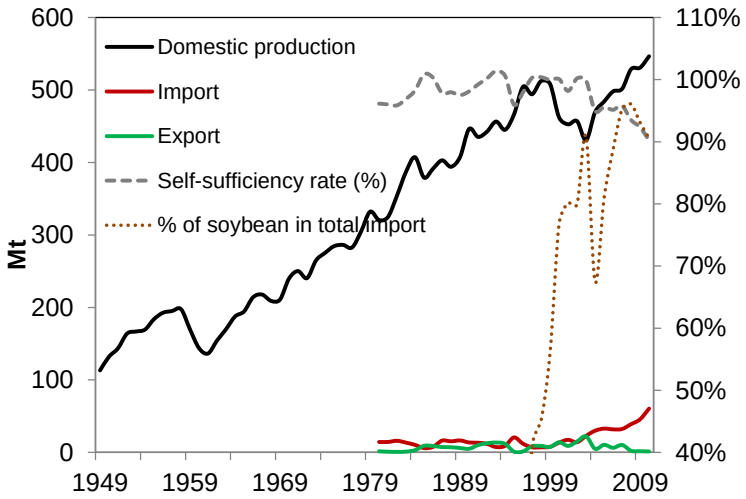


Figure 1. Domestic production, import, export, and self-sufficiency ratio of grain (including rice, wheat, maize, and soybeans in the Chinese statistics; see details in section 1.3) in China, 1949-2010. Data source: National Bureau of Statistics of China.

However, several issues are expected to cloud or challenge China's continuous efforts to meet its growing domestic demand for food in both quantity and quality and to improve its food security in the coming decades.

- While China is expected to remain self-sufficient in major grain crops, the overall gap between demand and supply is very likely to increase. According to a recent projection by the OECD and FAO, China's agricultural growth is expected to slow down over the next decade (2013-2022), with production growing by 1.7% annually but consumption by 1.9% annually (OECD and FAO 2013). These trends anticipate a further but modest opening of China's agricultural sector and may have a major influence on world markets.
- The increasing urbanization of China and rising affluence of its residents has led to several challenges, e.g., agricultural land loss and dietary change. China's arable land is already edging dangerously close to the "red line" of 1.8 billion mu (about 120 million hectare) needed to ensure its grain security (Liu et al. 2012), with a per-capita level (0.09 hectare) only about 40% of the world average in 2011 (NDRC 2009a). Growing rural-urban migration has resulted in not only a shortage of rural labors for food production, but also a potential increase

of income and thus a gradual change of dietary habits (less grain, more vegetables and animal and aquatic products; see Figure 2) in the future.

- Serious global and regional environmental challenges are fueling increasing concerns about food security. China's agricultural production has already been constrained by its limited and unevenly distributed land and water resources, which may continue shrinking in the face of global climate change (Liu et al. 2013b; Zhao and Huang 2011a). The excessive application of agrochemicals (chemical fertilizers, plastic films, and pesticides), meanwhile, leads to a serious deterioration of arable soil and nonpoint-source pollution. The average national use of chemical fertilizers has increased six-fold since 1975 and far exceeds the world average (Liu et al. 2012). These environmental consequences will further constrain the growth of China's food production.

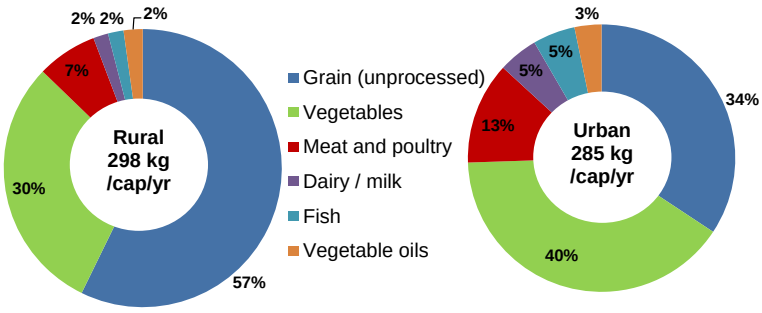


Figure 2. Rural and urban diet structure in China in 2011. Data source: National Bureau of Statistics of China. Note data exclude consumption outside the household and weights of measurement may differ from data of other sources.

1.2 Food losses and food waste in China: with both eyes open

As the economic and environmental costs of crop yield increase are getting higher and other efforts from the supply side are becoming more difficult, food security issue is further complicated by the fact that a considerable amount of food is lost or wasted along the entire life cycle (Liu et al. 2013a). FAO has estimated that roughly one third of the annual food production in the world (or 1.3 billion tons) does not reach the consumer mouth (Gustavsson et al. 2011). Many other estimates have shown similar range (Hall et al. 2009; Beretta et al. 2013; Monier et al. 2010; Fox 2013). For example, the UK Waste and Resources Action Programme (WRAP) found that the food wasted per year is 22-25% of that purchased (by weight) in the UK (WRAP 2009). All these remarkable numbers remind us that it is important and necessary to have both our eyes open on food value chain: not only to increase the on-farm production, but also to reduce the post farm-gate food losses and food waste.

Chinese agricultural development boasts a long standing of history. However, the agricultural production system in China has long been based on small-scale production, with about 240 million small farmers involved currently (Zhao and Huang 2011b). This decentralized operation system induces not only a conflict with the process of agricultural modernization, but also a low efficiency in production and post-harvest handling. Being still a developing country and a vast country with huge west-east disparity, China suffers a lot in the post-harvest food losses as many other developing countries do, due to inadequate infrastructure, knowledge, and technology (Gustavsson et al. 2011; Parfitt et al. 2010; FAO 2012; UNEP 2012; Hodges et al. 2011; Liu et al. 2013a).

Even more striking is the increasing affluence and skyrocketing catering sector in China and the consequent food waste at consumer stage. The past decades since China's reform and opening-up policy in the late 1970s have witnessed an economy miracle in this country. Meanwhile, the annual

income of Chinese urban and rural residents has substantially increased (about 30-fold for rural household net income and 40-fold for urban household disposable income over the 1980-2010 period), and the retail sales of catering sector have ballooned from 8 billion Yuan in 1980 to 1.8 trillion Yuan in 2009 (see Figure 3). According to data of National Bureau of Statistics, during the five years from 2007 to 2011 when global financial crisis prevailed, the revenue of catering industry has maintained a steady annual growth of about 14% (Deloitte 2012). As increasingly prosperous and busy consumers in China are eating more and more meals away from home (Bai et al. 2010), food waste generated in the restaurant and catering sector has also sharply increased and raised growing public concerns in recent years.

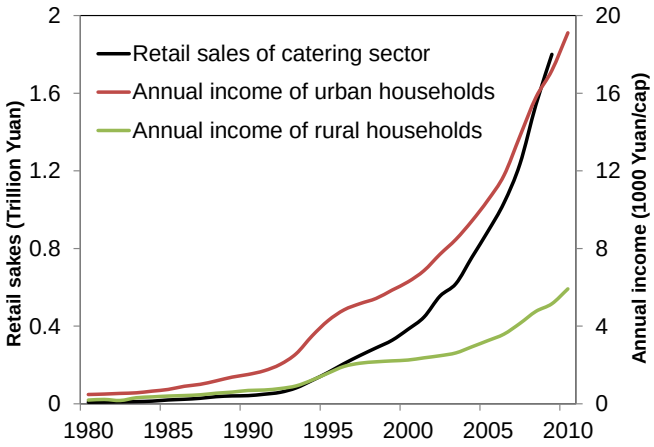


Figure 3. Retail sales of catering sector (trillion Yuan) and per capita annual income (1000 Yuan) of urban and rural households in China, 1980-2010. Numbers are in nominal terms. Data source: National Bureau of Statistics of China.

The enormous food losses and food waste lead to serious environmental consequences in two ways: (i) a waste of upstream resource inputs, e.g., water (Ridoutt et al. 2010; Lundqvist et al. 2008), land use (Kummu et al. 2012), and energy (Cuéllar and Webber 2010), and their embodied environmental impacts, e.g., greenhouse gas emissions (WRAP and WWF 2011; Reynolds et al. 2012; Venkat 2012); and (ii) downstream waste disposal and environmental impacts (Dorward 2012; Garnett 2011; Kim et al. 2013).

In China, municipal solid waste (MSW) generation has kept an 8-10% increase in recent years and reached 352 Mt (or 440 kg/cap) in 2010. Food waste takes up a high share in MSW in almost all cities (see Table 1), roughly ranging from 50% to 70% (Tai et al. 2011), and most of them are mixed with other solid waste in MSW and eventually incinerated and landfilled (for example, on a national average 56.6% was landfilled in 2009) (Hu et al. 2012). This exerts growing pressure on waste management and consequent environmental impacts (e.g., water pollution, soil degradation, GHG emissions) mitigation in urban areas.

Table 1. Quantity of food waste and its share in MSW in the eight pilot cities in 2008 (Tai et al. 2011)

	Food waste amount (tonnes/day)	Share in MSW (%)
Beijing	725.84	66.19
Shanghai	588.33	71.14
Guangzhou	268.79	52.00
Shenzhen	300.26	51.10
Hangzhou	129.85	53.00
Nanjing	137.65	70.59
Xiamen	74.33	74.63
Guilin	15.20	61.31

Therefore, reducing food losses and food waste means not only a necessity to ensure food security, but also offers an opportunity to mitigate various environmental impacts. Finding those opportunities, however, requires an understanding of the pattern and scale of food waste throughout the supply chain and the relevant policy and regulatory framework (Fox 2013). This information remains poorly understood for China, despite growing media coverage and public concerns in recent years. The data in the literature are either out of date and fragmented as for many other developing countries (Parfitt et al. 2010), or not so country specific (for example, in the FAO report (Gustavsson et al. 2011), China has been aggregated together with Japan and South Korea in the "Industrialized Asia"). This report aims at providing an overview and a first systematic estimate of food losses and food waste in China, based on literature data, informed estimates, and other public available information.

1.3 Food value chain and definition of food waste

A food value chain was described in Figure 4. Food losses and food waste occur at various stages of the chain, and can be defined and measured in different ways and units as shown in the literature (Table 2). The definitions of food loss or food waste greatly vary depending on country or research angle, and there is apparently no universal consensus yet on the definitions and measurements of food waste. According to FAO, food losses refer to "the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption" and "food losses occurring at the end of the food chain are rather called food waste" (Gustavsson et al. 2011; Parfitt et al. 2010).

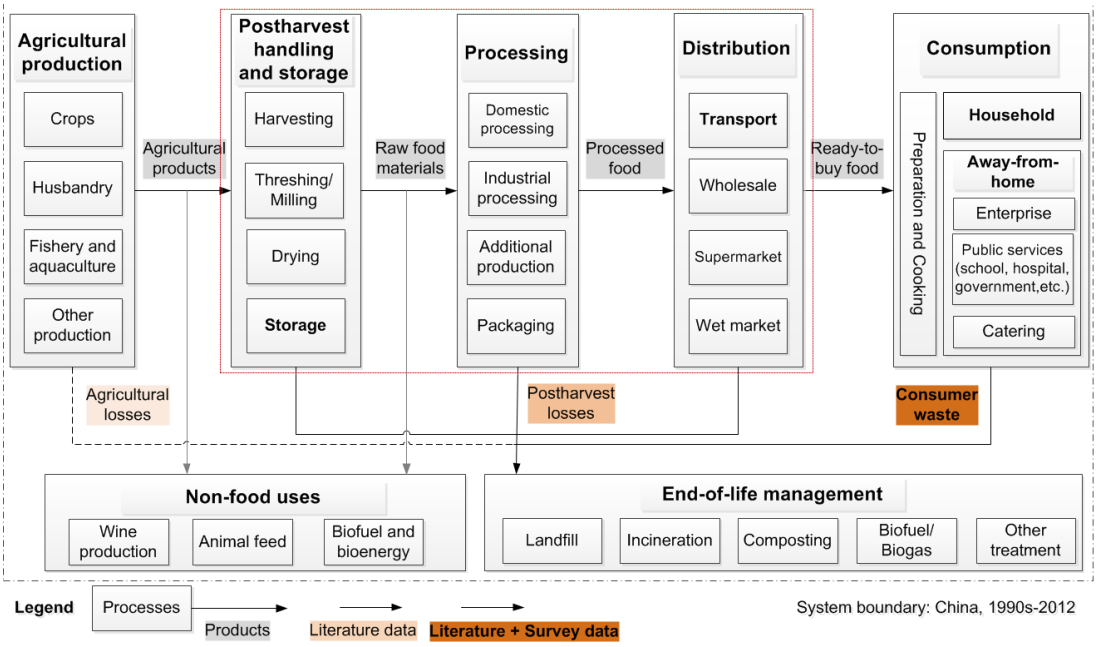


Figure 4. Food losses and food waste along the different stages of the food value chain.

Within this report, we refer pre-consumer stage losses as "food losses" and consumer stage loss as "food waste". We have differentiated three main life cycle stages that food waste could be found: agricultural production stage (on-farm losses before the process of harvesting begins), post-harvest (between harvesting and human consumption, including harvesting, storage, processing, and distribution) stage, and consumer stage (both at the household level and for meals away from home). Non-food use that gets out of the food chain has also been identified and quantified. Note this is only a conceptually visualization of the food production and consumption system. Therefore it may not represent a strict step-by-step flow of food and there are overlaps between different processes. For

example, storage may occur at processing and distribution stages as well and transportation occurs at almost each stage.

There are seldom data on food waste from official governmental statistics in China. We thus have to make a first estimate additionally based on two "unofficial" sources: (i) data from several first-hand field survey, and (ii) data from peer-reviewed publication, expert interviews, and gray literature (e.g., reports published by industry groups and non-governmental organizations). We prefer to use first-hand data when possible. The data cover a wide range both over space (mainly different provinces within China) and through time (from early 1990s to 2012), although we try to use the data for some mid- and late 2000s and for national average if possible. This means we present only a "best estimate snapshot" for the current food waste situation in China which should be cautiously interpreted for any temporal or interregional comparisons.

Avoidable or unavoidable data of food waste are not available for China. Therefore food loss and food waste figures presented in this report cover both avoidable and unavoidable parts.

Whenever possible, we have tried to distinguish different types of food, for example cereals, roots and tubers, oil crops and pulses, fruits and vegetables, meats, and aquatic products. Important to mention is that the definition of food commodities is slightly different in China: "*Liangshi"* in the Chinese statistics, which can be roughly translated as "staple food", includes not only "cereals" in the FAO statistics or "grain" in the USDA statistics (i.e., wheat, rice, maize), but also potatoes (as "roots and tubers" in the FAO statistics) and soybeans (as "oilseeds and pulses" in the FAO statistics). Since the data often cannot be disaggregated, we keep using *liangshi* as a separate type.

Table 2. Definition, measurement unit, and determining approach of food losses and food waste.

	Sub-type	Note	Example
Definition	Life cycle perspective	"food losses" (pre-consumer stage) v.s. "food waste" (consumer stage)	(Parfitt et al. 2010)
	Moral perspective	"human consumption" v.s. "non-food use (animal feed, bioenergy, etc.)"	(Gustavsson et al. 2011)
	Functional perspective	"avoidable" (edible) v.s. "possibly avoidable" (can be eaten) v.s. "unavoidable" (not edible under normal circumstances)	(WRAP 2011)
Measurement unit	By weight	kg (absolute or percentage)	
	By calorific or nutritional value	joule/calorie (absolute or percentage)	
	By monetary value	dollar (absolute or percentage)	
Determining approach	Bottom-up	average or scale-up based on survey	
	Top-down	total food supply minus calculated food consumption	(Hall et al. 2009)

2. Collection and verification of statistical data on food loss and waste in China

2.1 Agricultural losses

Losses of agricultural products occur already at the initial stage of farm gate. Agricultural losses of vegetable commodities and products are mainly caused by diseases, insects, weeds, and rodents, severe weather during planting, and inefficient seeding. Agricultural losses of animal commodities and products refer mainly to death and sickness before post-harvest handling (animal death during breeding for bovine, pork, and poultry meat; discards during fishing for fish; and decreased milk production due to dairy cow sickness (mastitis) for milk).

We have presented the results of agricultural losses for main vegetable and animal commodities and products in China as a "candle stick" stock chart in Figure 5. Note that all the detailed information for references we used is documented in the Appendix and the supplementary spreadsheet (the same for Figures 6). The eleven case studies for *liangshi* (grain) suggest approximately an average agricultural loss of 5-9% (the average is calculated as ±20% of the median value when there are more than five samples, and otherwise estimated by the author), with the highest estimate as 15% and the lowest estimate as 1.7%. Pre-harvest infections (e.g., pests) and natural disasters (e.g., draught) contribute the most to such a loss. For example, according to China Agriculture Statistical Report, 21.6 Mt of grain (or about 4% of the output) was lost due to diseases, insects, weeds, and rodents in 2010. Additionally, the low efficiency of seeding has also resulted in a certain loss: About 20 Mt of grain is used for seeding each year in China, which can be reduced by 40% when compared to the efficiency in industrialized countries (唐为民 1998).

There are very few estimates (only one to two) for fruits and vegetables and animal commodities and products. It is estimated that 20-30% of fruits and vegetables are lost at the agricultural stage. For different types of meat, a loss of 5-10% can be observed.

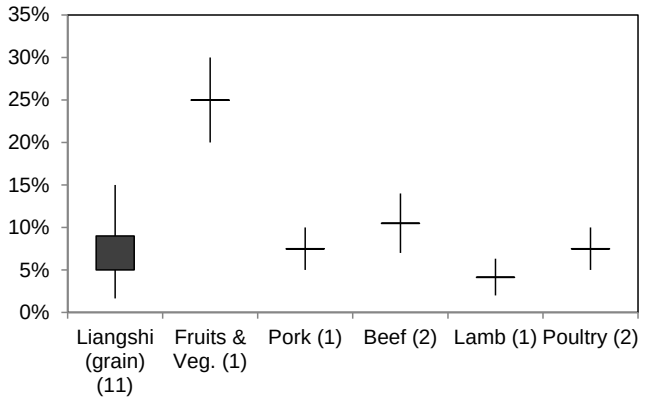


Figure 5. Agricultural losses of main vegetable and animal commodities and products in China. The candle sticks represent the maximum, the average (±20% of the median if there are over five samples, otherwise the author's estimate), and the minimum from top to bottom. The numbers in the brackets indicate the number of case studies we found in the literature. Data sources are detailed in the Appendix and the supplementary spreadsheet.

2.2 Postharvest food losses

Post-harvest losses refer to food damage and degradation during different post-harvest handling and processing stages from the beginning and completion of harvesting to the moment of final consumption. They include harvesting losses, such as when grain is threshed, winnowed, and dried or when animals are transported to the slaughterhouse, as well as losses along the chain during transportation, storage, and processing. We aggregate them into four sub-stages, post-harvest handling (i.e., harvesting, threshing, and milling, and drying), storage, processing, and distribution, and present the results for different food commodities and products in Figure 6.

By food commodity and product:

Because China's food supply has constantly and largely been depending on staple food such as rice, wheat, and maize, most of the previous estimates for postharvest food losses concentrate on *liangshi* (grain). The majority of grain losses, as shown in Figure 6(a), are found in post-harvest handling (4-6% on average) and storage (5.7-8.6% on average). In processing and distribution, the average loss of grain is 2.2-3.3% and 1-1.5%, respectively.

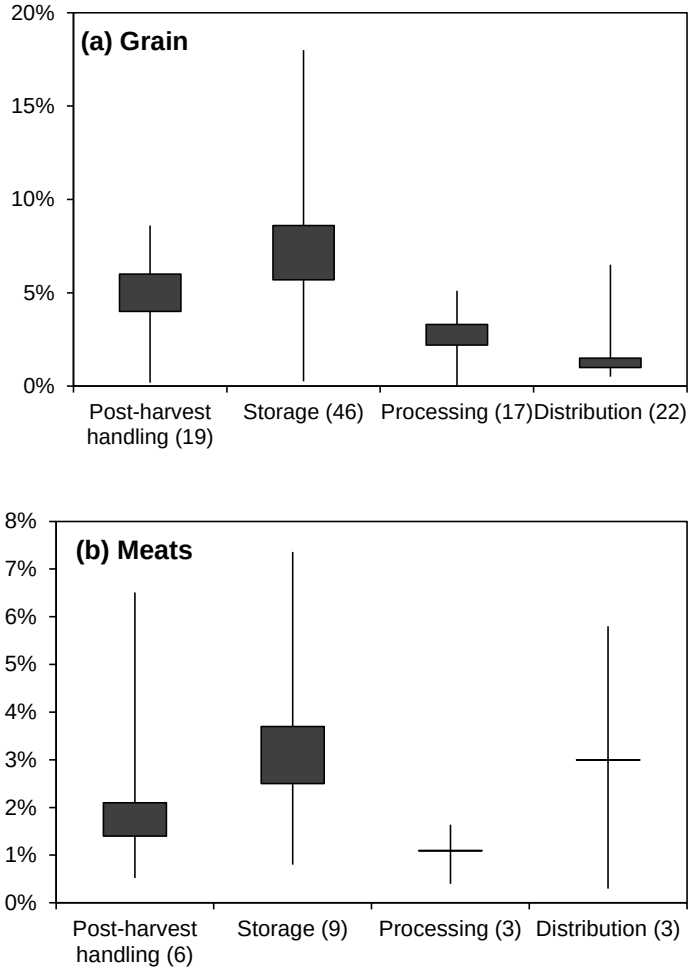
There are fewer studies for postharvest losses of meats (Figure 6(b)). The loss rate at post-harvest handling, storage, processing, and distribution stages of meats can be approximated as 1.4-2.1%, 2.5-3.7%, 1.1%, and 3%, respectively. One study also estimates that about 2%, 4%, and 3.2% of fish and aquatic products are lost at the harvesting, storage, and distribution stages, respectively (许世卫 2007).

Perishable food such as fruits and vegetables shows a high postharvest loss (Figure 6(c)). In storage and distribution, the average loss of fruits and vegetables is estimated as 15% and 10%, respectively.

By life cycle stage:

Storage. Figure 6 clearly demonstrates that storage contributes the most to postharvest losses for all types of food. One notable reason behind this is the decentralized agricultural system in China. According to State Administration of Grain's "Special Programme for Construction of Scientific Grain Storage in Rural Households in the 12th Five Year (2011-2015) Plan", there are currently about 250 million rural households in China, in which over 85% is involved in grain production (SAG and NDRC 2011).

China's grain storage appears as a pyramid structure (Figure 7): over 50% of grain is stored by farmer households (despite a decrease from 70-80% in the 1990s), 25% by commercial enterprises, and the remaining 25% by local and central governments (Wu 2012). While the governmental granary shows a low loss rate (less than 0.5%, close to the level in in industrialized countries), high storage losses are found at farmer households when the grain is being stored for auto-consumption (normally half a year to a year) or while the farmer awaits a selling opportunity or a rise in prices.



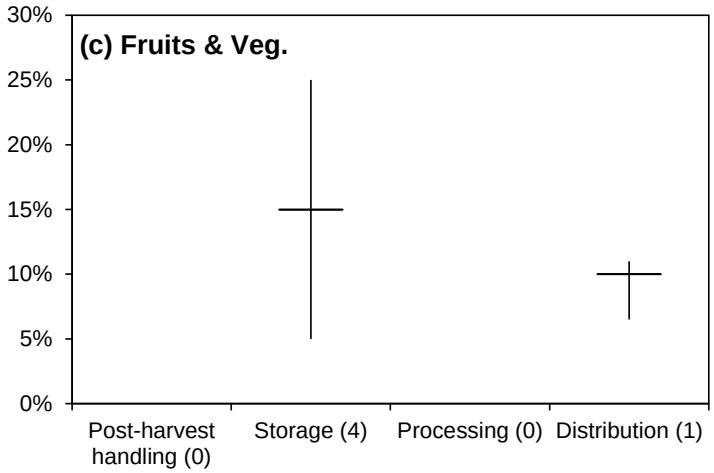


Figure 6. Postharvest losses of *liangshi* (a), meats (b), and fruits and vegetables (c) in China at different stages. Data sources are detailed in the Appendix and the supplementary spreadsheet.

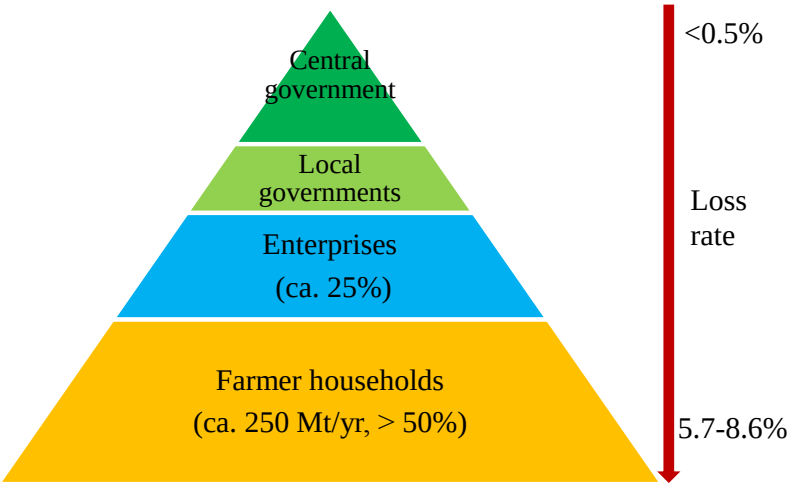


Figure 7. The pyramid structure of grain storage and associated loss rate in China. Data sources are detailed in the Appendix and the supplementary spreadsheet.

Grain losses at farmer household storage are mainly caused by insects, fungi, and rodents because of their insufficient awareness, knowledge, and infrastructure (see an illustration of household and national granary in Figure 8). In a survey funded by Ministry of Agriculture in 2011, 58.6%, 32.3%, and 55.2% of the over 700 sample households across China have reported cereal storage losses resulting from insect infestations, mold damage, rat infestations, respectively (赵妍 et al. 2011). On average, it was estimated that 49%, 30%, and 21% of China's grain loss is caused by rodents, fungi, and insects, respectively (SAG and NDRC 2011).

Figure 8. Simple household granary (e.g., pottery, jute sacks, and plastic bags) compared to modern governmental granary in Shandong province. Photos credited to Fengliang Chen, Shandong Academy of Agricultural Sciences.

Although there are no official statistics on the amount of food losses during storage, our estimates above appear in the same range as recently quoted by two governmental officers, Mr. Ren Zhengxiao, director of State Administration of Grain, China (Ren 2013) and Mr. Zhang Tianzuo, director of the Bureau of Agricultural Products Processing, Ministry of Agriculture, China (Zhang 2012) (see Mr. Zhang's estimate for the percentage and volume of food loss at storage in Table 3).

Table 3. Food losses at the storage stage in China, estimated by Zhang Tianzuo, director of the Bureau of Agricultural Products Processing, Ministry of Agriculture (Zhang 2012).

Food type	Percentage of loss	Volume of loss in 2011
Liangshi	7%-10%	15-22.5 Mt
Vegetables	15%-20%	100 Mt
Fruits	10%-15%	14 Mt
Potatos	15-25%	16 Mt

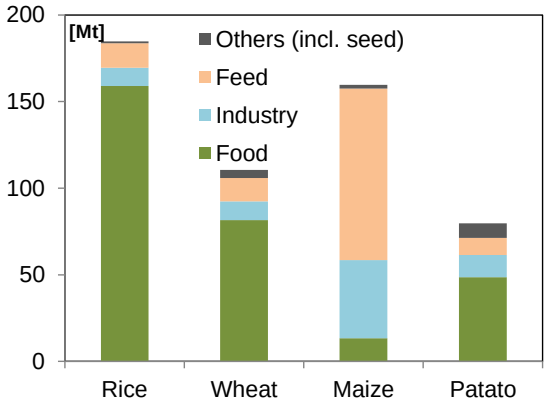


Figure 9. Consumption structure of main grain crops in China in 2010 (姜长云 2012; Jin 2012)

Processing. As the gradual improvement of people's living standards and change of their daily diet structure in China, the main source of staple food supply has already shifted from household to market. According to a survey by Ministry of Agriculture, 70% of the urban households and 40% of rural households in China already rely on market supply for daily ready-to-eat food. However, currently only a small fraction of food in China is industrially processed (see consumption structure of main grain crops in Figure 9) and the efficiency of food processing and retailing is still very low, resulting

in a considerable loss of food. For example, as high as 69% of China's potato is consumed as fresh (not processed) potatoes (Reardon et al. 2012). In comparison, this fresh consumption ratio of potato is only 22% in industrialized countries such as Canada (Lupescu and Gray 2012).

Distribution. Losses in transportation and distribution occur mainly because mechanized bulk handling is not yet popularized in China. For example, over 80% of grain is still loaded and unloaded in bags during transportation and the manually transported jute sacks are still widely used across China (Xi 2010).

Geographical and temporal variation:

Since these sparse literature data cover a wide range of years and locations, it is difficult to generate statistically meaningful temporal trends or geographical comparisons. However, there are some general tendencies which can be observed, despite the information gaps and uncertainties.

Geographically, northern China tends to show a higher postharvest storage loss than southern China. According to a survey by State Administration of Grain (SAG and NDRC 2011), the average household grain storage loss in northeastern provinces, northwestern provinces, the middle and lower reaches of Yangze River, and the Yellow-Huaihe-Haihe Plain is 10.2%, 8.8%, 7.4%, and 5%, respectively. This geographical variation may be explained by, among other factors, the climatic condition and planting structure. With regard to different crops, the national average household storage loss of maize is 11%, much higher than 6.5% for rice and 4.7% for wheat.

Technological and infrastructural change in the past decades, for example the improvement of cold storage and road infrastructure and the spread of mobile phones, are likely to have reduced the postharvest wastage over time. For example, a recent survey by Asia Development Bank found the postharvest physical wastage of potato to be only about 7% and that of rice to be only about 1-2% in some provinces of China (Reardon et al. 2012), which strongly contradicts with previous assertion of a level of over 20% (Gustavsson et al. 2011). This may suggest that China's food supply chains have become more efficient and affirm a point reiterated in an earlier review that there is a tendency to overstate losses in relation to traditional agricultural systems in developing countries (e.g., due to the use of out-of-date data) (Parfitt et al. 2010).

2.3 Consumer food waste

Food waste at consumer stage occurs both at the household level and during meals away from home. According to FAO, much less food is wasted at the consumer level in low-income countries than in medium- and high-income countries (Gustavsson et al. 2011). As the world largest emerging economy, China already starts to suffer a high wastage of food during consumption, especially in the urban areas and in the catering and restaurant sector.

There is little information about food wastage in the Chinese households. A back-of-the-envelope calculation for China's household food waste equates to about 5.5 Mt of grain every year (Zheng 2011; Liu et al. 2013a), or roughly 2.5% of China's annual grain output. This is still low on a per capita level nationally (4-5 kg/yr), but the overall amount is already approaching the level of UK (WRAP 2011). Surveys in large cities in China, for example Beijing, also show a much higher level than this national average (25.6 kg/cap/yr) (张保霞 and 付婉霞 2010).

Food waste during away-from-home meals is more severe. As a 2011 survey conducted by China Agricultural University shows, 28.3% of canteen food ends up in rubbish bins on campuses nationwide (Wang 2013).

Our previous first-hand field surveys in Beijing in 2005 and in Lhasa in 2011 in the cratering and restaurant sector show that the food wasted is about 11-17% of that ordered (by weight; varying by food type and class of restaurant, see Figure 10 and Figure 11). This share is higher than the normally assumed national average, or 10% (Wang 2013), although a lack of clarity over the definition of food waste among different studies and a lack of larger scale survey across China makes this comparison fragile.

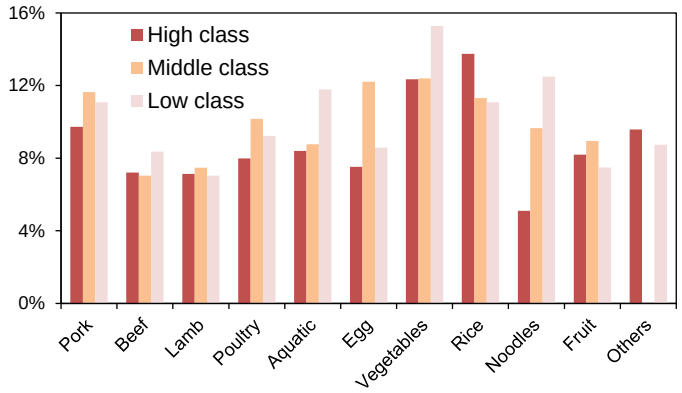


Figure 10. Catering food waste in Beijing by food type and class of restaurant, survey conducted in 2005 for 2211 tables in selected restaurants across Beijing (许世卫 2005).

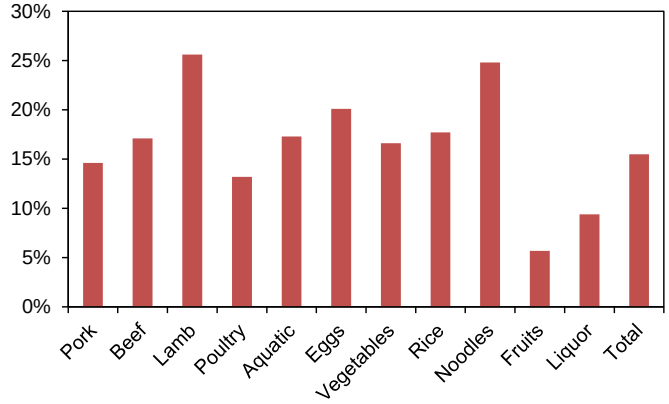


Figure 11. Catering food waste in Lhasa by food type, survey conducted in 2011 and 2012 for 443 tables in selected restaurants across Lhasa (王灵恩 et al. 2013).

It was estimated that in total over 50 Mt of grain is wasted annually at consumer stage in China (Zheng 2011), higher than that lost at pre-consumer stages (35 Mt, excluding the agricultural stage) (Ren 2013). The majority of consumer food waste is found in mid- to high-end restaurants and public service canteens (together about 90%) (Zheng 2011). This pattern is notably different from that in western countries, where households produce the largest fraction of food waste. For example, in EU27, households are responsible for about 42% (38Mt) of the total food waste, while food service sector only produce 14% (12.3 Mt) of that waste (Monier et al. 2010).

Consumer food wastage in China is expected to continue increasing in the coming years, due to the growing affluence, escalating urbanization, and high trend of food waste in the catering and restaurant sector. For example, a survey in the early 1990s (詹玉荣 1995) shows that the average wastage of rice and wheat in restaurants is only 1.8-3.3% and 2.5-6.5% (varying by class of restaurant), respectively; these two ratios have risen to 9.2-22.4% and 10.8-24.7% (varying by class of restaurant), respectively, according to a recent survey in 2008 (张浩 and 姚咏涵 2009). This agrees with the majority of

previous studies which show that as the proportion of income spent on food declines, food wastage increases (Parfitt et al. 2010; Gustavsson et al. 2011).

Note that the above numbers do not include a significant amount of food that is not used for direct human consumption purposes. These non-food uses are mainly for wine production and animal feed in China (see the consumption structure of rice, wheat, maize, and potato in Figure 9). For example, the production of alcoholic drinks made from grain consumes over 20 Mt of grain a year in China, a number that is still growing in recent years.

Several reasons can be identified as key drivers behind the increase in food waste in the restaurant and catering sector in China:

- ***Culture matters.*** China features long history of its own eating and dining culture. On the one hand, many food byproducts (e.g., bones, blood, heads, tails, liver, kidneys, and other internal organs) are efficiently used in many Chinese cuisines. On the other hand, people get used to hanging out or discussing business after a meal. Bai et al. found that hosted meals accounts for 24-27% of total household consumption for food away from home in Beijing (Bai et al. 2010). The communal dining tradition makes food waste almost inevitable in China (Wang 2013).
- ***Face counts.*** The fear of losing face (or referred as *mianzi* in Chinese) is frequently identified as a key reason to waste food in China. Over-ordering food is believed to be a way of showing respect to guests and displaying generosity. This is particularly serious in reception meals and group and event dining (e.g., wedding dinner) (Wang 2007).
- ***Government pays.*** Dining at public expenses is also fuelling food waste, an issue earmarked by Xi Jinping soon after he took over the leadership (Xinhua News 2013a). Extravagant government banquets have become a significant source of food waste and attracted growing concerns from both the media and the public in recent years.

3. Policy information on food loss and waste in China

We have summarized the recent (issued after the year 2007) regulations, policies, and official plans relevant to food losses and food waste in China in Table 4. Several features could be identified while reviewing this body of policy literature.

First, food losses and food waste is attracting growing public and government concerns in China; however, there are not so many regulations or policies in place. Moreover, many of them cover waste or municipal solid waste in general but not specifically adapted to food waste and losses.

Second, national policies and regulations relevant to food losses and food waste can be categorized as two groups: that address food waste generation and that deal with food waste treatment. Quite a few of them focus on postharvest losses (especially at storage), but there are not so many on consumer food waste. Food waste management systems are often operated under the responsibility of local governments and municipalities.

Third, several government ministries and agencies in China have been identified to be relevant for policy making in food waste reduction and treatment (e.g., NDRC and MOA in Table 4); however, they are currently working rather independently. For example, while the collection and transportation of food waste is regulated by Ministry of Housing and Urban-Rural Development, its treatment is regulated by Ministry of Environmental Protection. These institutions need to be brought together and integrated to develop a more comprehensive approach for addressing food waste (for example, under a high level committee). These top-down initiatives may have the highest potential in the context of Chinese political system.

One recent example is the immediate effect of the new Chinese leadership's campaign against governmental food waste. The Xinhua News Agency reports that due to the Politburo's "Eight Rules" the sales of high-end restaurants in Beijing and Shanghai have declined by over 35% and 20%, respectively, in the spring festival of 2013 comparing to last year, while the popular and public banquets show still an increasing trend in sales at the same time (Xinhua News 2013b). If this tight control of governmental banquets would continue to function, it may help reduce food waste in China.

Table 4. Recent regulations, policies, and official plans addressing food losses and food waste in China. The policies are ordered by chronological sequence. "R" indicates those addressing mainly food waste reduction, and "T" indicates those addressing mainly food waste treatment.

Regulations, policies, and plans	**Main content**	**Issuing date**	**Issuing division**	**Type**
Administrative Rules on Municipal Solid Waste	Detailed regulations on municipal food waste clearance	2007/04/28	MHURD	R
Outline of the Programme for Mid- and Long-term National Grain Security (2008-2020)	Major targets and countermeasures to enhance the storage, processing, and retailing system of grain	2008/11/13	SC	R
Food Security Law	Regulations on safety issues of food waste treatment (e.g., clause 28: recycled food waste not allowed for food production)	2009/2/28	NPC	T
Planning for 50 Mt New Production Capacity of Grain (2009-2020)	Countermeasures and targets to reduce both agricultural losses (1-2% reduction of insect infestations by 2020) and postharvest losses	2009/11/3	NDRC	R
Administrative Rules on Storage and Warehousing in Grain and Oil Industry	Detailed measures and reporting regulations on grain storage	2009/12/29	NDRC	R
Outline of the Programme for National Pig Slaughtering Industry (2010-2015)	Major targets for improving efficiency in slaughtering, processing, and retailing and market concentration of the slaughtering industry	2009/12/31	MOC	R
State Council Circular to Further Enhance Grain Saving and Food Waste Reduction	Detailed countermeasures on organizing, educating, supervising, and inspecting the work on food waste reduction in China	2010/1/18	SC	R
Special Programme for Construction of Scientific Grain Storage in Rural Households in the 12th Five-Year (2011-2015) Plan	To hand out standard storage instruments for 8 million households and reduce their storage loss to 2%; to construct 1000 pilot steel granaries (capacity over 100 ton) in major grain producing areas; to establish technical guidance and service systems for farmers	2011/03	NDRC and SAG	R
China's 12th Five-Year Plan (2011-2015) for Environmental Protection	Detailed plan for household waste collection and treatment (a safe treatment rate of 80% in urban areas by 2015)	2011/12/15	MEP	T
Development Plan (2011-2020) for a Grain-Saving Animal Husbandry Industry	Short term and mid- and long-term targets for non-grain fodder production	2011/12/21	MOA	R
Development Plan (2011-2020) for the Vegetables Industry	Countermeasures for reducing postharvest losses of vegetables	2012/1/16	NDRC and MOA	R
China's 12th Five-Year Plan (2011-2015) for Construction and Development of National	Measures to improve the efficiency of trade, retailing, wholesale of grain	2012/1/21	SAG	R

Grain Market System				
China's 12th Five-Year Plan (2011-2015) for the Meet Industry	Measures to improve the efficiency of processing and retailing of meat	2012/2/24	MIIT	R
Eight Rules on Improving Style of Work and Enhancing Close Ties With the People	A campaign against official extravagance and governmental reception meals at public expenses	2012/12/4	Politburo	R
Plan of Action for Implementation of Resource Saving and Loss Reduction in the Grain Production Sector	Specific technical standard and code for design for grain loss reduction	To be issued soon	SAG	R
Grain Law	Specific clauses (clause 33 in the draft) to promote grain saving and combat food waste	Draft for comment promulgated on 2012/02/21	NPC	R+T

Note: NDRC (National Development and Reform Committee), SAG (State Administration of Grain), SC (State Council), NPC (The National People's Congress), Politburo (the Political Bureau of the Central Committee of the Communist Party of China), MOA (Ministry of Agriculture), MHURD (Ministry of Housing and Urban-Rural Development), MOC (Ministry of Commerce), MIIT (Ministry of Industry and Information Technology), MEP (Ministry of Environmental Protection).

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Appendix: Metadata for references used in this report

References	Unit	Food commodity	Lifecycle coverage	Method of estimation	Year of estimation	Geographical and sample coverage
Zhan, 1995 (詹玉荣 1995)	kg + %	Grain (wheat, rice, maize, and others)	HS, P, D, C	s	1992	1400 samples (in 574 counties and 22 provinces)
Xu, 2005 (许世卫 2005)	kg + %	Pork, beef, lamb, poultry, aquatic products, eggs, vegetables, rice, wheat, fruits, others	C_{afh}	s	2005	2211 catering tables in Beijing
Zhang and Yao, 2009 (张浩 and 姚咏涵 2009)		Grain (wheat, rice, and others)	C_{afh}	s	2008	216 restaurants in 159 counties in Henan province
Deng et al., 2002 (邓精华 et al. 2002)	%	Grain	HS	s	1992-1993	Chongyang county, Hubei province
Lan et al., 2006 (兰盛斌 et al. 2006)	%	Grain	HS	s	1984 and 2004	17 counties in 8 provinces
Guo and Sun (郭成 and 孙东升 2006)	%	Grain (maize)	D	ns		Northeastern China
Xu, 2007 (许世卫 2007)	kg + %	Grain, meats, aquatic products, fruits, vegetables	HS, P, D, C	ns	2007	National average
Zhang et al, 2009 (张永恩 et al. 2009)	kg + %	Grain	Post-harvest, C	ns	ns	National average
Wang, 2009 (王若兰 2009)	%	Grain	HS	s	2008	40 national storehouse in Henan province
Zhang et al., 1998 (张健 et al. 1998)	kg + %	Grain	AP, HS, P, D, C	l	1998	National average
Zhou et al., 2005 (周云 et al. 2005)	%	Maize and rice	HS	s	2005	Over 70 households in 15 counties in Liaoning province
Gao et al., 2008 (高树成 et al. 2008)	%	Maize	HS	l	2008	Liaoning province, northeastern China
Wu and Tan, 1998 (武文斌 and 谭本刚	kg + %	Grain	HS	l	1992	National average

1998)						
Zheng, 1994 (郑景云 1994)	kg + %	Grain	AP	l	1950-1990	National average
Ping, 2005 (平海 2005)	kg + %	Grain	HS, D	l	2004	National average
Ying et al., 2005 (应霞芳 et al. 2005)	%	Rice	HS, P, D	s	2004	27 households in 9 villages in Zhejiang Province
Ren, 2013 (Ren 2013)	kg + ¥ + %	Grain	HS, D, P, C	l	2011	National average
Zhang, 2012 (Zhang 2012)	kg + ¥ + %	Grain, fruits, potatoes, vegetables	HS	l	2011	National average
SAG, 2009 (SAG 2009)	kg + ¥ + %	Grain	HS	l	2006	National average
SAG and NDRC, 2011 (SAG and NDRC 2011)	kg + %	Grain (maize, rice, and wheat)	HS	s	2009	National average
Zhu et al., 2006 (朱邦雄 et al. 2006)	%	Rice	HS	s	2004-2006	Three counties in Hunan and Jiangxi provinces
Cao and Jiang, 1999 (曹宝明 and 姜德波 1999)	%	Grain	HS, P, D, C	s	1989-1991, 1993-1994	342 households in three counties in Jiangsu province
Chen, 1998 (陈愿柱 1998)	%	Grain (rice, maize, soybeans) and peanuts	HS	s	1997	100 households in 17 counties in Jiangxi province
Ma and Chu, 2007 (马红波 and 褚庆全 2007)	%	Grain	AP	l	2004	National average
Tang, 2007 (唐柏飞 2007)	%	Grain	HS	s	2006	National average
Tang, 1998 (唐为民 1998)	%	Grain	AP, HS, P, D, C	l	1997	National average
Peng, 1992 (彭珂珊 1992)	%	Grain	HS, P, D, C	l	1990	National average
Li, 2008 (李秉安	%	Grain	HS	s	2007	Qingyuan county, Liaoning province

2008)						
Chen et al., 2012 (陈锋亮 et al. 2012)	%	Wheat	HS	s	2011	154 households in 12 counties, Shandong province
Zhu et al., 2009 (朱钢 et al. 2009)	%	Rice	HS	s	2007	16 households in Taicang city, Jiangsu province
Jin and Lan, 2004 (靳祖训 and 兰盛斌 2004)	%	Grain	AP	l	ns	National average
Zheng, 2000 (郑伟 2000)	kg + %	Rice	HS	s	1999	357 households in 17 counties, Jiangxi province
Cai, 2012 (蔡新国 2012)	%	Grain	HS	s	2006	Ningxia province
Li et al., 2010 (李文娟 et al. 2010)	kg + %	Grain	AP	l	1990-2005	National average
Zheng and Zhao, 2007 (郑轩 and 赵志强 2007)	kg + %	Grain	HS	l	2005	National average
NDRC, 2009 (NDRC 2009a)	%	Grain	AP	l	2007	National average
Zhang et al., 2012 (张春娥 et al. 2012)	kg + %	Grain	HS	s	2011	15 villages in Ningxia province
Jiang et al., 2008 (蒋春贵 et al. 2008)	%	Grain	HS	l	2007	National average
Wang et al., 2005 (王若兰 et al. 2005)	%	Grain	HS	l	2004	National average
Xinhua News, 2005 (Xinhua News 2005)	kg + %	Grain, fruits, vegetables	AP	l	2004	National average
Xi, 2010 (Xi 2010)	%	Grain	HS, D, C	l	2008	National average
Zheng, 2002 (郑风田 2002)	kg	Grain	AP, HS, P, D, C	l	1998	National average
Zheng, 2011 (Zheng 2011)	kg + ¥	Grain	C_h, C_{afh}	l	2010	National average

Peng, 1997 (彭珂珊 1997)	kg + %	Grain	AP, HS, P, D, C	l	1996	National average
SAG, 2008 (SAG 2008)	%	Grain	HS	s	2008	8 counties in Chongqing
Wu, 2013 (Wu 2013)	%	Rice, maize, wheat	HS, P, D	l	2010	Henan province and national average
Reardon et al., 2012 (Reardon et al. 2012)	%	Rice, potato	HS, P, D	s	2010	Jiamusi in Heilongjiang province and 320 households in 2 counties in Gansu province
Parfitt et al., 2010 (Parfitt et al. 2010)	%	Rice	HS	s	ns	Zhejiang province
Yao, 2009 (Yao 2009)	%	Pork	AP	l	2008	National average
Shen, 2008 (Shen 2008)	%	Poultry (chicken)	AP	l	2007	National average
Huang, 2011 (黄岳新 2011)	%	Pork	D	l	ns	National average
Chen, 2005 (陈克建 2005)	%	Pork	HS	l	ns	National average
Zhou, 1988 (周成稳 1988)	%	Pork	HS	s	1985	A slaughterhouse in Taizhou, Jiangsu province
Liu, 1990 (刘常武 1990)	%	Pork	HS	l	1990	National average
Shao and Liu, 1995	%	Pork	HS	s	1994	Guizhou province
Zhang and Chang, 2009 (张磊 and 常来发 2009)	kg + ¥ + %	Pork	HS, D	s	2007	Beijing
Du et al., 2009 (杜燕 et al. 2009)	%	Beef	HS	s	2008	A typical slaughterhouse
Xia et al., 2007	%	Meat	HS	l	2006	National average
Jiang et al., 2004	%	Beef	HS, P	s	2003	A slaughterhouse in Dongying, Shandong provice
Luan, 2009 (栾远达	%	Pork	P	L	2008	National average

2009)						
Wang and Meng, 2009 (王明利 and 孟庆翔 2009)	%	Beef	AP	l	2008	National average
Lu et al., 2010 (路文敏 et al. 2010)	%	Pork	HS	l	ns	National average
Zhang and Xu, 1994 (张伟力 and 徐水平 1994)	%	Beef	HS	s	1992	34 samples
Sun, 2012 (Sun 2012)	%	Pork	HS	s	2010	Zizhong county, Sichuan province
Wang, 1987 (王家达 1987)	kg	Pork	HS	s	1985	124 samples
Zhu et al., 2008 (朱志盈 et al. 2008)	%	Pork	HS	s	2008	1500-1700 samples in Kaiyuan, Liaoning province
Gu and Wang, 2007 (顾华兵 and 王晓峰 2007)	%	Poultry	AP	l	2007	National average
NDRC, 2009 (NDRC 2009b)	kg + ¥	Beef and lamb	AP	s	2008	National average

Note: (1) Measurement unit: "%" = percentage of waste in total input; "kg" = physical value; "¥" = monetary value; (2) Lifecycle coverage: Agricultural production (AP), postharvest handling and storage (HS), Processing (P), Distribution (D), Consumption (C; including household consumption: C_h, and away-from-home consumption: C_{afh}); (3) Method of estimation: s = First-hand field survey or questionnaire survey; l = Literature data, model simulation, or informed estimates; ns = not specified.

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