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# A Study of Food Waste in the Catering Industry in Beijing

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**Abstract:** Currently, the topic of food waste and its environmental impacts is attracting increasing attention among academic researchers. Based on an investigation of restaurants in Beijing, this study analyzes the quantities, structures, characteristics and costs of the agricultural resources related to food waste in the catering industry in Beijing. The results show that: (1) The average food waste per capita per meal is about 75.02 g (raw) for food away from home among Beijing urban residents, which means that about 10.52% of the food is wasted. (2) According to the quantitative ranking of different categories of food waste, vegetable is the most wasted, followed by meat, aquatic products, and grains. The foods in the other categories are wasted much less. (3) Food waste is affected by the restaurant type, as well as the number, gender, age, education level, and consumption motivation of the consumers. (4) Based on the estimated food waste per capita, about 417.92 thousand tons of food is wasted annually at the consumption stage in the catering industry in Beijing. This food waste amount is equivalent to approximately 765.53 tons of cereals which are wasted, and this represents 79.66% of cereals production and 13.15% of cereals consumption in Beijing. Estimated by the required land use, this amount of food waste means that the total production of approximately 166.12 thousand ha of arable land is being wasted in Beijing.

**Key words:** food waste; catering industry; empirical survey; food security

## 1 Introduction

Nowadays, food waste has gradually become a focus of research globally, and topics related to the influences and consequences of food waste are especially prevalent. Generally, studies about food waste have two main characteristics. Firstly, many of them are conducted in developed countries and emphasize household waste and food consumption (Wenlock et al., 1980; WRAP, 2009; WARP, 2010). Compared with the situation in developed countries, fewer studies about food waste in developing countries are available, and most of them focus on the stages of harvest and storage. Secondly, the focus of this research varies from the amounts and causes of food waste (Kantor et al., 1997; Rebecka and Annika, 2004; Cuellar et al., 2010), the technologies and policies to reduce food waste (FAO, 1981; Christer, 2002; Lyndhurst and WRAP, 2012), and the recycling of food waste (Francesca et al., 2015; Karmee and Sanjib, 2016; Visschers et al., 2016).

China has a large population but only limited per capita arable land. Over the past few decades, China has invested a great deal of resources in improving the yields of arable land (Norse and Ju, 2015), including chemical fertilizers, pesticides, plastic sheeting, water conservancy facilities, and electricity (Jin et al., 2016; Wang, 2016; Fang and Liu, 2018). However, these inputs not only cost vast amounts of national wealth, but also bring many problems, such as the non-point source pollution from excessive fertilizer and pesticides, and greenhouse gas emissions (Zhang et al., 2016a; Fan et al., 2020; Wei et al., 2020). Thus, with the massive resources being invested, increasing the agricultural

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yield has become increasingly more difficult. Based on this situation, reducing food waste becomes an important way to solve the problem of food security in China.

In order to find solutions for reducing food waste in China, the amounts, structures, and characteristics of food waste should be known. Current food waste studies in China are mainly on the theoretical level, focusing on the concept and progress of food waste (Cheng et al., 2012; Gao et al., 2013; Gao et al., 2015; Wang et al., 2015). Thus, more basic scientific research is needed.

In this paper, we use the method of field investigation to study the amount and the factors influencing food waste in the catering industry in Beijing. Based on the outcome, we then calculate the waste in terms of resources and environmental impacts. This study provides a method to calculate food waste accurately and an approach for studying the influences of various factors on food waste. It serves as an important test case and represents progress in food waste research outside of the theoretical stage. We hope to support subsequent studies and possibly influence the city's governance to achieve a reduction in food waste.

## 2 Research method

### 2.1 Data collection

This study is based on data collected in July 2013 in Beijing, with a total of 2564 samples from 124 restaurants. The sample selection includes three steps. First, stratified sampling is used to select the sample districts in Beijing. Of the 16 districts, we selected Dongcheng, Haidian and Changping districts to represent the inner ring area, middle ring area and outer ring area. Second, the restaurants in the three districts are selected. We categorize restaurants into large, middle, and small sizes, and use a random method to select individual restaurants. The numbers of large, middle and small restaurants surveyed in Dongcheng are 11, 23, and 18, respectively, while those in Haidian and Changping number 21, 42, 57 and 8, 22, 45, respectively. The last step is to select the samples in each restaurant. We use the isometric method according to the total number of customers in each restaurant within a day, the rate of rejection, and the expected sample number.

In this survey, the data for each sample is collected in three parts. The first is face-to-face consumer questionnaires, to obtain information about the consumer's age, employment, education level, income, and the dining reasons. The second part is the information recorded by the investigators, including the number of dishes, each consumer's characteristics (height, weight, age and gender), whether packaging is involved or not, dining time, the price of each dish, and other factors. The third part is the weight of each dish recorded by the investigators, including the total weight of each dish before and after consumption and the weight of each category of food after consumption (Fig. 1).

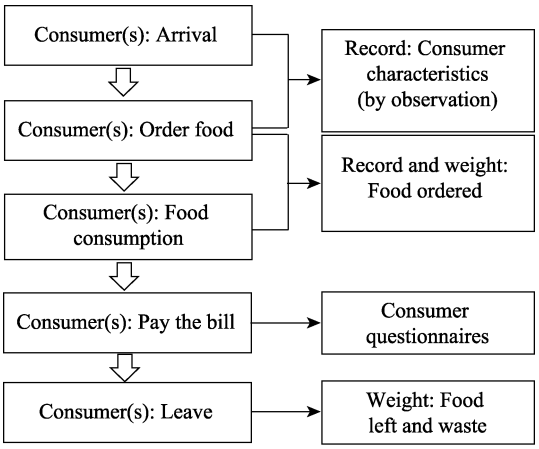


Fig. 1 Steps of the food waste survey

In this study, three aspects are adopted to ensure the reliability of the data. First, the standard for selecting the investigators is strict. Investigators must have former research experience, and each of them was selected based on interviews. Second, before the formal investigation, we carried out training of the investigators, including the explanations of the questionnaire, the survey process, and scene simulation. Third, investigators must have the ability to communicate and cooperate with the restaurant staff. Fourth, in different stages, we used electronic scales to weigh each dish to ensure the accuracy of the investigation.

The materials used for different dishes varied greatly, as did the cooking methods. To facilitate the calculation and analysis, we made a food/material classification table (Table 1) based on the Classification and Computer Coding of Agri-product Market Information (Agriculture Industry Standard of China, NY/T 2137–2012). Based on this table, after excluding the inedible parts left by the customer, we classify and calculate the materials of the "edible" food waste, and transform the amount of cooked food to raw food. Therefore, the amount of food waste in this report refers to the weight of the calculated equivalent of raw food.

Table 1 Food /material classification

| Food | Materials | Cooking methods |
|---|---|---|
| Principal foods | Rice, wheat, peanut, corn and others, usually in the form of soup, noodles, bread or dumplings | Steam, boil, stir-fry, roast, simmer, deep-fry, marinate, braise |
| Meats | Pork, beef, mutton, chicken, duck and others, including three sorts: pure meat, ribs and offal | |
| Aquatic products | Fish, shrimp, crab, shellfish and others | |
| Vegetables | Root/melon/bulb/leaf/aquatic/permanent vegetables, cabbage, brassica, mustard, solanaceous, potato, mushroom, beans & bean products and others | |
| Eggs | Chicken eggs and other eggs | |
| Dairy | Milk, dairy products and others | |

### 2.2 Food waste amount estimation

We calculated the total amount of food waste based on food waste per capita per meal using the following equation:

$$W_{\mathrm{T}} = W_{\mathrm{p}} \times P_{\mathrm{co}} \times N \times n \quad (1)$$

where $W_{\mathrm{T}}$ is the total amount of food waste in one district; $W_{\mathrm{p}}$ is the amount of food waste per capita per meal in the same district; $P_{\mathrm{co}}$ is the percentage of FAW (food away from home); $N$ is the population size; $n$ is the number of meals. In this paper, $W_{\mathrm{p}}$ and $P_{\mathrm{co}}$ are calculated from data obtained during the field survey; $N$ is the citizen population in Beijing; and $n$ is calculated by the number of days and the number of meals in one day. As a standard, the number of meals in one day is taken as 2.3, according to Bai et al. (2010). The total amount of food waste generated from the urban catering iustry in Beijing includes two parts: the waste generated by local residents and the waste generated by tourists.

$T$ estimation of the waste generated by local residents is calculated based on the urban population in Beijing, local residents' rate of eating in restaurants, and the measured food waste rate. According to the 2013 Beijing Statistical Yearbook, the total population of Beijing is 17.83 million. According to data from our investigation on food waste in 2012 in Beijing, the rate of eating in restaurants for urban residents in Beijing is approximately 25%.

The data from the investigation on food waste in 2012 in Beijing are also used to calculate the per-capita food waste amount. The calculation of food waste generated by tourists in Beijing is based on the number of tourists, per-capita traveling duration, the rate of eating in restaurants and the per-capita food waste amount. According to the "Basic Facts and Figures of Travel and Tourism of Beijing 2013" conducted by the Beijing Municipal Commission of Tourism Development, the number of tourists traveling to Beijing is 147.55 million person-trips annually and the per-capita traveling duration is 4.82 days. Since tourists are non-residents, their rate of eating "outside the home" is considered to be 100%. The per-capita food waste amount is calculated based on the data from the investigation of food waste in 2013 in Beijing.

### 2.3 Food waste environmental and resources effect estimation

The concept of food waste represents more than just the food which has been wasted. Besides the food itself, the resources consumed to produce the food should also be taken into consideration in the total loss of resources. Some studies evaluate this resource loss through the water footprint and ecological footprint (FAO, 2013; Zhang et al., 2016b; Zhang et al., 2016c; Zhang et al., 2017). In this study, we evaluated the loss of resources from the perspective of cereals and agricultural cost in the catering industry in Beijing, using the 'grain equivalent coefficient' and grain yield in Beijing. The equations for these calculations are as follows:

$$F_{\mathrm{w}} = \sum W_{i\mathrm{T}} + \sum \frac{W_{\mathrm{gT}}}{\alpha_{\mathrm{g}}} \quad (2)$$

$$A_{\mathrm{w}} = \sum \frac{W_{i\mathrm{T}}}{Y_i} + \sum \frac{W_{\mathrm{gT}}}{\alpha_{\mathrm{g}} Y_{\mathrm{a}}} \quad (3)$$

where $F_{\mathrm{w}}$ is the total loss of cereals of food waste in the Beijing catering industry; $W_{i\mathrm{T}}$ is the direct loss of cereals from the food waste in the catering industry in Beijing; $W_{\mathrm{gT}}$ is the indirect loss of cereals from the food waste in the Beijing catering industry including vegetables, meats and so on; and $\alpha_{\mathrm{g}}$ is a grain equivalence coefficient (Cao, 2013); $A_{\mathrm{w}}$ is the total loss of arable land due to food waste in the Beijing catering industry, $Y_i$ is yield of crop $i$, and $Y_{\mathrm{a}}$ is average yield of cereals in Beijing.

$$R_{\mathrm{w}i} = \frac{R_{i\mathrm{T}}}{A_{\mathrm{T}}} \times A_{\mathrm{w}} \quad (4)$$

where $R_{\mathrm{w}i}$ is the loss of agricultural resources due to food waste in the Beijing catering industry; $R_{i\mathrm{T}}$ is the total input of agricultural resources in Beijing; and $A_{\mathrm{T}}$ is the total area of arable land in Beijing. In this study, agricultural resources refer to Total Agricultural Machinery Power (TAMP), Rural Electricity Consumption (REC), and Consumption of Chemical Fertilizers (CCF).

## 3 Results

### 3.1 Amount and structure of food waste

There are three key indicators for each sample: The amount of ordered food, the amount of consumed food, and the amount of leftovers. The first and last indicators are directly recorded by the investigators, and the amount of consumed food is calculated from the other two indicators. Meanwhile, food waste does not equal the amount of leftovers, because there are some inedible parts. Thus, we also calculated the amount of food waste and the food waste rate.

According to the results of the calculation, urban residents in Beijing order 1994.61 g food and left behind 378.44 g food, for an 18.97% food waste rate per meal. According to the survey, there are 2.45 persons at each table on average. Excluding all of the inedible parts, the per-capita amount of food waste per meal is 75.02 g (raw), and the food waste occurs at a rate of 10.52% (Fig. 2).

According to the classification of the food/ingredients, we analyzed the amount of each material used for cooking. The results show that vegetables and meat (pork, beef and mutton) are wasted the most, making up 41% and 20.18% of the total waste, respectively. Grains (rice, wheat and

maize), tubers and aquatic products also make up more than 10% of the total waste, at 12.48%, 11.72% and 11.17%, respectively. Beans and eggs make up about 3% of the total waste (Fig. 3).

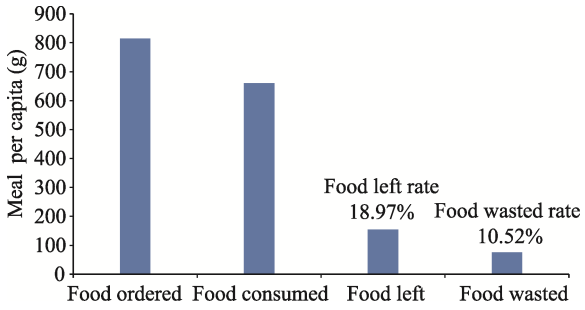


Fig. 2 Food waste in the catering industry in Beijing

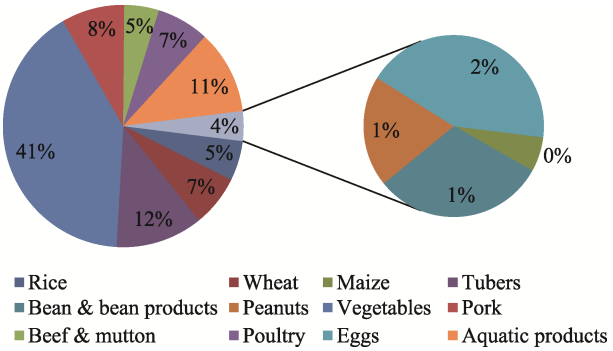


Fig. 3 Structure of food waste in the catering industry in Beijing

In terms of meat, the largest amount of wastage comes from pork, followed by poultry meat. The amounts of wasted beef and mutton are relatively small (Fig. 3). Among cereals, the largest amounts of wastage come from flour and rice, reaching the per capita amounts of 5.66 g and 4.41 g, respectively. Comparatively, the amounts of wasted corn and other kinds of cereals are far less. In addition, there is a tight connection between the wastage structure and the cereal consumption structure. Since this investigation was conducted in the northern part of China, the proportion of cooked wheat-based food consumed is relatively high and the amount of wasted cooked wheat-based food is also slightly higher than that of wasted cooked rice.

## 3.2 Characteristics of food waste

### 3.2.1 Consumer number and gender

All the guests sitting around one table and sharing food from the same dishes are the traditions of Chinese food culture. Thus, the number of consumers at a table is an important factor to consider. According to this research, 91.18% of samples include 4 or fewer consumers. The results show that with the increasing of the number of consumers at a table, the amount of food waste first increases and then declines (Fig. 4). The lowest amount of food waste is 47.30 g person$^{-1}$ per meal when a person is eating alone, and the highest amount is 206.01 g person$^{-1}$ per meal when there are 9 consumers at a table sharing dishes.

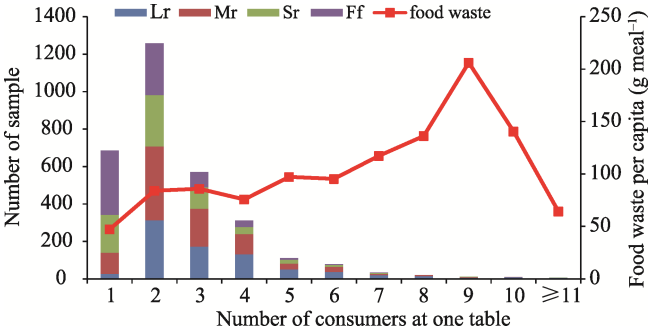


Fig. 4 Food waste for different numbers of consumers

Note: Lr: large-scale restaurants; Mr: medium-sized restaurants; Sr: small-sized restaurants; Ff: fast food restaurants.

This study also selects samples to compare the generation of food waste by gender. Consumers eating alone are selected as the samples. The results show that males waste more food than females, and the amounts are 61.99 g person$^{-1}$ per meal and 40.32 g person$^{-1}$ per meal, respectively (Fig. 5).

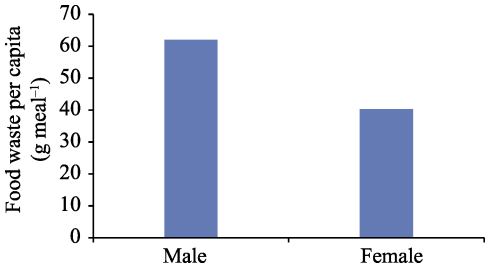


Fig. 5 Food waste by male and female single consumers

### 3.2.2 Types of restaurants

We categorize restaurants into four types according to their areas: small-sized restaurants (Sr), medium-sized restaurants (Mr), large-scale restaurants (Lr) and fast food restaurants (Ff), with areas of 30–50 m$^2$, 50–150 m$^2$, >150 m$^2$ and < 30 m$^2$, respectively[1].

Among the various types of restaurants, large-scale restaurants generate food waste the most, at 94.01 g per capita. This amount is much higher than the per-capita food waste of 75.02 g in the previous investigation. The per-capita food waste generated in medium-sized restaurants is less than the waste in large-scale restaurants, but more than in small-sized restaurants. Fast food restaurants have the smallest amount of per-capita food waste, at 34.01 g per capita (Fig. 6).

[1]Classification of restaurants is from the Bureau for Health Inspection and Supervision of Beijing which is responsible for the daily supervision and management of restaurants.

To make this research more precise, the food waste rate is also calculated. Considering the amount of food that is ordered and consumed in large restaurants, although the amount of food wasted is highest, the food waste rate is not. The results show that there are higher rates of food waste in Mr and Sr. The potential factors driving these differences might be the different skill levels of cooks and sanitary differences between different categories of restaurants. In our investigation, large restaurants had the best sanitary conditions. Only 2.38% of large restaurants are sanitary classified as C (where C stands for average), the rest are A or B (where A stands for excellent). In contrast, 51.85% of small restaurants had sanitary conditions of C. [2]

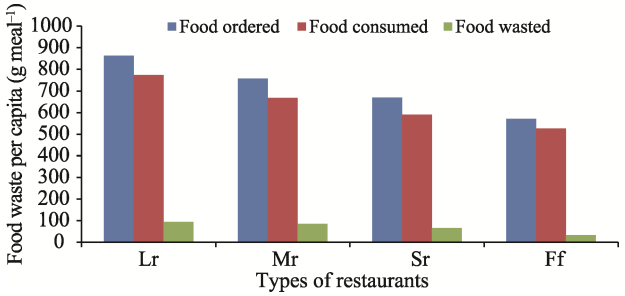


Fig. 6 Food waste in different restaurant types

Note: Lr: large-scale restaurants; Mr: medium-sized restaurants; Sr: small-sized restaurants; Ff: fast food restaurants

### 3.2.3 Age

Among the investigated samples, consumers mainly belong to two age groups: From 21 to 30 and from 31 to 40. In the investigation, only a few consumers were aged below 20 or above 61, which is consistent with the current situation of eating in restaurants by residents (Fig. 7). Consumers of the age group from 41 to 50 generate more food waste than consumers of the age group over 61. This is because consumers with ages from 41 to 50 have stable family and career situations, so they deeply care about their reputation and face when they eat out. Therefore, they usually tend to order more dishes than they can finish. However, most consumers with ages over 61 had experienced the Great Famine (1959–1961), so they are used to saving food and avoiding waste.

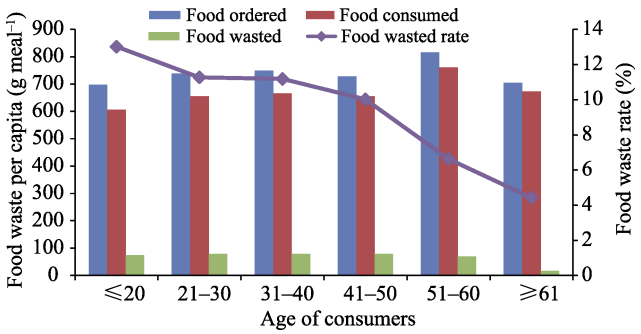


Fig. 7 Food waste of different consumer ages

### 3.2.4 Educational level

Generally, the food waste is reduced when the consumers' educational level increases. The results show that consumers with primary and secondary school education waste more than 100 g food per capita per meal, while consumers with higher education levels waste less than 80 g food per capita per meal (Fig. 8). This suggests that high school education plays an important role in reducing food waste from the educational aspect.

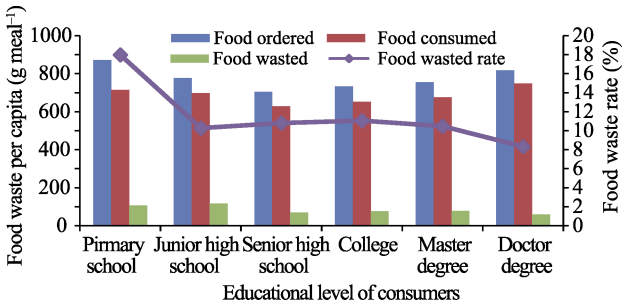


Fig. 8 Food waste of consumers with different education levels

### 3.2.5 Consumption motivations

In the survey, we classified consumption motivations into five types, which are public/business consumption, family parties, friends' parties, working meals, and others. The results show that friends' parties and public/business consumptions waste more food, at 106.15 g person$^{-1}$ per meal and 80.92 g person$^{-1}$ per meal, and the food waste rates are 12.89% and 11.91%, respectively. There is less food waste in family parties and working meals, at 61.08 g person$^{-1}$ per meal and 58.32 g person$^{-1}$ per meal, or 8.85% and 9.93% food waste rates, respectively (Fig. 9).

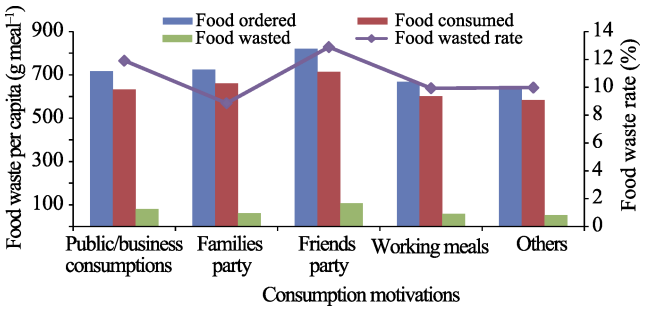


Fig. 9 Food waste of consumers with different motivations

## 3.3 The amount of food waste and its resource environmental effects

According to the calculation, the total amount of food waste in the urban catering industry in Beijing is about 417.92 thousand tons per year. Of that amount, the total amount of food waste generated from local residents' eating out in

[2] Data source: the Bureau for Health Inspection and Supervision of Haidian District and Beijing.

Beijing is about 282.51 thousand tons per year, and the amount of food waste generated by tourists in Beijing is about 135.41 thousand tons per year. Considering the inedible food components, such as soap and seasoning, the food left behind totals about 833.84 thousand tons per year.

The results show that the food waste in the catering industry in Beijing is equivalent to a loss of 765.53 thousand tons of cereals, which means that 79.66% of the total cereals yield in Beijing is wasted. From the perspective of environmental loss, this represents a loss of 166.12 thousand ha arable land (Fig. 10), about 75.12% of the total arable land area in Beijing. A reduction of half of the food waste in the catering industry in Beijing could save about 37.59% of the agricultural resources input in cereals production (Table 2).

Table 2 The costs of agricultural resources of food waste in the Beijing catering industry

| Types of agricultural resources | Arable land ($\times10^3$ ha) | Cereals ($\times10^3$ t) | TAMP ($\times10^3$ kW) | REC ($\times10^6$ kW h) | CCF ($\times10^3$ t) |
|---|---|---|---|---|---|
| Cost of food waste | 166.12 | 765.53 | 1562.12 | 3649.98 | 96.24 |

Note: TAMP: Total Agricultural Machinery Power; REC: Rural Electricity Consumption; CCF: Consumption of Chemical Fertilizers.

Considering that the production of different food types needs various resource inputs, we calculate the proportions of different types of food and evaluate the environmental losses of each type. The results show that the beef and mutton, pork, and poultry meat wasted contribute the most, which make up 34%, 26%, and 12% of the total loss. Although vegetables make up a larger proportion of food waste, the environmental loss it contributes is less than 2% of the total loss (Fig. 10).

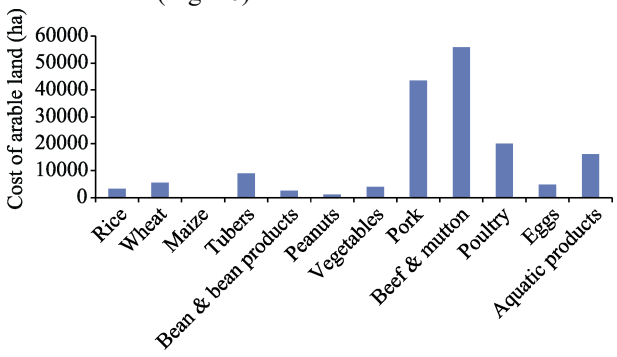


Fig. 10 Cost of arable land of food waste in the Beijing catering industry

## 4 Discussion and conclusions

### 4.1 Discussion

This paper uses first-hand data from consumer questionnaires and food waste weighing in restaurants in Beijing. The data support the quantitative analysis of food waste and guarantee the accuracy and scientific validity of the results. Therefore, this study is meaningful for the food waste research field internationally. For further studies, the following three issues need to be addressed.

(1) How much food is wasted in China?

In this paper, we evaluated the amount of food waste in the catering industry in Beijing. For further study, spatial variations need to be considered. China has a great diversity of cultures and natural products, and people in different areas have different food preferences and dietary patterns. This means that the amounts and structures of food waste are expected to vary among different areas and districts.

Secondly, the catering industry is only one part of the food consumption system. To evaluate the comprehensive situation of food waste, food consumption at home and canteens also need to be included. Additionally, tourists bring more food waste (Zhang et al., 2018), so with the booming of tourism, the food waste of tourists needs to be the focus of more academic attention.

Thirdly, food waste happens at every stage of the food supply chain (Munsol et al., 2017; Sara et al., 2018; Raife et.al, 2020). The food waste in the earlier stages of harvest, storage, and sale in China should not be ignored. Further studies can include food waste in the processes of production, processing, storage, transport, and sale.

(2) What are the costs of generating food waste?

Food waste can lead to series of consequences. According to the FAO, 9.2% of the world's population was exposed to severe food insecurity in 2018 (FAO et al., 2019). Food waste seriously threatens food security. Because of the waste, we need to produce more food using more arable land, water resources (Liu et al., 2013), fertilizers and pesticides, and energy. These increased inputs come with threats to sustainable production. Additionally, we must expend huge efforts to process the waste to avoid contaminating the land and water. This study evaluates the cost of cereals and agricultural resources related to food waste in the catering industry in Beijing. There are also some studies which focus on the recycling of food waste into organic fertilizers or fodders (Hu, 2012; Wen et al., 2016). Because it is essential to consider the effect of food waste disposal and potential for reuse of the waste, more research is needed to reveal the true costs of food waste.

(3) How can food waste in China be reduced?

All of the stages in the food supply chain are generating food waste (Parfitt et al., 2010; Gustavsson et al., 2011; Liu et al., 2013). This study focuses on the consumer level because the consumption stage food waste issue is severe in China. But there are more factors that needed to be explored.

Food waste is not merely an issue of food production and

consumption, but also a problem of society and culture. To reduce food waste, we need to combine the efforts of different stakeholders, such as governors, researchers, catering industry associations, enterprise operators and consumers, to take advantage of the means of policy, technology, culture and so on. A comprehensive approach is necessary to reduce food waste.

### 4.2 Conclusions

Based on a field survey, this study made a quantitative analysis of food waste in the catering industry in Beijing. It generated the following conclusions:

(1) The per-capita food waste is about 75.02 g person$^{-1}$ per meal in the catering industry in Beijing, with a 10.52% food waste rate.

(2) Vegetables make up the highest proportion of food waste, followed by meats, aquatic food and grains.

(3) The amounts of food waste vary with the number of consumers sharing food together, the types of restaurants, and consumers' genders, ages, educational levels, and consumption motivations.

(4) The total amount of food waste in the urban catering industry in Beijing is about 417.92 thousand tons per year, among which the urban residents waste about 282.51 thousand tons per year, and tourists waste about 135.41 thousand tons per year.

(5) The food waste generated in the catering industry in Beijing is equivalent to a loss of 765.53 thousand tons of cereals or 166.12 thousand ha of arable land. Meats make up the largest proportion of the environmental losses.

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# 北京市餐饮业食物浪费研究

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**摘　要：**食物浪费研究已经成为国际研究热点，食物浪费带来的资源环境效应也成为全球关注的焦点。本研究基于实证分析，在大规模实地调查基础上，对餐饮业食物浪费的数量、结构、特点及农业资源代价进行了研究。研究结果表明：1) 北京市城镇居民在外就餐消费平均每餐人均浪费生食量为 75.02 g，浪费率约为 10.52%。2) 在各类食物中，蔬菜的浪费量是最高的，其次为肉类、水产品和谷物，其他类食物浪费量较少。3) 食物浪费受餐馆类型、消费者人数与性别、年龄、受教育程度和就餐目的等因素影响并表现出不同的特点。4) 北京城市餐饮业食物浪费总量约为 41.79 万吨/年，这意味着北京市每年仅餐饮业餐桌消费浪费约 76.55 万吨粮食，是北京市粮食总产量的 79.66%，粮食总消耗量的 13.15%，相当于北京 16.61 万公顷耕地的无效生产，占北京市耕地总面积的 75.12%。

**关键词：**食物浪费；餐饮业；实证研究；粮食安全