



Examining the determinants of food waste behavior in China at the consumer level

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Abstract

Food loss and waste are global problems for food security, as one-third of all food produced globally does not reach the consumer's table. These numbers seem unreasonable when the data presented by the Food and Agriculture Organization of the United Nations (FAO) in 2021 accounts for more than 800 million undernourished people and about 2.3 billion without access to adequate food throughout the year. This study examines the determinants of food waste behavior at the consumer level in China, the most populous country in the world. The survey used data from 3,857 online questionnaires of families living in selected Chinese metropolitan areas across all provinces. The research methodology used an ordered multinomial logit model to estimate the impact of the explanatory variables on the frequency and amount of household food waste. The results showed that food waste increased with income, age, and education but at a decreasing rate. Additionally, the demographic characteristics of households, food planning, and meal preparation had a statistically significant influence on food waste. The findings of this study, therefore, provide evidence that household food waste is highly dependent on people's behavior, and its reduction may depend on public policies and educational campaigns to make families aware of the problem.

Keywords Food waste · Food security · Consumer behavior · China · Logit model

1 Introduction

According to the Food and Agriculture Organization of the United Nations (FAO), one-third of the food produced for human consumption worldwide is lost or wasted, which equates to approximately 1.3 billion tons per year (FAO, 2011). Despite these figures, a multi-agency report estimated that around a tenth of the global population – up to 811 million people – suffered undernourishment in 2021, and more than 2.3 billion people did not have year-round

access to adequate food (WHO, n.d.). Conceptually, food loss (FL) concerns all stages of the food supply chain, excluding interactions with the final consumer, whereas food waste (FW) occurs at the consumer level (FAO, 2019). Food loss and waste aggravate food insecurity and represent misuse of productive resources. The United Nations Environment Programme notes that, if global food loss and waste were a country, it would be the third largest source of greenhouse gas emissions, contributing to climate change, biodiversity loss, and pollution.¹ The agency also estimates that food waste from households, retail establishments, and the food service industry totals 931 million tons annually, of which 61% occurs in homes. Therefore, examining food waste motives at the household level will produce subsidies for designing an appropriate strategy to improve food management at the consumption level.

In China, the world's largest emerging economy, food security is a particular concern, as it encompasses approximately 20% of the world's population and 7% of the world's arable land. Despite a notable increase in

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¹ UNEP -United Nations Environment Programme (2021).

agricultural production in recent decades, agricultural land in China has declined owing to urbanization (Li et al., 2022). Therefore, increasing farm productivity and managing food loss and waste in the supply chain are critical for Chinese food security strategies. Although the country's agricultural productivity has grown steadily in recent years (Fan et al., 2018), reducing food loss and waste remains a public policy concern (Wang et al., 2022). More than 35 million tons of food are lost or wasted annually in China, representing 6 percent of the country's food production, and would be enough to feed 100 million people. Approximately half of this total 17–18 million tons, is wasted yearly at the final stage of the food supply chain, that is, on retail or consumption (Marchisio, 2020). According to the Economist Intelligence Unit, a catering industry survey conducted in Beijing, Shanghai, Chengdu, and Lhasa estimated that the amount of food wasted was 93 g per person per meal, representing 12% of the total served. The report also estimated that one-sixth of the total grain produced in the country is wasted annually in production, processing, and transportation because of poor equipment and logistical inefficiencies. Furthermore, millions of tons of food are wasted every year in the form of leftovers and outdated foods thrown away by supermarkets.²

According to van Geffen et al. (2016), at the consumer level, which includes households and food services, FW – food waste is highly influenced by factors related to individuals' characteristics, social norms, household infrastructure, and skills. In empirical studies, variables typically include age, family income, educational level, job occupation, marital status, food shopping planning, cooking routines, food freezing, managing leftovers, and kitchen infrastructure. Understanding the influence of these factors is essential for developing food waste reduction policies and strategies (Li et al., 2022). One of the limitations of studies on food waste is the difficulty of recording the type and amount of food waste in households and food services. Researchers have used different metrics to assess food waste, such as direct measurement (e.g., weighing disposable food and garbage collection) and surveying (questionnaires and interviews) (Xue et al., 2017). All of these methods have advantages and disadvantages based on time, cost, accuracy, objectivity, and reliability. In large-sample studies, direct measurements are detailed and accurate, but can be more impractical. Weighing food waste, for example, requires using a scale and individual training at home to record the amount of food discarded. However, using a survey is more appropriate for a large-sample, low-budget study. However, this depends on the accuracy of individual observations of the quantity and quality of wasted food (van Herpen et al., 2019).

The main objective of this research was to examine the determinants of food waste behavior in China using a sample of 3,857 observations collected from people living in selected Chinese metropolitan areas. A survey collected data from individual households asking questions about the frequency, quantity, and type of food discarded at home. Questionnaires were also used to gather information on individuals' demographic characteristics, household food management, and food waste awareness. Information on the target variables, the amount and intensity of domestic food waste, was obtained through responses ordered on a Likert-type scale. Assuming that the explained variables are ordinal, the ordered logit model is an appropriate empirical strategy (Greene, 2003).

2 Literature review

Food waste results from multiple management-related behaviors in the planning, purchasing, storage, and consumption of food in households and food services. At each stage of food purchasing and preparation, personal factors, such as culture, demographics, lifestyle, and perceptions, influence food waste (Heng & House, 2022). An in-depth examination of the factors influencing all forms of FW is of fundamental importance to implement policies related to the reduction or prevention of FW at the consumer level. With this objective, several studies using different methodological approaches have attempted to understand consumer behavior concerning food waste (Fanelli, 2019). Online questionnaires enable researchers to determine the amount, type, and frequency of discarding domestic foods using qualitative information (Jörissen et al., 2015). Interviewees' responses to qualitative questions may express some degree of agreement, intensity, or frequency, coded on a Likert-type scale (Qi & Roe, 2016).

In an international survey of observations from the US, Canada, the UK, and France, Heng and House (2022) measured the frequency of discarding fresh inedible fruits and vegetables through responses rated by individual households. The survey questioned the frequency of throwing away fresh fruits and vegetables that are no longer edible, with answers expressing an ordinal frequency scale including alternatives ever (1), rarely (2), sometimes (3), and often (4). An ordered *probit* econometric model was used to estimate the probabilities of a latent variable representing the level of food waste per individual, given a vector of respondents' demographic characteristics. Similar models estimate the chances of food waste according to a vector of explanatory variables using the ordered logit method as an empirical strategy (Hazuchova et al., 2020; Kim & Lee, 2020; Qi & Roe, 2016).

² Economist Intelligence Unit (2020).

This literature review identified common factors that influence household decisions towards waste food. Most studies have considered family composition and respondents' demographic characteristics as drivers of food waste. Researchers have assumed that decisions regarding the amount, frequency, and type of food wasted are dependent upon factors such as family size, educational level, income, age structure, gender composition, marital status, and employment situation (Annunziata et al., 2022; Li et al., 2022; Vittuari et al., 2020). Zhang et al. (2018), in a case study of the city of Shenzhen, and Edjabou et al. (2016), studying Danish families, found that food waste increases as family size grows. Coincidentally, Luo et al. (2021) found that food waste in rural China is also positively correlated with the number of household members. Nevertheless, several studies have found that the amount of food waste generated per capita decreases with increasing household sizes (Jörissen et al., 2015; Schanes et al., 2018). Income and education are highly correlated variables and may have a similar influence on food waste across studies. The positive effect of income on food waste is a consensus in the literature (Marangon et al., 2014; Secondi et al., 2015; Zhang et al., 2018); for wealthier groups. In addition, economic development and income growth are also important factors in food waste in rural China (Luo et al., 2021). However, increasing income is related to lower food waste (Lopez Barrera & Hertel, 2021). Similarly, Heng and House (2022) showed that education has a positive influence on food waste, while Mattar et al. (2018) and Li et al. (2022) showed that this positive impact becomes negative at higher levels of schooling.

Although there is no consensus on how age affects food waste (Schanes et al., 2018), Secondi et al. (2015) and Karunasena et al. (2021) demonstrate that individuals' age negatively impacts food waste with an increasing marginal effect, that is, consumers' propensity to waste food decreases as they age. According to empirical evidence, gender has an ambiguous impact on food waste (Schanes et al., 2018). Visschers et al. (2016) found that female sex was significantly associated with wasting more food, whereas Cecere et al. (2013) concluded that women generate less food waste. Some studies, have found no gender differences in food waste (Bretter et al., 2022; Principato et al., 2015). Marital status showed different results in the reviewed literature. Abd Razak (2017) found that single consumers in Malaysia tend to be more adaptable to avoiding food waste, while a study in Nigeria showed that married household individuals waste less food than single consumers (Sunday et al., 2022). Concerning the employment situation, a study conducted in the European Union (EU-27) in 2013 found that the unemployed and jobseekers waste, on average, less food than workers (Secondi

et al., 2015). In addition, some studies argue that families may underestimate food waste as they feed their pets with surplus food (Caldeira et al., 2019; Porpino et al., 2015).

Food management routines, such as planning shopping trips and food stocks, explain most of the variance in household food waste (Romani et al., 2018; Stancu & Lähteenmäki, 2022; Stefan et al., 2013). For instance, food purchasing frequency has a contradictory effect on food waste (Jörissen et al., 2015). When a family goes shopping more often to better match daily household needs, shopping frequency is likely to reduce food waste. Empirical studies suggest that overbuying increases food waste when more shopping trips are associated with discount and sales. Preparing a grocery list, however, can convert impulsive shopping into planned activity, thus mitigating food waste (Bravi et al., 2020; Mattar et al., 2018). Another aspect of planning food purchases is looking at information on product labels. In an online survey of American consumers, Kavanaugh and Quinlan (2020) found that participants who correctly identified food labels were less likely to report food-waste behaviors.

In addition to individual characteristics and food management procedures, methods and tools are important for preventing household food waste. Smart Fridges, electrolyzed water, and packaging, for instance, are imperative for prolonging the shelf-life (Al-Obadi et al., 2022; Cappelletti et al., 2022). Efficient food preparation practices, leftover cooking skills, and freezing make it possible to reuse edible foods (Schanes et al., 2018; Carroll et al., 2021; Brennan et al., 2021; Karunasena et al., 2021). However, Luo et al. (2021) found that in rural China, not all modern cookers reduce food waste, and only the use of food utensils with an appropriate capacity is related to lower waste. The literature also confirms the importance of consumer awareness and attitudes towards reducing food waste. American consumers, for instance, show little tolerance for visual food imperfections, but intolerance decreases for those with environmental concerns (Aschemann-Witzel et al., 2015). Comber and Thieme (2012) showed that pictures of bin cans on social networks raise consumers' feelings of guilt, leading them to reflect on their behaviors towards recycling and food waste. However, some researchers consider this as an alternative food waste reduction behavior (Talwar et al., 2021). 'Guilt', for instance, is also found to play an important role in reducing food waste (Quested et al., 2013). Culture factors are also very important for the study of factors influencing food waste. Food cultures and traditions in China are factors of out-of-home food waste (Xue et al., 2021). Being seen taking food home from a restaurant to avoid wasting it can lead to loss of face which is also called *Mianzi* affecting traditional Chinese behavior, attitudes and social norms profoundly (Liao et al., 2018).

3 Theoretical model

Becker's Theory of Allocation of Time assumes that households derive utility from consuming product Z according to a utility function that individuals maximize when subjected to a budget constraint. Instead of consuming purchased goods directly, households combine inputs x and time T_x to convert them into Z goods through a production function $Z_i = f(x, T_x)$ (Becker, 1965). In Lusk and Ellison's version of Becker's model, households convert raw food inputs (x) and time (t_f) into meals (z) via a production function $z = f(x, t_f)$. Food waste is derived from raw food inputs that are not transformed into meals (Lusk & Ellison, 2016).

Landry and Smith (2017) also presented an input-oriented view of production inefficiencies, according to which food inputs not used in household meal production are considered waste. Furthermore, the authors divided the household decision process into two stages: production (lower stage) and consumption (upper stage). At the lower stage, the model also assumes that homemade food production uses inputs x_1 (raw food, cooking ingredients, heating, freezing, labor, and others) to prepare household meals during time t_1 , and according to the technology parameter φ . In the food preparation process, the model assumes that there is an optimum level of input use x_1^o ($x_1^o \leq x_1$) that minimizes homemade food production costs, such that $(x_1 - x_1^o)$ is considered food waste (Landry & Smith, 2017).

The present model assumes that individual households maximize the utility of consuming two categories of nutritional products: homemade (z_1) and ready-made (z_2). Homemade food uses market-purchased food input (x_1), time input (t_1), and technology φ (tools, appliances, knowledge, experience, etc.) to produce z_1 amounts of food. G is the production function.

Consequently, the household indirect utility function for food production z_1 can be represented as

$$U_{z_1} = U[G_1(x_1, t_1; \varphi)]$$

Families also purchase ready-made food (x_2) which, is after handling (heating, freezing, washing, cleaning, storing, etc.). During period t_2 , and according to technology parameter φ^3 , it will be ready for consumption (z_2)⁴.

Accordingly, the household indirect utility function for ready-made meal z_2 can be expressed as follows:

$$U_{z_2} = U[G_2(x_2, t_2; \varphi)]$$

The total amount of food served by the household was $z = (z_1 + z_2)$. Therefore, the individual household utility function for food consumption is as follows:

$$U_{z_e} = U[(z_1, z_2); \tau]$$

where τ is a taste parameter that affects the translation of leisure and purchased goods into utilities (Huffman, 2011).

In the household production stage, we assume, as in Landry and Smith (2017), that the difference between food input used (x_1) and its cost-minimizing level (x_1^o) represents food waste (w_1).

The model also considers that if the amount of ready-made food purchased (x_2) exceeds the quantity served (z_2), the difference will signify food waste (w_2).

At the consumer level, food waste (w_3) is the difference between z and the total amount of food intake (z_e)⁵.

Therefore, the total amount of food waste (W) occurring during the household food production, market-purchased ready-made food handling, and food consumption stages is the sum ($w_1 + w_2 + w_3$). Thus, the disutility of food waste for an individual household (U_w) is given by:⁶

$$U_w = U[W(x_1, x_2); \gamma]$$

where γ denotes an awareness parameter, varying from 0 to 1, and weights the disutility of food waste on the total individual utility function. If $\gamma = 1$, the consumer is fully aware of food waste, whereas if $\gamma = 0$, the consumer is entirely unaware of food waste. For example, $\gamma = 0$, consumers derive all utility from food intake and are indifferent to food waste (Qi, 2018). Accordingly, the total utility function (U_T) accrued from home-made food consumption, ready-made food consumption, and food waste is represented by

$$U_T = U_{z_e} + U_w = U[G_1(x_1, t_1; \varphi), G_2(x_2, t_2; \varphi); \tau] + U[W(x_1, x_2); \gamma]$$

Furthermore, the household has a cash income constraint (I) attained from members' hourly wages (ω) working during hours for pay and from other income sources (V). The model also assumes that individual households allocate non-wage hours on ready-to-each food purchasing and handling (t_1) and food inputs purchasing and preparing (t_2), such that the household total time endowment (T) is

³ The model assumes that the household technology and knowledge parameter (φ) is indistinct, either producing or handling food at home.

⁴ Note that if purchased prepared food is for immediate consumption, $z_2 \cong x_2$ and $t_2 \cong 0$.

⁵ Ready-made foods that spoil or rot before it becomes a meal are counted in w_2 ; all other non-eaten foods are considered w_3 .

⁶ The disutility of food waste is related to factors such as the utility loss for not consuming available food, the monetary cost of food, the guilty feeling for wasting food, and environmental concerns (Qi, 2018).

$$T = t_1 + t_2 + h$$

Considering that consumers use the total income to purchase x_1 at price p_1 and x_2 at price p_2 , the family income constraint is represented as

$$I = \omega \cdot h + V = p_1x_1 + p_2x_2$$

Substituting $h = (T - t_1 + t_2)$ into the family income constraint equation and rearranging the terms, we find that

$$\omega T + V = p_1x_1 + \omega t_1 + p_2x_2 + \omega t_2$$

By maximizing the conditions of the utility function, the general form of the implicit demand function for the inputs used in the model is (Huffman, 2011):

$$x_i^* = D_{x_i}(p_1, p_2, \omega, V, \varphi, \tau, \gamma), i = 1, 2$$

$$t_i^* = D_{t_i}(p_1, p_2, \omega, V, \varphi, \tau, \gamma), i = 1, 2$$

$$W^* = D_W(p_1, p_2, \omega, V, \varphi, \tau, \gamma), i = 1, 2$$

That is, to maximize utility subject to a budget constraint, the individual household will indirectly depend on food input prices, ready-food prices, wage rates, other income sources, and the parameters of technology, taste, and food waste concern. The specific calculations are in the Appendix 1.

4 Methodology

4.1 The data

The data in this research were obtained from a survey conducted from July 12 to August 9, 2021, through WeChat and email questionnaires received from 3,857 individuals living in selected Chinese metropolitan areas distributed across all provinces of the country. Respondents must be the person in the household most involved in purchasing, handling, preparing, and disposing of food, with a minimum age of 18 years. This study aimed to obtain data on the demographic characteristics of respondents and their habits of buying, handling, preparing, and disposing of food at home.

4.2 The variables

The main objective of this survey was to examine respondents' attitudes towards food waste at home. The questionnaire sought to obtain this information through the following questions: How often did the family discard food at home? How much food does a family discard at home? Responses

Table 1 Dependent variables

Variables	Definition
<i>FOOD1</i>	How often do you discard food at home? [1-Never, 2-Very seldom, 3-Sometimes, 4-Often, 5-Everyday]
<i>FOOD2</i>	How much food do you discard each time? [1-None, 2-Very few, 3-Medium, 4-A lot, 5-Very Much]

were measured on a Likert-type scale ranging from 1 (minimum level) to 5 (maximum level). In cases of ordered discrete responses, the ordered logit model is the right choice for estimation (Greene, 2003).

The study estimated two types of models based on the choice of dependent variable. The first group used $y = \text{FOOD1}$ (frequency of food discarded) and the second used $y = \text{FOOD2}$ (amount of food discarded). Tables 1 and 2 define the variables used in the empirical model.

According to Annunziata et al. (2022), Vittuari et al. (2020), and Li et al. (2022), we take demographic factors into account first, including age structure, marital status, gender composition, educational level, family size, and income.

Food purchasing routines, such as planning shopping trips and food stocks, and food purchasing frequency and the amount of buying greatly affect household food waste (Romani et al., 2018; Stefan et al., 2013; Stancu & Lahteenmaki, 2022; Jorissen et al., 2015; Quedsted et al., 2013). Preparing a shopping list leads to lower food waste (Quedsted et al., 2013; Mattar et al., 2018; Bravi et al., 2020). Those who correctly identified food labels were less likely to report food-waste behaviors (Kavanaugh & Quinlan, 2020). Therefore, shopping frequency, shopping list, food storage conditions and food labels are included as explanatory variables in the empirical analysis. In Table 3, the *SHOP* is an index representing the average shopping frequency of consumers for four food groups: cereals and oil, meat, vegetables, and fruits. In addition, *PLAN* represents an average of three measures of planning food acquisition: shopping list (*LIST*), checking food storage conditions (*STORE*), and checking for food labels (*LABEL*).

Food preparation routines are important for preventing household food waste. Smart Fridges, electrolyzed water, and packaging are terrific for prolonging the shelf-life (Quedsted et al., 2013; Cappelletti et al., 2022; Al-Obadi et al., 2022). In addition, efficient food preparation practices, leftover cooking skills, and freezing make it possible to reuse edible foods which helps reduce food waste (Schanes et al., 2018; Carroll et al., 2021; Brennan et al., 2021; Karunasena et al., 2021). Takeaway also plays a significant role in food waste for its convenience (Visschers et al., 2016). The importance of consumer

Table 2 Demographic variables

Variables	Definition
AGE	Age of respondent
DAGE	Equals to 0 for respondents aged less than 33, and 1 otherwise
MARRY	Marital status [0-Unmarried/separated/divorced/widowed, 1-Married/cohabiting]
GENDER	Respondent gender [1-Female, 0-Male]
EDU	Level of education [1-Primary school, 2-Junior middle school, 3-High school, 4-Junior college, 5-Undergraduate college, 6-master's degree, 7-Doctoral candidate]
DEDU	Equal to 0 for elementary and secondary education and 1 otherwise
PEOPLE	How many people live in your house?
INCOME	What is your annual family income? 1(under RMB 30,000), 2(RMB 30,000 – 80,000), 3(RMB 80,000 – 150,000), 4(RMB 150,000 – 1 million), 5(RMB 1 – 10 million), 6(over RMB 10million).
DINC	Equal to 0 for income groups with annual family income less than RMB 1 million and 1 otherwise.

RMB stands for renminbi which is the name of the Chinese currency

awareness and attitudes towards reducing food waste are noted as well (Aschemann-Witzel et al., 2015; Comber & Thieme, 2012; Talwar et al., 2021; Qusted et al., 2013). According to the theoretical model in Section 3, technology including tools, appliances, and knowledge is a fatal factor which has an impact on food waste. Pets are another factor, since families feed their pets with surplus food which can decrease food waste (Caldeira et al., 2019; Porpino et al., 2015). All the above variables are considered. Table 4 shows the variables related to the process of food preparation in the household, and Table 5 presents the variables related to respondents' attitudes and behavior, as well as the possession of tools and appliances used to reduce food waste.

Table 6 shows the individual households' choice of reasons for discarding food. The respondent can choose one or

more options, and the variable *DISC1* represents the number of reasons chosen. Similarly, Table 7 lists the types of food the family commonly discards, and the variable *DISC2* represents the number of food groups discarded.

4.3 The empirical model

In the present study, the ordered logit model assumes that a latent dependent variable (y^*), representing the intensity or frequency of food waste, is estimated as a function of the explanatory variable vector (\mathbf{x}'). The econometric formulation is in line with Mallick (2009):

$$y^* = \mathbf{x}'\boldsymbol{\beta} + \varepsilon.$$

where $\boldsymbol{\beta}$ is a vector of regression parameters and ε is an error term.

Where **Model 1** is:

$$Y = FOOD1_i$$

Table 3 Food shopping planning variables

Variables	Definition
SHOP1	How frequently do you buy food - cereals and oil? [1-Never, 2-Very seldom, 3-Sometimes, 4-Often, 5-Every day]
SHOP2	How frequently do you buy food – meat? [1-Never, 2-Very seldom, 3-Sometimes, 4-Often, 5- Every day]
SHOP3	How frequently do you buy food – Vegetables? [1-Never, 2-Very seldom, 3-Sometimes, 4-Often, 5- Every day]
SHOP4	How frequently do you buy food – Fruits? [1-Never, 2-Very seldom, 3-Sometimes, 4-Often, 5- Every day]
SHOP	Shopping index: (SHOP1 + SHOP2 + SHOP3 + SHOP4)/4
LIST	Before shopping, do you prepare shopping list? [1-Never, 2-Very seldom, 3-Sometimes, 4-Often, 5-Always]
PLAN	Planning index: (LIST + STORE + LABEL) /3

Table 4 Food preparation variables

Variables	Definition
COOK	How often do you cook meal? [1-Never, 2-Very seldom, 3-Sometimes, 4-Often, 5-Every day]
LEFT	Will you save leftover for later meals? [1-Never, 2-Very seldom, 3-Sometimes, 4-Often, 5-Every day]
FREEZE1	Do you prepare food to freeze? [1-Never, 2-Very seldom, 3-Sometimes, 4-Often, 5-Every day]
FREEZE2	How often do you buy frozen food? [1-Never, 2-Very seldom, 3-Sometimes, 4-Often, 5-Every day]

Table 5 Attitude, behavior and tools variables

Variables	Definition
TAKE	Times per week do you order take away? 1(under 3), 2(3–4), 3(5–10), 4(over 10)
NONEED	Do you buy more food than you need just to have free delivery? [1-never, 2-rarely, 3-occasionally, 4-frequently]
EATMORE	Will you eat more than you want just to finish up? [1-Never, 3-Sometimes, 4-Sure]
WORRY1	Are you worried about food waste?
WORRY2	Do you usually take actions to avoid food waste?
WORRY	(WORRY1 + WORRY2) /2
TOOLS1	Do you have equipment to avoid food waste at home?
TOOLS2	Do you have knowledge to avoid food waste?
TOOLS	(TOOLS1 + TOOLS2) /2
PET	Are there pets in the house? [1-Yes, 0-No]

Model 1A:

$$x' = \text{EDU}_i, \text{DEDU}_i, \text{PEOPLE}_i, \text{MARRY}_i, \\ \text{GENDER}_i, \text{PET}_i, \text{LIST}_i, \text{DISC1}_i$$

Model 1B:

$$x' = \text{INCOME}_i, \text{DINC}_i, \text{FREEZE1}_i, \text{COOK}_i, \\ \text{TAKE}_i, \text{NONEED}_i, \text{EATMORE}_i, \text{DISC2}_i$$

And **Model 2** is:

$$Y = \text{FOOD2}_i$$

$$x' = \text{AGE}_i, \text{DAGE}_i, \text{WORRY}_i, \text{PLAN}_i, \text{SHOP}_i, \\ \text{TOOLS}_i, \text{LEFT}_i, \text{FREEZE2}_i$$

Other relevant empirical formulas are in the Appendix 2. Christensen (n.d.) addressed the problem of whether threshold intervals are equidistant or flexible. The threshold hypothesis examines whether the threshold is constant for $j=2, \dots, J-1$ (j is the ordered response) using the likelihood ratio to test the statistical difference between models with flexible and equidistant thresholds. Failure to reject implies that we may retain the model with equally spaced thresholds.

Model selection relies on goodness of fit measures, such as the statistical significance of the parameters, the Akaike Information Criterion (AIC), and the condition number of the Hessian (Cond. H). A smaller AIC suggests a better fit,

Table 6 Reasons for discarding food variables

Variables	Definition (Why do you usually discard food?)
DISC11	Food has expired (0-no, 1-yes)
DISC12	Food has gone bad (0-no, 1-yes)
DISC13	I dislike it (0-no, 1-yes)
DISC14	It is Bad cooked (0-no, 1-yes)
DISC15	I do not eat leftovers (0-no, 1-yes)
DISC1	(DISC11 + DISC12 + DISC13 + DISC14 + DISC15)

because it is directly related to the model's residual sum of squares (Enders, 2015). The condition number of the Hessian is the ratio of the largest to the smallest eigenvalues and is the degree of empirical identifiability of the model. A "Cond. H" number lower than 10^6 indicates that the model reached a well-defined optimum. No p-values are reported in the table for the threshold coefficients because they usually do not make sense to test whether they are equal to zero. Each threshold (cut-off point) represents the intercept of the logit model. Therefore, to calculate the log-odd ratio and odds ratio of food disposal in each threshold interval, we should use the corresponding intercept (threshold) (Christensen, n.d.).

5 Results

5.1 Descriptive statistics

Table 8 shows the frequencies of Likert scale responses on the dependent variables *FOOD1* (frequency of discarding food) and *FOOD2* (amount of food discarded). Most

Table 7 Kind of food discarded variables

Variables	Definition (What kind of food do you usually discard?)
DISC21	Cereals/Grains (0-no, 1-yes)
DISC22	Roots/Tuber (0-no, 1-yes)
DISC23	Beans/Seeds (0-no, 1-yes)
DISC24	Milk/Dairy (0-no, 1-yes)
DISC25	Meet/Protein (0-no, 1-yes)
DISC26	Fruit/Vegetables (0-no, 1-yes)
DISC27	Candy/Desert (0-no, 1-yes)
DISC28	Drinks (0-no, 1-yes)
DISC29	Compound dishes (0-no, 1-yes)
DISC210	Baking products (0-no, 1-yes)
DISC2	(DISC21 + DISC22 + DISC23 + DISC24 + DISC25 + DISC26 + DISC27 + DISC28 + DISC29 + DISC210)

Table 8 Descriptive statistics

Amount and Frequency of Discarding Food	Variables (Frequencies in %)	Likert Scale				
		1	2	3	4	5
	FOOD1	Never	Very Seldom	Sometimes	Often	Everyday
		13.7	35.1	27.0	12.0	12.2
	FOOD2	None	Very Few	Medium	A Lot	Very Much
		15.3	47.7	22.4	8.3	6.3
	AGE	PEOPLE	EDU	INCOME		
Demographic Variables	Mean	33	4	4.6	3	
	Minimum	18	1	1	1	
	Maximum	90	12	7	6	
Binary Choice Variables	Variables	1	0			
	GENDER	Women	Men			
	(%)	58	42			
	MARRY	Married	Not Married			
	(%)	48	52			
	PETS	Yes	No			
	(%)	38	62			
Reasons for Discarding Food	Variable	Description	%			
	DISC11	Food has expired	58.1			
	DISC12	Food has gone bad	71.8			
	DISC13	I dislike	40.1			
	DISC14	Food is Bad cooked	36.0			
	DISC15	I Do not eat leftovers	26.4			

respondents reported discarding food “Very Seldom” or “Sometimes” and in “Very Few” or “Medium” amounts. It also presents descriptive statistics of variables *AGE* (respondent’s age), *PEOPLE* (number of people in the household), *EDU* (respondents’ years of formal education) and *INCOME* (respondents’ income group). Additionally, it shows the results for the binary choice variables *GENDER*, *MARRY* and *PETS*, and the percentages of respondents who chose each reason to discard food.

Table 9 lists the types of food usually discarded in the household, where percentages do not add up to 100%, because respondents can choose more than one alternative.

Table 9 Food usually discarded

Variable	Description	%
DISC21	Cereals/Grains	31.0
DISC22	Roots/Tuber	43.1
DISC23	Beans/Seeds	35.9
DISC24	Milk/Dairy	32.6
DISC25	Meet/Protein	23.0
DISC26	Fruit/Vegetables	26.2
DISC27	Candy/Desert	11.4
DISC28	Drinks	7.2
DISC29	Compound Dishes	16.3
DISC210	Baking products	9.4

Table 10 Models with dependent variable food1

	MODEL 1A	MODEL 1B
VARIABLES	Estimates	Estimates
<i>EDU</i>	0.193***	–
<i>DEDU</i>	-0.429***	–
<i>PEOPLE</i>	-0.041*	–
<i>INCOME</i>	–	0.185***
<i>DINC</i>	–	-0.472***
<i>MARRY</i>	0.149**	–
<i>GENDER</i>	0.146**	–
<i>PET</i>	-0.191***	–
<i>LIST</i>	-0.055**	–
<i>FREEZEI</i>	–	-0.071***
<i>COOK</i>	–	0.060***
<i>TAKE</i>	–	-0.082***
<i>NONEED</i>	–	0.062**
<i>EATMORE</i>	–	-0.075*
<i>DISC1</i>	0.225***	–
<i>DISC2</i>	–	0.144***
Thresholds	Estimates	Estimates
112	-1.083***	-1.201***
213	0.740***	0.625***
314	1.955***	1.839***
415	2.793***	2.676***
FTH (LR-Statistics)	272.83***	274.36***
AIC	11524.92	11522.16
Cond. H	9.9e+03	7.1e+03

Signif. codes: p < 0.1% [***], 0.1% ≤ p < 1% [**], 1% ≤ p < 5% [*]

Table 11 Estimated coefficients, odds ratio and percent impact (**Model 1A**)

Variables	EDU	DEDU	PEOPLE	MARRY	GENDER	PET	LIST	DISC1
Estimates	0.193	-0.429	-0.041	0.149	0.146	-0.191	-0.055	0.225
OR	1.213	0.651	0.960	1.160	1.158	0.827	0.946	1.252
PI (%)	21.3	-34.9	-4.0	16.0	15.8	-17.3	-5.4	25.2

5.2 Logistic regression

The logistic regressions alternatively used the dependent variables *FOOD1* and *FOOD2* to capture respondents' behavior concerning food waste. Table 10 presents the statistical results of the ordered logistic regression for the models, with *FOOD1* as the dependent variable. Considering that there are five possible responses for *FOOD1* (*Never* = 1, *Very Seldom* = 2, *Sometimes* = 3, *Often* = 4, and *Every Day* = 5), the table also presents estimates and p-values for the cutoff points (1|2, 2|3, 3|4, and 4|5) of the latent variable y^* . The model used a likelihood ratio (LR) statistic to test the fixed threshold hypothesis, which, in both models, accepted the alternative hypothesis of flexible thresholds. The Akaike Information Criterion (AIC) was used for model selection, and the condition number (Cond. H) of 9.9×10^3 indicates the empirical identifiability of the models. All variables' coefficients and cut-off points in **Model 1A** and **Model 1B** were statistically significant at levels lower than 10% for the estimated models.

According to empirical studies, education positively impacts food waste, but at higher levels of schooling, this impact becomes negative (Li et al., 2022; Mattar et al., 2018). To test this hypothesis, Model 1A used the *EDU* variable and the dummy variable *DEDU*, equal to 0 for elementary and secondary education, and 1 for higher education. The coefficients' signs were positive for *EDU* and negative for *DEDU*, confirming the hypothesis of a positive impact at lower schooling levels and a negative impact at higher schooling levels. While most studies have found a positive relationship between family size and food waste, some have identified a decrease in per capita food waste (Jörissen et al., 2015; Schanes et al., 2018). In the present study, the negative sign for the coefficient of the variable *PEOPLE* may be related to the interviewees' impression of decreasing food waste per capita in larger households.

The *MARRY* and *GENDER* variables had positive coefficients, which suggests that being married and being female increase the odds of wasting food at home. It is possible that married respondents in China, particularly women, are more involved with home food preparation, while single individuals prefer eating out. However, the literature review is inconclusive regarding the impact of marital status and gender on food waste. The coefficients of the *PET* and *LIST* variables were negative, confirming the findings in the literature concerning the food waste reduction effect of owning a pet and preparing a food shopping list. *DISC1* had a positive coefficient, suggesting that respondents who reported more reasons for discarding food were more likely to discard it.

Each estimated coefficient represents the level of variation in the dependent variable on a logarithmic scale for a unit increase in the explanatory variable. Considering that it is not trivial to interpret these coefficients, as they are on a logarithmic scale, it is possible to obtain the odds ratio (OR) for each variable by converting the estimates to an exponential scale. With the odds ratio, we calculate the percentage impact (PI) on the dependent variable by changing one unit in each explanatory variable, keeping all other variables constant⁷. Table 11 shows the estimated coefficients, odds ratios, and percentage impacts for **Model 1A**.

According to the results, a unit increase in the respondent's level of education induced a 21.3% increase in the chances of food waste; however, the chance of wasting food decreased by 34.9% for individuals with higher levels of schooling. In addition, having one more person in the family reduced the chances of food waste frequency by 4%. Being single and female increased the odds of food wastage by 16% and 15.8%, respectively, while having a pet at home decreased the odds of food wastage by 17.3%. In addition, a unit increase on the Likert scale for preparing a shopping list reduces the odds of food wastage by 5.4%. Furthermore, one additional reported reason for food disposal is a 25.2% increase in the odds ratio of food waste.

Table 12 Estimated coefficients, odds ratio and percent impact (**Model 1B**)

Variables	INCOME	DINC	FREEZE1	COOK	TAKE	NONEED	EATMORE	DISC2
Estimates	0.185	-0.472	-0.071	0.060	-0.082	0.062	-0.075	0.144
OR	1.204	0.624	0.931	1.062	0.922	1.064	0.927	1.155
PI (%)	20.372	-37.635	-6.864	6.173	-7.844	6.395	-7.201	15.477

⁷ $PI = [(OR - 1) \times 100\%]$.

Table 13 Model with dependent variable *FOOD2*

MODEL 2	
Variables	Estimates
<i>AGE</i>	0.017***
<i>DAGE</i>	-0.247*
<i>WORRY</i>	-0.059*
<i>PLAN</i>	-0.124***
<i>SHOP</i>	0.082**
<i>TOOLS</i>	-0.089***
<i>LEFT</i>	-0.045*
<i>FREEZE2</i>	0.112***
Thresholds	Estimates
1 2	-1.734***
2 3	0.545**
3 4	1.810***
4 5	2.760***
FTH (LR-Stat.)	398.2***
AIC	10389.65
Cond.H	3.3e+05

Signif. codes: p < 0.1% [***], 0.1% ≤ p < 1% [**], 1% ≤ p < 5% [*]

In **Model 1B**, *INCOME* had a positive coefficient. However, the *dummy* variable *DINC* shows a negative sign for the coefficient, which may suggest that growing income is associated with increasing the odds of food waste only for lower levels of income. The *FREEZE1* variable showed a negative coefficient, suggesting that freezing food at home for later consumption works as a strategy to reduce food waste, in accordance with Schanes et al. (2018) and Secondi et al. (2015). The estimated coefficient of *COOK* was positive, suggesting that home cooking may be associated with higher levels of food waste. The variable *TAKE* also showed a negative sign, signifying that ordering food as an alternative to cooking at home is a food-waste reduction strategy. The *NONEED* variable had a positive coefficient, implying that getting more food than needed to take advantage of free delivery is a food wasting decision. On the other hand, the variable *EATMORE* showed a negative coefficient, suggesting that campaigns such as “clean plate” effectively reduce food waste. The *DISC2* variable, which represents the type of food discarded, had a positive coefficient, which may suggest a direct correlation between food diversification and food waste. Table 12 shows the estimated coefficients, odds ratios, and percentage impacts for **Model 1B**.

Table 14 Estimated coefficients, odds ratio and percent impact (Model 2)

Variables	AGE	DAGE	WORRY	PLAN	SHOP	TOOLS	LEFT	FREEZE2
Estimates	0.017	-0.247	-0.059	-0.124	0.082	-0.089	-0.045	0.112
OR	1.018	0.781	0.943	0.883	1.086	0.915	0.956	1.118
PI (%)	1.8	-21.9	-5.7	-11.7	8.6	-8.5	-4.4	11.8

The results showed that a unit increase in the income level increases the chances of food waste by 20.4%, but for the higher-income respondents, the chances of food waste decrease by nearly 38%. A one-level increase in the Likert scale of food preparation for freezing reduced the chances of food waste by 6.9%, and a one-unit increase in the home cooking frequency scale induced a 6.2% increase in the odds of food waste. In contrast, a one-unit increase in the frequency of buying takeaway food and eating everything to finish up the plate decreases the chances of food waste by 7.8% and 7.2%, respectively. An increase of one level in the response scale of buying more to get free delivery raises the odds ratio of food waste by 6.4%. Furthermore, the odds of food waste increased by 15.5% for each additional food group discarded by respondents.

Table 13 presents the statistical results of the ordered logistic regression for the models, with *FOOD2* as the dependent variable. Considering that there are five categories for *FOOD1* (*None* = 1, *Very Few* = 2, *Medium* = 3, *A Lot* = 4, and *Very Much* = 5), the table also presents estimates and p-values for the cut-off points (1|2, 2|3, 3|4, and 4|5) of the latent variable. The model used a likelihood ratio (LR) statistic to test the fixed threshold hypothesis, which accepted the alternative hypothesis of flexible thresholds. The results used the Akaike Information Criterion (AIC) for model selection and the condition number (Cond. H) of 3.3×10^5 indicates empirical identifiability of the model.

To test whether the impact of individuals’ age on food waste will change for older respondents, Model 2 used the variable *AGE* and a *dummy* variable *DAGE* with values of 0 for people below the age average (33) and one otherwise. The *AGE* variable coefficient was positive, and the variable *DAGE* had a negative coefficient, suggesting a positive impact of age on food waste, but according to a decreasing marginal effect as the individual ages. Although the literature is inconclusive regarding the impact of age and food waste (Schanes et al., 2018), Karunasena et al. (2021) found that the elderly have less food waste. It is worth mentioning that Li et al. (2022) reported an “inverted U” relationship between wasting food and age in the case of meals in restaurants and canteens; food waste was the lowest for people under 30 or over 60. However, food waste was positively related to age in the household setting. The variable *WORRY*, which represents the concerns and actions of respondents regarding food waste, presented a negative coefficient, which is in line with the reviewed literature (Aschemann-Witzel et al., 2015).

Table 15 Interval thresholds values and the likert scale for model 1

MODEL 1A		MODEL 1B	
Thresholds	Likert Scale	Thresholds	Likert Scale
$y^* \leq -1.083$	Never	$y^* \leq -1.295$	Never
$-1.083 < y^* \leq 0.740$	Very Seldom	$-1.295 < y^* \leq 0.527$	Very Seldom
$0.740 < y^* \leq 1.955$	Sometimes	$0.527 < y^* \leq 1.739$	Sometimes
$1.955 < y^* \leq 2.793$	Often	$1.739 < y^* \leq 2.576$	Often
$y^* > 2.793$	Every Day	$y^* > 2.576$	Every Day

The *PLAN* variable has a negative coefficient, which confirms previous research showing that shopping planning routines are likely to reduce food waste (Bravi et al., 2020; Kavanaugh & Quinlan, 2020; Mattar et al., 2018).

This is in line with empirical evidence linking the frequency of shopping trips to higher levels of food waste, particularly when shopping trips are associated with discounts and impulsive purchases (Mattar et al., 2018). The *TOOLS* variable showed a negative coefficient, suggesting that home appliances and technical information may reduce food waste. The *LEFT* variable presented a negative coefficient, confirming the results of previous research, according to which saving leftovers is a strategy to reduce food waste (Karunasena et al., 2021). The variable *FREEZE2* has a positive coefficient, implying that buying frozen food is an increasing food waste strategy. Table 14 shows the estimated coefficients, odds ratios, and percentage impact for Model 2.

A one-unit increase in the response scales of individual households related to worrying about food waste, planning food shopping, and saving leftovers for a later meal decreased the odds of food waste by 5.7%, 11.7%, and 4.4%, respectively. Furthermore, a unit increase in the frequency of food shopping and buying food to freeze increases the odds of food waste by 8.6% and 11.8%, respectively. Finally, a one-unit increase in the response scale of having tools and knowledge to avoid food waste is related to a decrease in the odds of wasting food of 8.5%. Tables 15 and 16 in the Appendix 3 show the interval threshold values and the Likert scale for the estimated models.

Table 16 Interval thresholds values and the likert scale for model 2

MODEL 2	
Thresholds	Likert Scale
$y^* \leq -1.734$	Never
$-1.734 < y^* \leq 0.545$	Very Seldom
$0.545 < y^* \leq 1.810$	Sometimes
$1.810 < y^* \leq 2.760$	Often
$y^* > 2.760$	Every Day

6 Conclusions and policy implications

Food loss and waste have become critical issues for food security. The Food and Agriculture Organization of the United Nations (FAO) has estimated that the world's food system throws one-third of all food produced annually. Compounding the problem of food security, losing and wasting food also means misusing resources allocated to the production, processing, and distribution of unconsumed food. This study focuses on food waste, which refers to food that reaches retailers, food service providers, and household consumers but ends up in garbage cans. This study focuses on the determinants of food waste behavior in Chinese urban households. For a largely populated country, such as China, a sound understanding of the factors determining food waste may represent good subsidies for formulating food security policies.

According to research results, food waste increases with age, education, and income, but at a decreasing rate. This does not mean that older, more educated, and wealthier people waste less food in absolute terms; the results only indicate that the odds of food waste decrease for these groups, which may be more susceptible to awareness factors such as food safety and the environment. In addition, food waste appears to be sensitive to household demographic characteristics, food management and processing, consumer behavior, possession of appropriate instruments, and technical knowledge. Wary meal planning, including the number of shop trips, checking food labels, making food purchasing decisions, using home appliances, and appropriately managing leftovers, could help individual households mitigate food waste problems. Additionally, the results suggest that eating more to finish the plate is a food waste reduction strategy, supporting the effectiveness of policies such as China's "clean plate" campaign.

Variables such as gender, marital status, and number of people in the household are structural and do not depend on a family member's decision. In such situations, the research results will serve as a food waste alert for families. In other cases, a proper understanding of the empirical results and the subsequent policy implications is crucial. For example, cooking at home is likely to increase food waste, whereas meal takeout is a food waste reduction strategy. This does not necessarily mean that a family should stop cooking at home and buy precooked food to reduce food waste. Instead, an appropriate policy implication is that individual households should be cautious about food waste when cooking at home.

Finally, the results of this study and the findings in the literature compose a body of evidence that domestic food waste is highly dependent on people's behavior, and that its reduction may depend on educational campaigns to increase families' awareness of the problem. It is also essential to consider that, as one of the fastest-growing income economies in the world,

China is already undergoing a structural shift, where people are increasingly eating out or buying pre-cooked meals. This change will undoubtedly contribute to reducing household food waste in the country. At the national level, governments, private companies, and nonprofit organizations are crucial in developing policies to reduce food waste. Simple changes in the food market towards offering products of alternative sizes and packaging, for example, may diminish food losses in the domestic environment. At the global level, international agencies in close cooperation with national governments must develop programs to ensure that most of the world's food supply goes from farm to table, with minimal loss and waste.

Appendix 1 – Supplementary calculations of theoretical model

A Lagrangian function (\mathcal{L}) maximizes consumer utility subjected to a budget constraint, as follows:

$$\mathcal{L} = U[G_1(x_1, t_1; \varphi), G_2(x_2, t_2; \varphi); \tau] + U[W(x_1, x_2; \gamma)] + \lambda(\omega T + V - p_1 x_1 - \omega t_1 - p_2 x_2 - \omega t_2)$$

where λ is the marginal utility of income. Solving the first-order conditions for x_1 , x_2 , t_1 , t_2 and W , we obtain

$$x_1: U'_{z_1} G'_{1x_1} - \lambda p_1 = 0$$

$$x_2: U'_{z_2} G'_{2x_2} - \lambda p_2 = 0$$

$$t_1: U'_{z_1} G'_{1t_1} - \lambda \omega = 0$$

$$t_2: U'_{z_2} G'_{2t_2} - \lambda \omega = 0$$

$$W: U'_W - \lambda p_1 - \lambda p_2 = 0$$

$$\lambda: \omega T + V - p_1 x_1 - \omega t_1 - p_2 x_2 - \omega t_2 = 0$$

And $U'_{z_1} > 0$, $U'_{z_2} > 0$, $G'_{1x_1} > 0$, $G'_{2x_2} > 0$, $G'_{1t_1} > 0$, $G'_{2t_2} > 0$, $U'_W < 0$.

U'_{z_1} and U'_{z_2} are, respectively, the marginal utilities of food intake z_1 and z_2 ; G'_{1x_1} and G'_{2x_2} are, respectively, the marginal products of inputs x_1 and x_2 ; G'_{1t_1} and G'_{2t_2} are, respectively, the marginal products of inputs t_1 in producing z_1 and inputs t_2 in producing z_2 ; and U'_W is the marginal utility of food waste.

Appendix 2 – Supplementary empirical formulas

As y^* is unobserved, we observe that

$$y = j \text{ if } \mu_{j-1} < y^* \leq \mu_j$$

where $j = 1, 2, 3, 4$, and 5 are the ordered responses, and μ 's are $(j - 1)$ unknown parameters representing cut points or thresholds, such that

$$0 < \mu_1 < \mu_2 < \mu_3 < \mu_4$$

Assuming $\varepsilon \sim N(0,1)$, the probability of the j -th outcome is given by

$$\text{Prob}(y = j) = \Phi(\mu_j - \mathbf{x}'\beta) - \Phi(\mu_{j-1} - \mathbf{x}'\beta)$$

where Φ is the cumulative logistic distribution, which is twice continuous and differentiable. The marginal effect of x for the j -th response is calculated as in (Greene, 2003) and Mallick (2009): In the present study, the cumulative logistic model is defined as

$$\text{logit}[P(Y \leq j|x)] = \mu_j + \beta'x, j = 1, \dots, J - 1$$

Appendix 3 – Interval thresholds values and the likert scale

The estimated thresholds represent the interval cutoff points for the continuous latent variable y^* , according to individual characteristics. Thus, the calculated value of y^* indicates the interval of y (Likert scale) that an individual is. For example, if an individual with a set of characteristics has a calculated value for the continuous latent variable y^* equal to -1.083 or less, he/she is more likely to be on a Likert scale ranging from 1 (never discard food). Table 15 shows all thresholds for the latent variable y^* and the respective Likert-scale intervals for Model 1A and Model 1B.

Table 16 shows all thresholds for the latent variable y^* and the respective Likert scale intervals for Model 2.

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Data availability The database for this research is available at the following URL: <https://raw.githubusercontent.com/chaveslima/data/main/foodwastechtrim.csv>.

Declarations

Conflict of interest The authors declared that they have no conflict of interest.

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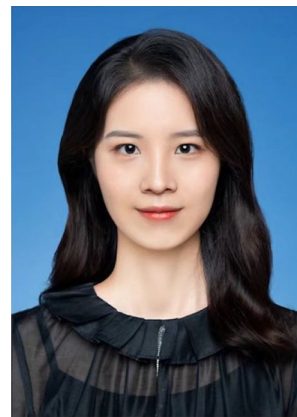
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