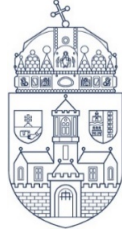


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QUESTIONS OF INNOVATION - FOOD WASTE MANAGEMENT

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1. Introduction

Food waste is one of the challenging issues facing humanity (Al-Obadi et al., 2022). According to research results by the Food and Agriculture Organization of the United Nations, the world's population is expected to increase from 7 billion nowadays to 9 billion in 2050, and food production will need to double to meet the needs of this population (FAO,2023). Every year, one-third of the world's food production is lost or wasted, approximately 1.3 billion tons of food worth more than \$1 trillion are lost, wasted, or disposed of (Mak et al., 2020). The huge loss and waste of food "from farm to fork" is actually enough to feed more than four times the world's 870 million hungry people in the world. Saving just a quarter of the amount of food lost or wasted could end global hunger (FAO,2023). Food waste not only means throwing away a lot of food, but also means that a lot of water, energy, land and other production materials invested in producing this food are also wasted. At the same time, it also brings huge amounts of greenhouse gas emissions, and the processing of these food wastes also brings huge environmental pressure to the city. Therefore, it is urgent to solve the problem of food waste Food waste covers the entire food life cycle, from agricultural production to manufacturing and processing, to retail and household consumption.

1.1. The research problem

This paper aims to provide an in-depth exploration of food waste management through three key questions:

- a. Research the root causes of food waste problems: Understanding the root causes of food waste is critical to developing effective prevention and reduction strategies. Food waste can be attributed to internal factors, that is, problems in the food system itself, such as production and supply chain packaging and storage, retail links, food spoilage, and food surplus in the catering industry; as well as external factors, such as natural, political, economic or sociocultural factors and environmental factors. This is related to the second research question, people's attitudes and awareness of

food waste. A comprehensive analysis of these factors will reveal the multifaceted nature of food waste.

- b. Attitudes and awareness towards food waste at the personal level in China and the EU: This part goes deeper into the personal level and examines the attitudes and behaviors of consumers in China and the EU. The survey will help discern whether problems with personal level or the food system itself contribute to food waste. Furthermore, it will evaluate existing food waste management methods and policies and identify their limitations, aiming to bridge existing knowledge gaps in this area.
- c. Analyze possible innovative opportunities and solutions in food waste management: The final question explores innovative opportunities and solutions to tackle food waste. It will explore the incorporation of Industry 4.0 technologies, such as cyber-physical systems, cloud manufacturing, Internet of Things (IoT), and additive manufacturing, in food waste reduction strategies. These technologies have the potential to revolutionize food waste management and drive the transition toward a circular economy.

The alarming statistics related to food waste and its potential to end global hunger highlight the importance of this research. By addressing these questions, this article strives to advance the current understanding of food waste management and provide insights into innovative strategies to reduce food waste. The following chapters will delve into each issue to provide a comprehensive analysis of the challenges and opportunities in food waste management.

Major research question:

Does innovation issue in food waste management?

Sub-question A: What is the reason for food waste? (Is food waste a personal level problem or a food system problem?)

Sub-question B: Regarding the current situation in China and the EU, what innovative methods can be used to reduce food waste?

1.2. The aim of research

This paper includes two parts: exploratory research and conclusive research. After basic literature analysis, the objectives of the conclusive study are formulated. This part is conducted using both qualitative and quantitative methods. This survey investigates current and innovative ways to reduce food waste. Exploratory study aims to find the main causes of food waste in China and the EU.

After basic literature analysis, the objectives of the conclusive study are formulated. This part is conducted using both qualitative and quantitative methods. This survey investigates current and innovative ways to reduce food waste.

The aims are as follows.

A1: To investigate the root causes of the food waste problem. (To identify personal level or issues with the food system itself contribute to food waste.)

A2: To provide new ideas for China and the EU to reduce food waste.

Overall, this paper aims to delve into the problem of food waste, analyze its causes from multiple perspectives, and propose innovative solutions to help reduce food waste and achieve a sustainable food system.

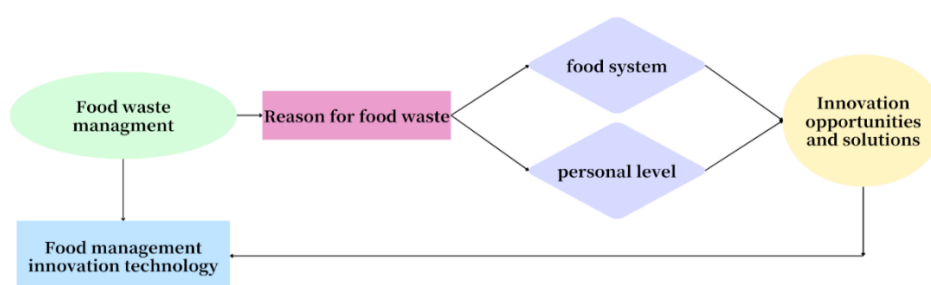


Figure 1. Food waste management technology roadmap

Source: Own construction

2. Literature Review

According to calculations by the Boston Consulting Group, food waste is expected to account for 33% of the total by 2030, reaching 2.1 billion tons, which translates into economic figures equivalent to US\$1.5 trillion. Food waste not only causes huge economic losses, but also has negative environmental and ethical impacts. According to the "State of Food Security and Nutrition in the World Report 2023", in 2022, 691 million to 783 million people will face hunger worldwide. At the median (approximately 735 million), there will be 122 million more hungry people in 2022 than before the 2019 COVID-19 outbreak. This rise in numbers is alarming and illustrates the seriousness of food safety and nutrition issues.

It is estimated that by 2030, nearly 600 million people around the world will face chronic malnutrition. Due to the impact of the COVID-19 epidemic and the war in Ukraine, 119 million people are expected to fall into this predicament, of which approximately 23 million are chronically malnourished due to the war in Ukraine. These data highlight the serious challenges facing the world and the need for aggressive measures to alleviate hunger and malnutrition.

Food waste is particularly serious in this context. Food waste is not only a waste of resources, but also violates social ethics. A large amount of food waste has led to excessive consumption of resources and environmental damage, exacerbating global food inequality (FAO; IFAD; WFP; WHO; UNICEF;, 2023). It is urgent to reduce food waste, improve nutrition levels in hungry areas around the world, and increase assistance and support for hungry people to create a more equitable, harmonious and sustainable future for people around the world.

In addition, according to the data report of the World Food and Oil Organization, as shown in Figure 1, from 2020 to 2023, the food price index will show an upward trend, especially the price of sugar. During the same period in 2022, global food prices have risen sharply. This may be due to the continued impact of the new crown epidemic and the Russia-Ukraine war, which have had a huge impact on the global economy and society. These price increases not only have a direct impact on food production and consumption, but also pose serious challenges to global poverty.

According to the World Bank's statistical model, for every 1% increase in global food prices, nearly 10 million people will fall into extreme poverty. This highlights the serious impact of rising food prices on poor people around the world (Food price watch (English). Washington, D.C., 2023). As food prices rise, the living costs of the poor will further increase and their living standards will face greater challenges, which will make things even worse for poor families who are already on the edge. Food prices are rising for many reasons, including strains on global supply chains, the impact of climate change on crop production, rising energy prices and war. In particular, global supply chain disruptions and production and transportation difficulties caused by epidemics and wars have put food supply under greater pressure, thereby driving up food prices.

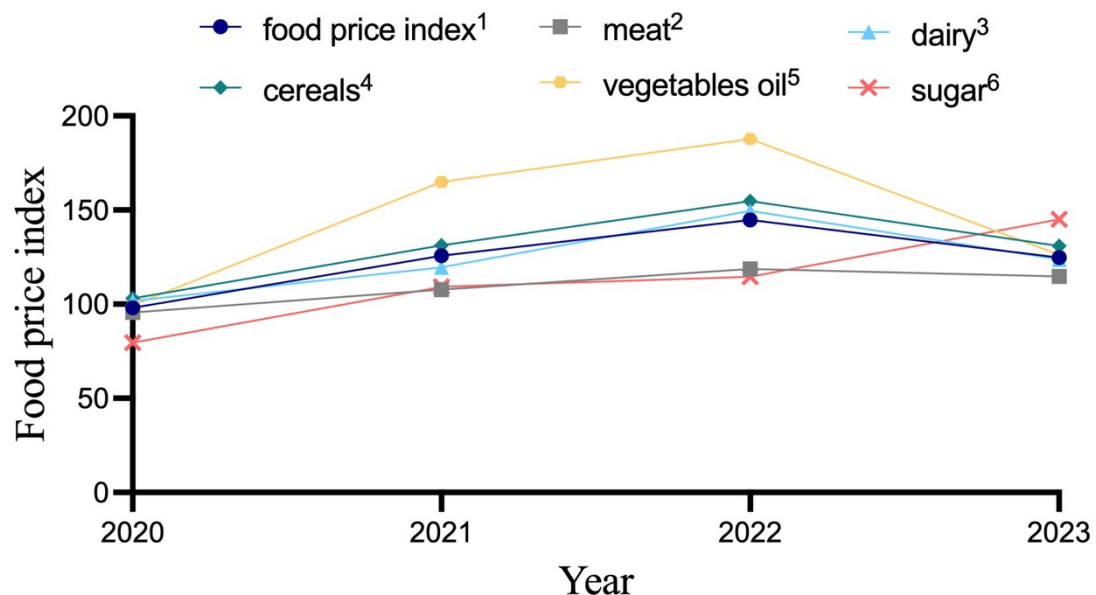


Figure 2. Globe food price index in 2022-2023

Source: FAO.

Food waste mainly causes problems in three aspects: economic losses, environmental social and moral and ethical doubts (Zhang et al., 2019). First, food waste results in huge resource losses. At an economic level, approximately one-third of the food produced globally each year is discarded or wasted, with quality and value lost throughout the food supply chain (the food supply chain refers to the journey of food

from farm to fork) (Aldaco et al., 2020). A large amount of food being wasted means a waste of resources, including the investment in production, processing, transportation and sales, etc. have become wasted. This not only wastes agricultural resources and production costs, but also causes trade losses and waste of market resources. For producers, businesses and consumers, food waste will directly lead to the loss of economic benefits, and will also have a negative impact on the economic development of individuals, companies and countries.

Secondly, food waste also has negative impacts on the environment and society. Food production consumes many of the world's resources, including energy, water, land, and more. In addition, the use of pesticides, herbicides, and chemical fertilizers also causes environmental pollution (Kibler et al., 2018; Sarkar et al., 2021). According to statistics, agricultural production accounts for more than 70% of global freshwater withdrawals. Cropland and pasture cover more than one-third of the Earth's land area, and 28% of agricultural land is used to produce food that is lost or wasted each year (FAO, 2023). A large amount of food is thrown away, which means that the water, land and energy resources consumed in the production process are wasted. At the same time, traditional food waste disposal methods include landfilling, composting, and incineration, which also cause a lot of pollution to the environment (Shadbahr et al., 2022). Most food waste generated by households and businesses goes directly to landfill. However, landfill leachate can lead to groundwater contamination, odors, unhealthy landscaping, and the growth of pathogens, causing soil leakage and human health problems. In addition, waste incineration releases large amounts of greenhouse gases (carbon dioxide and methane) into the atmosphere, which can also cause air pollution (Ghosh & Pramanik, 2023; Thiviya et al., 2022). Proper management of food waste is essential to protect the environment and human health.

Food waste will also exacerbate social inequality, make resource distribution more uneven, deepen the gap between rich and poor, and affect social stability and harmony. In addition, food waste has also been questioned ethically. In a world where food resources are stressed, vast amounts of food are thrown away, in stark contrast to the reality that hundreds of millions of people around the world face hunger and malnutrition. This phenomenon has raised questions about social justice and moral

responsibility, and people have begun to reflect on whether excessive consumption and wasteful behaviors are in line with common human values. Food waste is not only a waste of resources, but also a moral challenge to the unfair distribution of global food resources.

Food waste management is an integrated approach that involves the reduction, recycling and efficient disposal of food waste, with the aim of reducing negative environmental impacts and making more efficient use of limited resources. As the food waste problem becomes increasingly serious, food waste management is particularly important. Traditional food waste management methods include landfilling, incineration, composting, animal feeding and anaerobic digestion. However, landfilling and incineration are considered the least ideal options because they produce large amounts of greenhouse gases and toxic substances, causing severe environmental impacts. Despite this, landfilling and incineration are still the methods by which most food waste is disposed of due to their simplicity and lower cost.

In contrast, methods such as composting, animal feeding, and anaerobic digestion, although they can provide a certain degree of value-added utilization of residues, have been relatively less used in food waste management due to the low added value of the products produced. Composting technology uses organic waste for composting to produce organic fertilizers, but the market value of these fertilizers is relatively low, so composting has not been widely used. Animal feeding converts food waste into animal feed, but this method requires strict food safety and hygiene standards and has limited market demand. Anaerobic digestion uses microorganisms to decompose organic waste and produce biogas and organic fertilizers, but the operating cost of this technology is high, which limits its application scope in practice (Capson-Tojo et al., 2016; Esparza et al., 2020).

Although traditional food waste management methods have many limitations, with the improvement of environmental awareness and the continuous development of new technologies, people are committed to finding more sustainable and efficient food waste management solutions to cope with this severe environmental and Resource Challenges.

Food waste management is evolving innovatively to improve efficiency, reduce waste and promote sustainable food supply chains. Currently, advanced technologies such as intelligent data analysis technology, big data and artificial intelligence are widely used to monitor, predict and optimize supply chains to reduce food waste. The use of these technologies makes supply chain management more accurate and efficient, helping to reduce unnecessary food waste.

On the other hand, the application of traceability systems also provides important support for reducing food waste. Technologies such as blockchain and radio frequency identification (RFID) have been well applied in reducing food waste. RFID technology is a wireless communication technology that enables tracking and identification of items by embedding microchips and antennas into tags or tags. The RFID traceability system can achieve full traceability and management of products by attaching RFID tags to products and equipped with RFID readers. The source, flow and quality of food can be accurately tracked and recorded, thereby improving food safety and Transparency reduces waste caused by food quality issues.

In addition, the promotion of circular economy concepts promotes the recyclability and degradability of food packaging and containers, thereby reducing the generation of plastic waste and helping to build a more environmentally friendly food supply chain. In terms of social innovation, the food sharing economy has been launched to encourage individuals and businesses to donate excess food to charities, and a food recycling and redistribution network has been established, effectively reducing the incidence of food waste.

Curriculum education and awareness raising are also important ways to reduce food waste. By carrying out education and publicity activities, we raise public awareness of food waste, encourage consumers to purchase, store and use food more carefully, promote society's attention to the issue of food waste, and promote the entire society to move in the direction of reducing food waste (Alattar & Morse, 2021; Van Geffen et al., 2020). A deep understanding of the processes, techniques, and technologies of the food flow from farm to fork is critical for innovation in food waste management. This comprehensive understanding can not only reveal potential waste points in the food

distribution chain, but also encourage the development of more effective management strategies, thereby improving the sustainability and social innovation level of the supply chain. Because it can promote sustainability and social innovation along the value chain and increase economic benefits by adopting circular economy concepts (Al-Obadi et al., 2022).

Overall, food waste management not only benefits individuals and society, but also has a positive impact on the environment, resources, and the global food supply. First of all, reducing food waste can effectively reduce environmental burdens, reduce greenhouse gas emissions from landfills and incineration plants, and help mitigate climate change and reduce soil and water pollution. Secondly, effective management of food waste can improve resource utilization efficiency, reduce the waste of energy, water resources and land, and help protect the sustainable use of natural resources. Reducing food waste can also help improve the global food supply. By making full use of available food resources, we can meet the nutritional needs of more people and reduce the occurrence of hunger and malnutrition. Therefore, reducing food waste has become an urgent task that requires the joint efforts of governments, businesses and individuals. The government can promote food waste management by formulating policies and regulations, providing economic support, and conducting publicity and education. Companies can take innovative measures to reduce food waste rates by optimizing production processes, reducing packaging and improving inventory management efficiency. Individuals can also actively participate in reducing food waste by changing consumption habits, budgeting carefully, and storing food scientifically. Only through the joint efforts of all parties can we effectively reduce food waste and achieve the goal of sustainable development.

2.1. Causes of Food waste

(1) Causes of food waste at the food system level

In the food system, food waste occurs at every stage of the food supply chain, including farm, post-harvest, processing, distribution, retail and consumer stages (Xue et al., 2017). In the food industry, the issue of food waste is a very important issue. Waste

exists in the food industry in food production and processing, transportation, packaging, storage, distribution and processing waste disposal.

In the early stages of the food supply chain, such as food production, processing and transportation stages, food waste is caused by insufficient technical levels, such as insufficient technology in the processing process, lack of operating specifications and personnel training, which leads to food contamination. Another factor in waste. This is food waste caused by losses during the production process. During food transportation, damaged or inadequate transportation systems during transportation and problems during storage can also cause high-quality food to be wasted. It is often cited as the leading cause of food waste in developing countries. But this statement itself is a form of discrimination. Klaus et al. point out that in Europe the first step of the food supply chain also makes an important contribution to overall food waste, contrary to the view in developed countries that losses at the primary production stage are negligible (Bräutigam et al., 2014; Priefer et al., 2016).

In terms of food waste in agricultural production, both agriculture and livestock produce waste or by-products, but these may be organic waste (e.g. corn stover, manure) or low-quality fruits or vegetables, damaged produce, good or low quality By-products with commercial value, therefore, have great room for development and utilization (Giroto et al., 2015). However, due to lack of knowledge and technology, a lot of resources are wasted. This will also directly affect the income of farmers and consumers.

In the production stage of food processing and manufacturing, in order to cater to the market, the size of food packaging may be unreasonable, and strict requirements on specifications, colors and other aspects that do not affect the quality of the food itself will lead to excessive packaging and waste of food. When it comes to food storage and distribution, improper storage conditions, poor distribution channels, or marketing practices can ultimately lead to large amounts of food loss and food waste. Therefore, retail systems and marketing contribute to food waste primarily due to handling and storage issues.

Therefore, food waste is possible throughout the food supply chain. Once a mistake is made at any stage, food waste will result. Therefore, innovative supervision of the food supply chain is particularly important.

Research on food waste in food supply chains is interdependent and interdisciplinary. And related research remains highly fragmented, appearing in journals with different scopes and audiences (Chauhan et al., 2021). In addition to the problems of the food industry itself, government policies are also closely related to food waste. The government can promote food waste management by formulating relevant laws and regulations, providing incentives, and strengthening supervision. For example, the government can promote the food industry to adopt production and operation models that save resources and reduce waste, encourage enterprises to strengthen food loss monitoring and management, promote the rational design and utilization of food packaging, and promote the resource utilization of food processing waste. Government policy initiatives play an important guiding and promoting role in solving the food waste problem in the food industry, which will also directly affect the income of farmers and consumers.

(2) Reasons for food waste at the individual level

Food waste caused by individual behavior is considered to be one of the main contributors to food waste in the food supply chain (UNEP, 2021). Therefore, identifying the motivations behind this phenomenon as well as the decisive factors that can influence consumer decisions is crucial to reducing food waste, achieving sustainable development, and solving related ethical and moral issues (Setti et al., 2018). However, to date, there have been few studies investigating cognitive correlates of food waste-related behaviors (Ferro et al., 2022; Jaeger & Ares, 2022; Pelt et al., 2020). Many factors are affected at an individual level at different stages of food consumption: planning, acquisition, storage, preparation, consumption and leftovers management, etc. (Gimenez et al., 2023; D. M. A. Roodhuyzen et al., 2017). The complex and diverse drivers of food waste in these stages ultimately determine food waste.

Personal attitudes are often viewed as factors that directly influence behavioral tendencies or behaviors, while religious beliefs are often viewed as important influencing factors or prerequisites (Tsai et al., 2020). In terms of food-related decision-making, the researchers compared it with personal-level factors such as attitude towards food waste (Personal attitude), intention to reduce food waste (Intention), environmental awareness (Environmental awareness) and religious beliefs. (culture and religions)) and explore the correlation with food waste behavior (Elshaer et al., 2021; Hansen, 2022; Pappalardo et al., 2020; Vittuari et al., 2020). Currently, according to the research of Giordano et al., research on food waste motivations can be mainly divided into two main schools (Giordano et al., 2023). Some researchers believe that personal attitudes toward food waste and food waste reduction intentions to reduce food waste can directly influence behavior, thereby reducing the incidence of food waste. They argue that if individuals have a positive attitude and intention to reduce food waste, they are more likely to take actions such as buying the right amount of food, preserving food properly, and minimizing the waste of leftover food. Therefore, they emphasized the importance of personal attitude and intention to reduce food waste in reducing food waste and regarded it as one of the key factors affecting food waste (Aydin & Yildirim, 2021; Barone et al., 2019; Elhoushy & Jang, 2021; Lin & Guan, 2021; Neubig et al., 2020; Principato et al., 2022). Another school of thought is skeptical: they argue that a gap between attitudes and behavior may have an impact, but that daily habits and routines may hinder alignment with attitudes that support reducing food waste. They pointed out that even if individuals hold positive attitudes toward food waste, habitual behaviors and routine activities in daily life may make their behaviors inconsistent with attitudes (Elimelech et al., 2019; Giordano et al., 2019; Tsai et al., 2020; van der Werf et al., 2020). For example, although a person may be aware of the environmental impact of food waste and be interested in reducing waste, one may still be tempted by promotions or large packages when purchasing food and purchase more than needed. Therefore, these researchers believe that in addition to personal attitudes and intentions, individuals' daily habits and behavioral patterns are also important factors affecting food waste, and these factors may hinder the consistency between attitudes and behaviors.

A careful review of the literature revealed that the problem of food waste in the food supply chain is multifaceted and requires joint efforts from all parties, including

farmers, processors, consumers, managers, and society as a whole. However, due to the complexity of this issue, the results of previous studies are fragmented and lack systematic research. When dealing with this issue, we must take into account the mutual influence and interaction between different stakeholders and how various links in the food supply chain are related to each other. Only through in-depth and detailed research can we gain a comprehensive understanding of the causes and solutions to food waste, leading to the development of more effective policies and practices to reduce waste and improve resource utilization efficiency.

2.2. The current state of food waste management in China and Europe

2.2.1. The current state of food waste management in China.

In recent years, China's rapid economic development and the growing environmental awareness of the government and citizens have also led to greater attention to food waste management and rapid development in improving processing capabilities. The Chinese government's management of food waste reduction mainly focuses on increasing publicity to guide society to be thrifty and thrifty; promulgating regulations and policies to provide the basis for supervision and law enforcement, and supervising and restricting society and enterprises to manage food waste.

China has about 12 administrative departments responsible for food waste management, reduction, reuse and recycling. Four of the ministries are at the same administrative level and their functions interact and overlap (Li et al., 2019).

- The Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD) is the competent authority for solid waste treatment and disposal in China;
- The National Development and Reform Commission (NDRC) of the People's Republic of China is responsible for investment and funding, as well as the formulation and implementation of strategies for annual, medium-term and long-term development plans;

- The Ministry of Environmental Protection (MEP) is responsible for the overall coordination, supervision and management of environmental pollution prevention and control;
- The Ministry of Agriculture (MOA) oversees and regulates the reuse of FW as agricultural fertilizer and animal feed.

Various departments of the Chinese government cooperate with each other to continuously strengthen the management of food waste. In 2021, the government mainly proposes food waste management methods from multiple perspectives (The Ministry of Commerce of the People's Republic of China, the State Administration for Market Regulation and the National Government Offices Administration on Issues Concerning the Implementation of the Anti-Food Waste Law of the People's Republic of China., 2021). It is mainly aimed at the catering industry, taking food consumption, sales and anti-waste as the entry point, and at the same time handling the relationship with the Food Security Law and other relevant laws that are being drafted, and reducing food, food production, processing, storage and transportation and other links (CHENG Sheng-kui, 2022).

In addition, China has other laws and regulations to manage food waste. Article 14 of the Constitution stipulates in principle “enforce economy and oppose waste”. Article 9 of the General Provisions of the Civil Code (2020) stipulates the obligations of civil entities to conserve resources and protect the environment. Article 509 of the Contract Law requires parties to curb resource waste and protect the ecological environment during contract performance. Article 4 of the Environmental Protection Law (2014) incorporates resource conservation and recycling into the policy system to promote green and coordinated development. Article 10 of the Circular Economy Promotion Law (2018) requires citizens to establish a scientific view of environmental resources and guide green consumption patterns. Article 36 of the Agricultural Law (2012) encourages citizens to optimize the nutritional structure of food and advocates the public to save food. Article 4 of the Law on the Prevention and Control of Environmental Pollution by Solid Waste (2020), Article 21 of the National Security Law (2015), Article 5 of the Consumer Rights and Interests Protection Law (2013), and Food Safety Law (2018) and other relevant legal provisions also reflect the spirit of “saving resources and opposing waste”. The “Catering Industry Operation and Management

Measures (Trial)" stipulates the supervisory responsibilities and reward and punishment powers of relevant competent authorities on catering food waste.

However, China's current legislative provisions on food waste are relatively principled, scattered, lack systematicness and operability, and have low normative effectiveness. The scope of regulations is limited; there is a lack of targeted restrictions, guidance measures and systematic governance mechanisms, which makes it difficult to curb food waste. Problems such as the lack of widely recognized codes of conduct and ethics regarding waste lead to poor implementation results (CHENG Sheng-kui et al., 2021). In the next work, the Chinese government should combine concept supply. Integrating resource social concepts into food waste legislation. As a social resource, food should maximize the overall welfare of society to maximize resource efficiency, optimize resource order, and ensure resource security. The legislative level, model and positioning of food waste. Based on the principles of "preventing waste, saving resources, protecting the environment, and protecting public health", the main body of food waste legislation will be elevated to the Standing Committee of the National People's Congress and a specialized law will be formulated. Regulatory entities and measures. Subjects of legal regulation can be divided into public subjects and individual citizens. Actors can be effectively regulated through the integration of direct prohibition, tax adjustment, consumption guidance and other methods.

2.2.2. The current state of food waste management in EU

The latest estimates from Eurostat show that most food waste originates from households, food services and retailers, contributing over 70% to waste generation, with households accounting for 55%. This may be due to increased urbanization, a lack of awareness of the costs and resources used in food production, or retail methods that often lead consumers to purchase more food than they need. Therefore, educational campaigns are needed. It is vital to provide advice and practical advice through awareness campaigns to reduce household food waste. (Figure3 below shows distribution of food waste in EU). While the processing sector account for the remaining 19% of total waste. Preventing and reducing food losses in this sector can be based on increasing awareness of correct processing techniques, providing packages in different

sizes to meet different consumer needs and innovative packaging solutions, improving use-by date marking, and using food that is not intended for human consumption.

Europe uses different levels of waste management, a hierarchy of solutions based on different steps (i) food waste prevention; (ii) reuse for human consumption and animal feed; (iii) material recovery as inputs to the food and chemical industries; (iv) nutrient recovery; and (v) energy/fuel recovery, as shown in fig. 3 (Albizzati et al., 2021; Girotto et al., 2015).

Circular economy, defined as the long-term protection of product value, materials and resources in the economy by reducing waste generation. Raw materials including fossil carbon, minerals, metals, biomass will be produced into products, traded, utilized and then enter the waste hierarchy through sharing, reuse, redistribution and recycling (Carus & Dammer, 2018; Graziani, 2017; Plan, 2011). As early as 2015, the EU began to implement the first circular economy action plan and develop food waste measurement methods (Commission, 2015). By 2020, a new circular economy action plan was implemented after updating (Commission, 2020). The focus is no longer on recycling, but on design, reuse, sharing, durability and repair. The new measures also include a transitional monitoring framework, through which the Action Plan enriches the necessary means to monitor progress (Corona et al., 2019; Farmer, 2020; Johansson, 2021). However, the implementation of national food waste policies across European countries is not uniform. Countries such as Germany, the Netherlands, and Portugal have all shown positive responses to the circular economy, and this member state is at the forefront of European CE. Among them, the Netherlands has developed a large number of private and public sector roadmap plans and formation strategies. However, in Eastern European countries such as Poland, Hungary, and Latvia, progress has been slow and intermittent (Domenech & Bahn-Walkowiak, 2019; Hartley et al., 2020; Marino & Pariso, 2020; Smol, 2023; Zielińska, 2019).

Furthermore, according to the European Commission, there are some that are important criteria in the food waste management process, as described in Table 1: effectiveness, efficiency, relevance, consistency, and EU added value (Caldeira et al., 2019; Nicastro & Carillo, 2021).

Effectiveness	Consider the success of the intervention
Efficiency	Assessing the relationship between what is needed to implement preventive actions and
Relevance,	Consider the connection between the goals to be achieved and the needs of society as a whole
Consistency	Assess whether the intervention follows a logic in relation to other interventions;
EU added value	is the sum of all other criteria

Table 1 Criteria for food waste management in EU

Source: Eurostat.

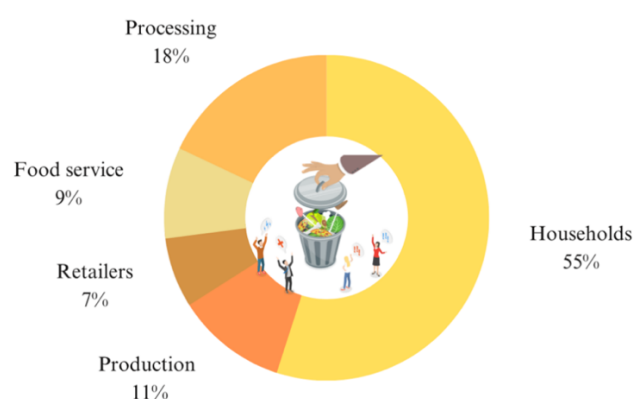


Figure 3 Distribution of food waste in EU

Source: Eurostat.

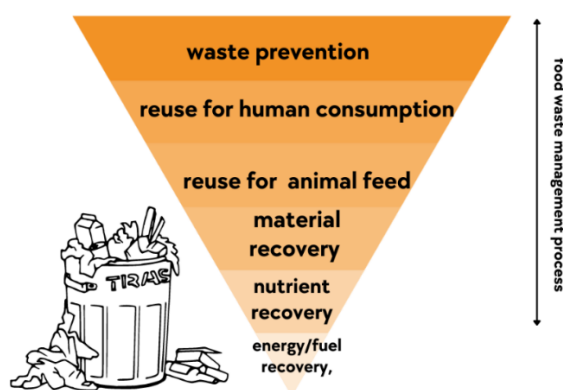


Figure 4 EU food waste management

Source: Eurostat.

2.3. Innovation methods to reduce food waste

Reducing food waste is a global challenge with important implications for addressing food security, environmental sustainability and efficient resource use. The application of innovative methods in this area is becoming increasingly critical to help us manage the food supply chain more effectively, reduce food loss and increase the shelf life of food. These include using technology, improving supply chain management, increasing consumer awareness and adopting sustainable production and packaging methods. Through innovation, we can tackle food waste more effectively and create a more sustainable and sustainable food system for future generations.

According to the study by Muna et al., most of the research papers on food waste management were collected from Waste Management (10%), Journal of Cleaner Production (6%), International Journal of Hospitality Management (6%), Sustainable Development" (4%), "Total Environmental Science" (4%). The remaining 70% of publications are in journals such as Sustainable Resources, Conservation & Recycling and Food Research International (Al-Obadi et al., 2022).

We can divide innovation in food waste management into two flows: one is social innovation and the other is technological innovation. Social innovation often innovates in unique concepts, action frameworks, models, structures, processes, facilities, rules & regulations, and new organizational modes (Al-Obadi et al., 2022). Then use some strategies and campaigns to promote social effects to reduce food waste. Both the EU and China are constantly innovating in policies, such as the circular economy proposed by the EU and the anti-food waste law in China. The Combined-Network Scheme :A green account with strict supervision and automatic exchanging kiosks in Shanghai China, this innovation helps in reducing food waste management costs (Xiao et al., 2020). Research by Zhao et al showed social innovation in food distribution, food sharing, food rescue and food donation, there are eco-villages, kitchen communities, social supermarkets, solidarity stores, food banks, online food markets, online food sharing, public street actions and educational programs and other innovative social measures and forms to reduce waste (Zhao et al., 2023). What's more, On the role of social innovation in food redistribution activities, existing research shows that in order

to maximize the impact of food redistribution, it is necessary to establish connections between “waste place” and “need place” through social innovation (Huang & Tsai, 2021; Lombardi & Costantino, 2020; Sutinen & Närvänen, 2022; Zhao et al., 2023).

Another flow is technological innovation, current technical research on food waste management mainly focuses on how to deal with wasted food but there are few technologies for preventing food waste, mainly the creation of digital platforms. As shown in Table 2, these are the innovation techniques for managing the food waste caused.

Composting technology is a method based on the biodegradation of organic matter under aerobic conditions. By promoting the decomposition of organic matter, it has fast degradation speed and low cost. It is widely used in factories, families or communities. Anaerobic digestion technology is a micro-processing technology that converts macromolecules in food waste into hydrogen, organic acids or methane, reducing the volume and pollution level of the waste, while also generating renewable energy. In addition, advanced treatment technologies such as waste-to-energy and bioremediation provide new ways for environmental protection and resource utilization. As an emerging concept, biorefinery achieves comprehensive utilization of resources and self-sustainable development by optimally utilizing biomass to produce a variety of products. In addition, the application of intelligent identification technology and the Internet of Things in food waste management also brings new possibilities for waste treatment.

Technology	Innovation	Reference
Composting	Composting is based on the biodegradation of organic matter under aerobic conditions. Factory, home or community composting	(Accinelli et al., 2020; Adusei-Gyamfi et al., 2022; Sánchez, 2022)
Anaerobic digestion	Macromolecular substances in food waste are converted into hydrogen, organic acids or methane by cooperating to promote anaerobic reactions mediated by acidic and methane microorganisms. Divided into a four-stage system (hydrolysis, acidification, acid production and methane production). Micro-scale AD technology.	(Degueurce et al., 2022; Molino et al., 2013; Wang et al., 2018; Wang et al., 2022)
Advanced processing technology for renewable fuels (waste-to-energy)	Using biodiesel from waste cooking oil can reduce greenhouse gas production, reduce soil and water pollution, and reduce overall production costs.	(Sharma et al., 2021)
Bioremediation of legacy waste technologies	Bioremediation using microorganisms has been accepted as an environmentally friendly and economical treatment method for the disposal of hazardous petroleum hydrocarbon contaminated wastes (oily wastes). Transgenic plants and associated bacteria constitute a new generation of genetically modified organisms for bioremediation.	(Gupta & Prakash, 2020; Rena et al., 2022; Shivalkar et al., 2021)
Biorefineries	a framework or a structure in which biomass is utilized in an optimal manner to produce multiple products and tries to be self-sustaining and not harmful to the environment. Production of biodegradants, biocompostable polymers, PHA, cellulose acetate and lactic acid biopolymers.	(Raj et al., 2022; Saral et al., 2022; Theagarajan et al., 2019; Tsang et al., 2019)
Intelligent recognition technology	Smart eNose: detecting food waste through gas emissions; Internet of Things in food waste: Classification and real-time data monitoring; Convolutional neural networks for intelligent waste: Classification, object detection and segmentation through visual features	(Gull et al., 2021; Rahman et al., 2022; Sunny et al., 2019; Wang et al., 2021; Wu et al., 2023)

Table 2 Innovation techniques for food waste management

Source: Own construction

3. Materials and methodology

The secondary literature, and some official surveys based on authorial announcers were used to analyze the current state of food waste management in China and Europe, causes of food waste in food system and innovation ways to reduce food waste. The primary surveys, including questionnaire (Appendix 1) was used and online sampling technique was used to collect the data. The questionnaire as a quantitative method was applied to analyze attitudes towards food waste and the reason of food waste on personal level among Chinese citizens and citizens in the Europe. The questionnaire was conducted in two languages as Chinese and English.

3.1. Declaration of the survey location

China is one of the most populous countries in the world, so the food waste problem here is huge. In recent years, the Chinese people's awareness of food waste has gradually increased, and more people have begun to pay attention to the importance of not wasting food. China's culture and eating habits greatly influence food waste. For example, there is often leftover food in the banquet culture and the way food is processed leads to a lot of food waste. In addition, China's rapid economic growth has led to more people living a relatively wealthy life, which has also led to more food waste. This also raises issues of social inequality and resource distribution. This has attracted great attention from the Chinese government, which has actively adopted policy measures to promote the reduction of food waste. For example, restaurants are prohibited from serving large portions, Operation Disc is promoted, and food donations and recycling are encouraged.

Europe countries generally have higher environmental awareness and have realized at an earlier stage that food waste is not only a waste of resources, but also causes environmental pollution problems. Europe countries are relatively rich in agricultural resources, but this also makes food waste easier. There is a certain gap between rich and poor in Europe countries. Some people have more financial ability to buy food, but they are also more likely to waste it. A lot of waste results from substandard appearance or standardized food. Today, awareness of food waste is higher in the Europe, with many

people preferring to buy more sustainable food and working to reduce waste. The Europe has also adopted a series of regulations and policies to reduce food waste, including food labeling requirements and incentives for donating food.

In general, both China and the Europe face food waste problems, but due to their respective cultural, economic and policy differences, the approaches and people's attitudes are slightly different. However, reducing food waste is of global importance to reduce resource waste, reduce environmental pressure, and improve social equity. The surveys were conducted in China and Europe. It was distributed on social network platforms and a total of 872 valid questionnaires were collected. The investigation period is from November 2023 to February 2024.



Figure 5 Questionnaire distribution poster

Source: Own construction

3.2. Survey design and investigation technique

Food waste is a multi-dimensional and multi-disciplinary problem (Raquel et al., 2015). Ertz et al showed the relative importance of attitudes, norms and perceived behavioral control as predictors of consumer food waste behavior (Ertz et al., 2021). Among them, many authors believe that the level of awareness and attitude towards food waste are important factors affecting food waste (Graham-Rowe et al., 2014; D. M. Roodhuyzen et al., 2017; Van Geffen et al., 2020). To clarify the causes of household food waste and determine respondents' attitudes towards the issue, the questionnaire was designed based on previous research. According to previous research, the food waste model mainly considers the following six factors: environmental awareness, materialism, purchasing behavior, dietary choices, food handling, waste recycling and waste prevention, religious beliefs, and personal perceptions and expectations (Abdelradi, 2018; Aktas et al., 2018; Ammann et al., 2021; Gracia & Gomez, 2020; Raquel et al., 2015; Veselá et al., 2023). The questionnaire part of this paper focus on the impact for food waste from personal level. Based on these factors, we adjust some factors which are personal level. Therefore, we screened and designed some variables, as described in Table 3.

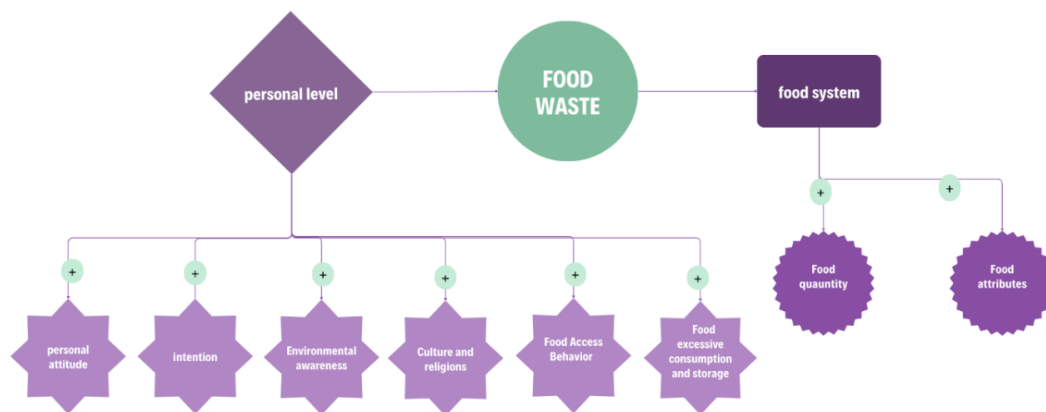


Figure 6 Food waste reason framework of questionnaire

Source: Own construction

Concept	Items
Excessive consumption and storage	1. Saved food and eventually not used (15) 2. Cook more than my guests and I can eat (18)
Quantity of food	1. How much food do you have waste each week? (16) 2. Percentage of total food do you waste each week? (17)
Food attributes	• Food spoilage • Food expired • Food not tasty • Food safety (20)
Personal attitude	1. I think food should not be wasted (21) 2. I feel unhappy when uneaten food is thrown away (22) 3. Throwing away food affect you (23) 4. I concerned about food waste (24) 5. proactively learn about food waste (25) 6. Whether food waste awareness campaigns influence your decision-making? (26)
Intention	1. Have you ever proactively thought about how you use food in your daily life and reduce food waste (30) 2. Are you tired or guilty of wasting food (31)
Food access behavior	1. buy more than I need (13) 2. Food packaging size (14)
Environmental awareness	1. Fully understand the hazards of food waste to the environment (27) 2. There are many specific strategies or habits that help me reduce food waste (32)
Culture and religions	1. My culture or belief does not allow me to waste food (28) 2. My culture or beliefs influence my food choices and attitudes (29)

Table 3 Survey statements used to measure each model structure

Source: Own construction

3.3. Analytical technique

After getting the primary data, reliability and validity analysis were used in these sampling. T test and one-way ANOVA were used to determine whether there is a significant difference between two groups of sample means. PLS-SEM (Partial Least Squares Structural Equation Modeling) is a statistical analysis method designed to study complex relationships between variables.

Reliability and validity analysis

After getting the primary data, a descriptive statistic was used in these samplings and the data was analyzed by SPSS software.

(1) Cronbach's alpha method was performed to check the reliability of the answers appearing in the questionnaire. Cronbach's alpha, is a statistical method widely used

in the field of psychometrics (the science of measuring psychological traits) to assess the internal consistency of a set of related items or questions in a questionnaire or survey or reliability (Connelly, 2011). Cronbach's alpha ranges from 0 to 1. The closer the value is to 1, the higher the internal consistency of the item, indicating that the item reliably measures the same underlying construct. A high Cronbach's alpha indicates that the scale is a strong and consistent measure of the construct (Tavakol & Dennick, 2011).

Cronbach's alpha works as follows:

- Gathering data: First, you need a set of items or questions designed to measure the same construct or trait. For example, if you are measuring "anxiety," you might have a set of questions related to anxiety symptoms.
- Calculate individual scores: Give the questionnaire to a group of individuals and collect their responses. For each individual, their score is calculated by summing or averaging their responses to the items.
- Calculate population variance: Calculate the population variance of the scores of all individuals in the sample. This represents the overall variability in responses to the items.
- Calculate the between-item variance: Next, calculate the variance between the individual items. This reflects the variability between responses to different items within the scale.
- Calculate Cronbach's Alpha: Cronbach's alpha is calculated using the following formula:

$$\alpha = \frac{N}{N - 1} \left(1 - \frac{\sum_{i=1}^K \sigma_i^2}{\sigma_T^2} \right) \quad (2.1)$$

Where:

- N is the number of items in the scale.
- k is the number of items in the scale.
- σ_i^2 is the variance of each individual item.

- σ_T^2 is the total variance of the scores.

(2) KMO (Kaiser-Meyer-Olkin) test and Bartlett's test are two common statistical methods used to evaluate factor analysis. They help researchers decide whether factor analysis is suitable. These two methods are often used together.

KMO test (Kaiser-Meyer-Olkin test):

Purpose: The KMO test is used to evaluate the correlation between items in a data set to determine whether factor analysis is suitable. It measures the suitability of the data to ensure the rationality of factor analysis. The KMO value is usually between 0 and 1, with the closer to 1 indicating that the data is suitable for factor analysis.

Working principle: The KMO test calculates a KMO value based on the correlation matrix in the data. This value reflects whether the correlation between the observed variables is strong enough to perform factor analysis. Generally, KMO values above 0.6 or 0.7 are considered suitable.

Bartlett's test:

Purpose: Bartlett's test is also used to evaluate whether the data are suitable for factor analysis. It evaluates whether the correlation between observed variables is significant based on the null hypothesis that there is no correlation between observed variables. If the p-value of Bartlett's test is below the significance level (usually 0.05), then the null hypothesis is rejected, indicating that the data are suitable for factor analysis.

Working principle Bartlett's test calculates a statistical value that is related to the degrees of freedom and then compares it to the critical value of the chi-square distribution. If the statistical value is significantly greater than the critical value, the data is suitable for factor analysis.

Average Variance Extracted Test

Average Variance Extracted (AVE) is an indicator in reliability and validity analysis and is used to evaluate the internal consistency and external validity of the construct. Compared with Cronbach's Alpha indicator, AVE pays more attention to the correlation

and variability between items within the measurement instrument. Compared with validity analysis, AVE can also be used to evaluate the external validity of measurement tools. The higher the average extracted variation (AVE) value, the higher the internal consistency. If the average extracted variation (AVE) value of the latent variable is above 0.5, the internal quality of the model is ideal. In this study, the questionnaire was divided into 7 dimensions for analysis, as shown in Table 3 and Figure 4. The scale questions have 6 different dimensions, including Environmental awareness, Food access behavior, Excessive consumption and storage, Intention, and Personal attitude ,Quantity of food, conduct AVE analysis to evaluate the external validity of 6 dimensions.

Discriminant Validity analysis

Discriminant validity is used to evaluate the degree of difference between different constructs to ensure that they are measured independently. Commonly used methods to test discriminant validity include the Fornell-Larcker criterion. The Fornell-Larcker criterion is to compare the AVE of a construct with its correlation coefficient with other constructs. The Fornell-Larcker criterion can be used to evaluate discriminant validity. According to this criterion, if the AVE of a construct of a scale should be greater than its correlation coefficient with other constructs, it means that the constructs of the scale have good discriminant validity. Taking into account the accuracy of the test results, in the Fornell-Larcker criterion test, this study further calculated the square root of AVE, and compared the correlation coefficients between the results after solving the square root of the construct's AVE and other constructs. Generally speaking, the value of the result after solving the square root of AVE is larger, indicating that the construct can explain its observed indicators to a higher degree and has better validity.

3.4. Difference analysis of demographic variables

The demographic variable difference analysis method is a statistical analysis method used to compare the differences in certain demographic variables between different groups or samples. Among them, Gender: T test is used to compare the differences between two genders (males and females). T-test is used to determine whether there is a significant difference between two groups of sample means. Other demographic variables (such as age, education level, etc.): Use One-Way ANOVA to compare

differences between three or more groups. One-Way ANOVA was used to compare differences between three or more groups. Duncan's test and LSD test were then used as post hoc comparisons. Duncan's test is a method based on comparing the difference in means for each pair of treatment conditions to determine whether there is a significant difference. The LSD test is a multiple comparison method designed to find the smallest difference value that statistically proves a significant difference between two treatment conditions.

3.5. PLS-SEM analysis

Introduction to PLS-SEM model principle

PLS-SEM (Partial Least Squares Structural Equation Modeling) is a statistical analysis method designed to study complex relationships between variables. The algorithm principle of PLS-SEM includes two main aspects: estimation of the inner model and the outer model. The internal model is a model about the relationship between observed variables (manifest variables) and latent variables (latent variables). The core of this algorithm is to obtain a series of weight vectors by minimizing the sum of squared residuals between the observed variables (observed variables) and the response variables (latent variables). These weight vectors represent how the observed variables combine with the latent variables to best explain the variability of the latent variables. The external model is a model about the relationship between latent variables, describing the direct and indirect effects between latent variables. PLS-SEM uses the PLSR algorithm to estimate path coefficients between latent variables. These path coefficients quantify the influence of one latent variable on another latent variable. Overall, PLS-SEM gradually optimizes the model parameters by alternating the estimation of internal and external models to interpret the data in the best way. It combines the characteristics of principal component analysis and path analysis, and is especially suitable for situations where the sample size is small, the data distribution is non-normal, or the variable relationship is complex.

Since consumer behavior and attitudes cannot be directly estimated, this study uses SmartPLS software to conduct structural equation modeling (PLS-SEM) analysis, as shown in Table 2 for the conceptual framework model. It allows the use of latent

variables as dependent or explanatory variables in analyses, while modeling many relationships simultaneously.

Analysis of PLS-SEM model fitting level results

It is crucial to evaluate the fit level of the PLS-SEM model, including analyzes of reliability and validity. Reliability refers to the stability and consistency of a measurement instrument, and in PLS-SEM it is usually assessed by examining the internal consistency of latent variables. Validity refers to whether the measurement tool can accurately measure the concept to be measured. In PLS-SEM, it is usually divided into two categories: internal validity and external validity. These tests help researchers confirm the credibility of their measurement tools and models, thereby improving the reliability and credibility of the research.

Multicollinearity analysis

The presence of high correlation between independent variables in a model is called collinearity and may affect the stability and reliability of model estimates. Under the PLS-SEM model, a preliminary assessment of the multicollinearity of each predictor variable shows that the tolerance (VIF) value of each predictor variable should be greater than 0.20 (less than 5). At a given VIF value, the tolerance of all predictor variables is greater than 0.20, so no obvious multicollinearity problems are found. It shows that when building a relationship model, each predictor variable can provide independent information without being strongly affected by other predictor variables. This helps ensure the stability and reliability of the model, so it can be initially believed that there is no obvious multicollinearity problem in the constructed relationship model.

3.6. Hypothesis

Hypothesis 1: Consumers' personal attitude towards reducing food waste is related to different food waste behaviors.

Hypothesis 2: There is a correlation between consumers' intention to reduce food waste and food waste behavior.

Hypothesis 3: High environmental awareness has a positive and significant effect on personal attitude and food waste behavior (Personal attitude).

Hypothesis 4: Religiosity is relevant to food waste reduction behaviors.

Hypothesis 5: The Chinese respondent group has a higher positive impact of personal environmental awareness on food acquisition behavior than the European respondent group.

Hypothesis 6: In terms of food attributes, European respondents are more concerned about whether food has spoiled than Chinese respondents.

Hypothesis 7: Factors such as supply chains, retail links, and food donation policies in the food system will influence consumer food waste.

3.7. Systematic literature review approach

For studies on reducing food waste, we adopted a systematic literature review approach. The first stage was to develop research questions and inclusion and exclusion criteria. The inclusion criteria used in this systematic review were (i) focusing on innovative management and technologies that reduce food waste. of research, (ii) academic peer-reviewed journals and research articles, (iii) publications written in English, and (iv) papers published within the research timeline (2013-2023). Exclusion criteria were those that (i) were not relevant to the topic of interest.

3.8. Statistic software

All data were processed and analyzed using the following software: SPSS statistic, SmartPLS4, and Graphpadprism10.

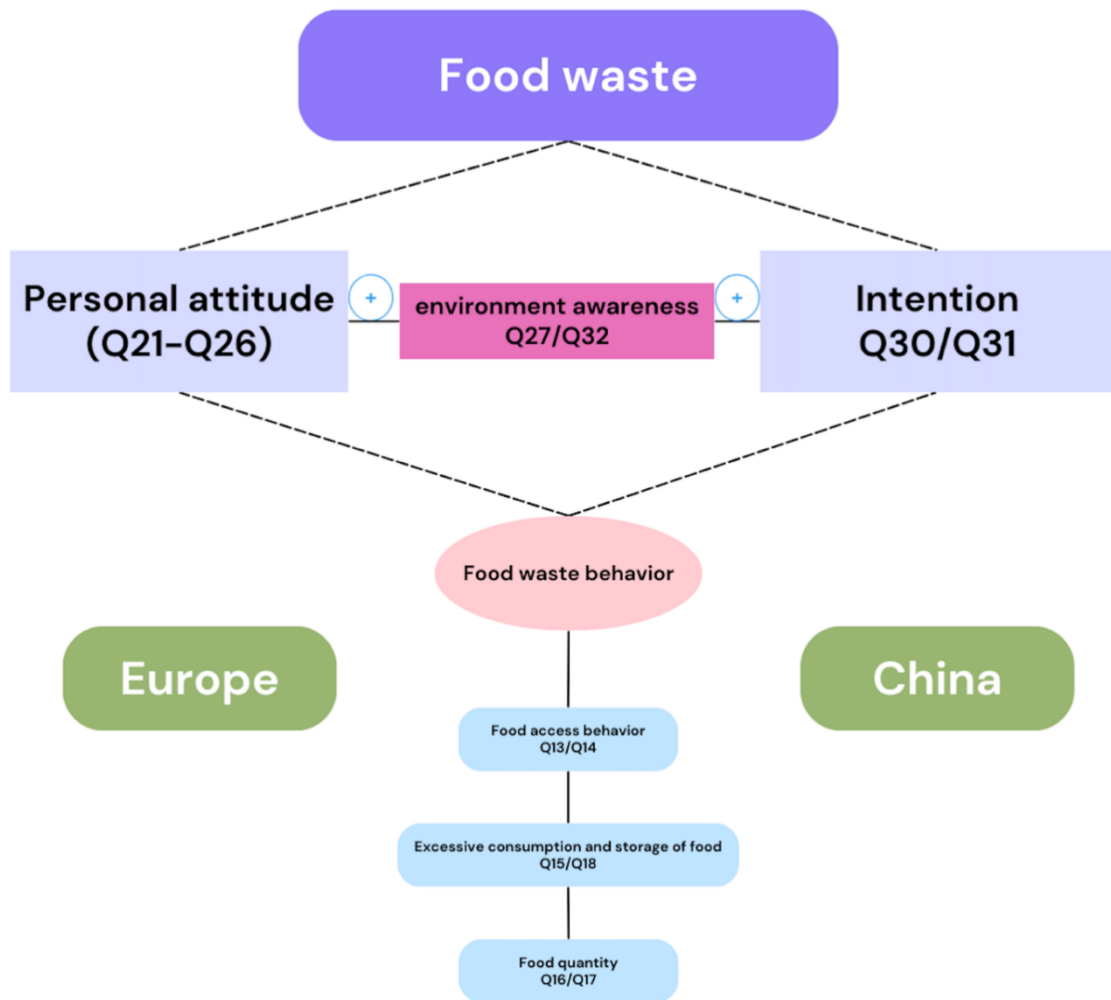


Figure 7 Hypothesis for food waste

Source: Own construction

4. Result analysis

According to the survey results, a total of 958 responses were collected. Among them, responses that took less than 90 seconds to complete were eliminated, and since our survey mainly focused on comparing the situation in Europe and China, participants from other regions were excluded, finally resulting in 872 valid responses. Among these responses, a total of 420 participants came from China, a total of 452 participants from Europe. Chinese participants accounted for 48.2% and European participants accounted for 51.8%.

4.1. Sample characteristics

Through statistical analysis of the questionnaire results, we obtained the following basic information about the demographic variables.

Gender: There are slightly more female respondents than male respondents in both China and Europe, especially in China, where there are 7% more female respondents than male respondents. This may reflect that women are more likely to participate in surveys or pay more attention to the topic when it comes to food waste.

Age: In China, respondents aged 40-49 account for a smaller proportion, 12.6%; while respondents under the age of 20 account for up to 27.4%. In Europe, the largest number of respondents are between the ages of 20 and 29. This may reflect differences in food waste concerns or behavioral habits among different age groups. In addition, both regions have the fewest respondents over 59 years old, which may be related to our method of distributing the questionnaire (online delivery)

Education level: In China and Europe, most respondents have university degrees and only 2 respondents are illiterate. This suggests that people with higher levels of education may be more willing to participate in such surveys, or that people with higher levels of education may be more conscious about reducing food waste.

Religious beliefs: In China, the majority of respondents have no religious affiliation (70.2%), while in Europe, only 10% have no religious affiliation and Christians make up the majority. This may reflect the differences in religious beliefs between China and

Europe, and whether the presence or absence of religious beliefs may have an impact on personal behavior.

Living Environment: In China, respondents are mainly located in small towns and rural area, while in Europe they are mainly located in metropolitan city and suburban areas. This may be related to lifestyles and food supply patterns in different regions, thus affecting food waste.

Family type: In China and Europe, the nuclear family (parents and children) is the most common family type. This reflects the global prevalence of nuclear families and may be related to household size and food purchasing and usage habits.

Main sources of income and income levels: In both China and Europe, employment is the main source of income. In terms of income level, low-income and middle-income groups account for a larger proportion of Chinese and European respondents. For high-income groups, European respondents are five times as many as Chinese respondents. This may be related to the global economic structure and income distribution, and also reflects that the food waste problem may have a certain correlation with economic conditions. This shows that people with higher incomes are less concerned about food waste.

Table 4 shows the basic characteristics of Chinese and European respondents, including age, gender, education, occupation, area of residence, monthly income and religious beliefs et al.

Personal profile	Options	Frequency		Percentage(%)	
		China	Europe	China	Europe
Gender	Female	231	247	55	54.6
	Male	180	204	42.9	45.1
	Prefer not to say	9	1	2.1	0.2

Table 4 Basic characteristics of respondents (cont.)

Source: Own construction

Personal profile	Options	Frequency		Percentage(%)	
		China	Europe	China	Europe
Age	<20	115	30	27.4	6.6
	20-29	75	139	17.9	30.8
	30-39	70	104	16.7	23
	40-49	53	93	12.6	20.6
	50-59	97	54	23.1	11.9
	>59	10	32	2.4	7.1
Education	Illiterate	2	0	0.5	0
	primary	69	82	16.4	18.1
	Intermediate	89	169	21.2	37.4
	University degree	260	201	61.9	44.5
Religious affiliation	Buddhism	86	10	20.5	2.2
	Christianity	21	183	5	40.5
	Islam	5	123	1.2	27.2
	Hindusim	3	46	0.7	10.2
	Other	10	45	2.4	10
	No religious affiliation	295	45	70.2	10
Living environment	Metropolitan city	118	153	28.1	33.8
	Suburban area	75	153	17.9	33.8
	Small town	158	62	37.6	13.7
	Rural area	69	84	16.4	18.6
Family type	Single, living alone	46	36	11	8
	Married	103	66	24.5	14.6
	Have a partner, but not married	33	48	7.9	10.6
	Nuclear family (parents and children)	173	159	41.2	35.2
	Extended household (living with other relatives)	12	38	2.9	8.4
	one-parent family/	17	24	4	5.3
	Sharing or living together	19	63	4.5	13.9
	Others	17	18	4	4

Table 5 Basic characteristics of respondents (cont.)

Source: Own construction

Personal profile	Options	Frequency		Percentage(%)	
		China	Europe	China	Europe
Primary source of income	Employment	275	390	65.5	86.3
	Business	108	273	25.7	60.4
	Agriculture	75	54	17.9	11.9
	Other	31	18	7.4	4
	No primary income source	38	4	9	0.9
Income	Below €5,000	92	78	21.9	17.3
	€5,000- €15,000	127	173	30.2	38.3
	€15,000 - €40,000	76	137	18.1	30.3
	Above €40,000	14	56	3.3	12.4
	Prefer not to say	111	8	26.4	1.8
Economic status	Low income	171	167	40.7	36.9
	Middle income	182	212	43.3	46.9
	High income	14	66	3.3	14.6
	Prefer not to say	53	7	12.6	1.5

Table 6 Basic characteristics of respondents (cont.)

Source: Own construction

4.2. Questionnaire Reliability and Validity Analysis

SPSS Reliability analysis

Among 872 samples, we tested the 20 scale questions of the questionnaire and obtained Cronbach's alpha coefficient of 0.850 (Q12-Q19; Q21-Q32), which is higher than 0.7, which shows that the questionnaire is very reliable (Table 5).

Sample	Items	Cronbach's alpha
872	20	0.850

Table 7 Reliability analysis include 20 items

Source: Own construction

Analysis of the "Item Overall Statistics" shown in Table 6 shows that the revised item-total correlations for Q12 and Q19 were -0.039 and -0.433 respectively, which reduced

the overall reliability. Therefore, we decided to remove Q12 and Q19 to improve overall reliability. After deleting the two questions Q12 and Q19, we conducted reliability analysis again.

	Scale Mean If Item Delete	Scale Variance If Item Delete	Corrected Item-Total Correlation	Cronbach's alpha If Item Delete
Q12	42.31	141.403	-0.039	0.861
Q13	41.96	126.404	0.518	0.84
Q14	41.92	127.415	0.517	0.84
Q15	41.76	125.461	0.524	0.839
Q16	42.74	133.32	0.417	0.845
Q17	42.44	128.162	0.412	0.844
Q18	41.89	125.287	0.515	0.84
Q19	40.85	158.093	-0.433	0.896
Q21	42.62	130.103	0.517	0.841
Q22	42.52	128.179	0.666	0.837
Q23	42.39	127.832	0.645	0.837
Q24	42.62	129.07	0.639	0.838
Q25	42.25	126.443	0.58	0.838
Q26	42.16	125.143	0.605	0.836
Q27	42.17	125.963	0.614	0.837
Q28	41.68	120.799	0.551	0.838
Q29	41.78	122.106	0.562	0.837
Q30	42.38	125.848	0.567	0.838
Q31	42.26	125	0.646	0.835
Q32	42.05	123.385	0.608	0.836

Table 8 Items total statistics

Source: Own construction

After deleting these two questions (Q12 and Q19), we conducted a reliability analysis and found that the reliability increased to 0.907, as showed in Table 7, represents a significant improvement in the internal consistency of the questionnaire. Thus, in the later research, we considered deleting these two questions in the subsequent analysis.

Sample	Items	Cronbach's alpha
872	18	0.907

Table 9 Reliability test of the questionnaire after delete Q12; Q19

Source: Own construction

Classification analysis of scale questions

We conducted a validity test on the processed questionnaire, and the KMO obtained was 0.943, which was greater than 0.7. Sphericity test is less than 0.001. It can be seen that this survey and results are reliable and valid and worthy of attention.

The principal component method was used to extract factors for further analysis, and the maximum variance method was used to rotate the factors. Three ingredients are extracted. Cumulative variance rate: 56.671%. Variables Q22, 23, 24, 25, 26, 27, 30, 31, and 32 belong to component 1, and the variance explanation rate is 26.307%; variables Q13, 14, 15, 18, 28, and 29 belong to component 3, and the variance explanation rate is 20.843 %; variables Q16 and 17 belong to factor 3, and the variance explanation rate is 9.521%.

Kasier-Meyer-Olkin Measure of Sampling		0.943
Bartlett's Test of Sphericity	Approx.Chi-Square	6632.282
	df	15.300
	Sig.	0.000

Table 10 KMO and Bartlett's test

Source: Own construction

variable	Maximum load	attribution factor
Q30	0.744	1
Q31	0.692	1
Q24	0.69	1
Q22	0.654	1
Q25	0.637	1
Q32	0.616	1
Q27	0.594	1
Q26	0.586	1
Q23	0.586	1
Q21	0.544	1
Q15	0.79	2
Q18	0.749	2
Q13	0.728	2
Q29	0.648	2
Q14	0.638	2
Q28	0.63	2
Q17	0.626	3
Q16	0.611	3

Table 11 Factor loading table

Source: Own construction

Note) Factor 1: Personal attitudes and behaviors towards food waste; Factor 2: Food purchasing and consumption behavior; Factor 3: Scale and awareness of food waste.

Average extracted variation assessment for questionnaire

The average variation extracted (AVE) indicates the internal consistency of the latent variable structure. The higher the value, the higher the internal consistency. If the average variation extracted (AVE) of the latent variable is above 0.5, the intrinsic quality of the model is ideal. After analysis, the AVE value in the environmental awareness dimension is 0.724, that is, the measurement of the environmental awareness dimension explains 72.4% of the variance in the concept of "Environmental awareness"; the AVE value in the food access behavior dimension is 0.73, that is, the measurement of the food access behavior dimension explain for the concept of "Food access behavior" is 73%; the variance explained for the concepts of " Excessive consumption and storage ", "Intention ", "Personal (resistance to food waste) attitude", and "Quantity food ", the AVE values are 78.4%, 75.5%, 56.7% and 63.9% respectively, and each variable has good reliability.

Factor	AVE
Environmental awareness	0.724
Excessive consumption and storage	0.73
Food access behavior	0.784
Intention	0.755
Personal attitude	0.567
Quantity of food	0.639

Table 12 AVE reliability assessment

Source: Own construction

Discriminant validity analysis

By analyzing the environmental awareness, food access behavior, excessive consumption and storage, intention t, personal (resistance to food waste) attitude and quantity of food in this research scale, the results after solving the square root were compared with those other than the own variables. Use the correlation coefficients between other research variables and other variables to judge the construct level of the scale. It can be seen from the results in the table below (such as Table 11) that the result of solving the square root of the AVE of environmental awareness is 0.851. The correlation coefficient between environmental awareness and other research variables ranges from 0.352-0.661. The result of solving the square root of the AVE of environmental awareness is higher than its correlation coefficient with other variables.

The correlation coefficient value range of the behavior of excessive consumption and storage of food and other research variables is between 0.137-0.637. After solving the square root of the AVE of the behavior of excessive consumption and storage of food, the result is 0.885. The result is higher than its correlation coefficient with other variables. The square roots of the AVE solutions for food waste reduction intention, personal (resistance to food waste) attitude, quantity of food and food access behavior are 0.869, 0.753, 0.799, 0.855 respectively, which are higher than the correlations of the above variables and other variables respectively. This scale has good structural validity.

	Environmental awareness	Excessive consumption and storage	Food access behavior	Intention	Personal attitude	Quantity of food
Environmental awareness	0.851					
Excessive consumption and storage	-0.476	0.885				
Food access behavior	0.491	-0.637	0.855			
Intention	0.609	-0.283	0.365	0.869		
Personal attitude	0.661	-0.405	0.5	0.682	0.753	
Quantity of food	0.354	-0.137	0.337	0.431	0.54	0.799

Table 13 Discriminant validity result

Source: Own construction

4.3. Analysis of Demographic Variables

Gender Disparities

Gender, as a crucial factor in society, exerts profound influences on individual behaviors and attitudes. Conducting an analysis of gender disparities in our deeper comprehension of the extent to which gender impacts food waste behaviors. As showed in Table 12, we conducted a comparison of gender disparities across six different dimensions of food waste. The results indicate that only in the dimension of excessive consumption and storage does gender disparities exist ($p = 0.036 < 0.05$). This suggests that significant disparities between males and females exist concerning excessive consumption and storage of food.

	Female	Male	T	p
Excessive consumption and storage	2.59±1.15	2.43±1.05	2.11	0.036*
Quantity of food	1.73±0.82	1.81±0.86	-1.36	0.173
Personal attitude	1.92±0.67	1.94±0.74	-0.41	0.68
Intention	2.00±0.94	2.05±0.95	-0.78	0.44
Food access behavior	2.42±0.99	2.40±0.97	0.29	0.77
Environmental awareness	2.26±0.97	2.21±0.98	0.76	0.45

Table 14 Independent sample T test of Gender

Source: Own construction

(Note) *: $p < 0.05$; **: $p < 0.001$

Age Disparities

Analyzing age disparities holds significant importance in food waste management. By understanding the differences among different age groups in terms of consumption habits, awareness levels, and personal attitudes towards food, it provides a basis for formulating targeted management strategies. According to Table 13, we found significant age disparities in the dimensions of excessive consumption and storage of food, environmental awareness, and food access behaviors (with F values of 18.692, 6.775, and 6.476 respectively, all p values < 0.001).

Therefore, governments, businesses, and various sectors of society can develop corresponding policies and projects based on the characteristics of different age groups to minimize food waste, enhance resource utilization efficiency, and ultimately achieve sustainable development goals.

	<20	20-29	30-39	40-49	50-59	>59	F	p
Excessive consumption and storage	3.21±1.11 ^a	2.5±1.12 ^{bc}	2.31±1.01 ^{cd}	2.19±1.07 ^{ce}	2.64±0.99 ^b	2.0±1.05 ^e	18.692	<0.001 **
Quantity of food	1.67±0.87 ^a	1.83±0.84 ^a	1.81±0.83 ^a	1.8±0.81 ^a	1.69±0.88 ^a	1.81±0.86 ^a	1.012	0.409
Personal attitude	2.04±0.71 ^a	1.96±0.71 ^a _b	1.96±0.75 ^{ab}	1.81±0.66 ^{bc}	1.93±0.7 ^{ab}	1.94±0.74 ^c	2.527	0.28
Intention	2.24±1.09 ^a	2.05±0.97 ^a _b	2.06±0.96 ^{ab}	1.9±0.85 ^b	1.96±0.95 ^b	2.05±0.95 ^b	2.516	0.28
Food access behavior	2.6±0.93 ^a	2.5±1.05 ^a	2.24±0.91 ^b	2.19±0.95 ^b	2.63±1 ^a	2.40±0.97 ^b	6.775	<0.001 **
Environmental awareness	2.52±1.01 ^a	2.29±1.03 ^a _b	2.3±0.97 ^{ab}	1.99±0.89 ^{cd}	2.23±0.9 ^{bc}	2.21±0.98 ^d	6.476	<0.001 **

Table 15 One-way ANOVA of Age

Source: Own construction

Education Level Disparities

Education level is closely associated with individual awareness and behavioral tendencies. Individuals with higher levels of education often exhibit higher environmental awareness and resource utilization consciousness, and they are more inclined towards adopting a frugal and environmentally friendly lifestyle, thereby

reducing food waste. Additionally, analysis of education level disparities can help reveal differences among groups with varying levels of education in terms of food waste behaviors, attitudes, and intentions, thus providing a basis for targeted management strategies.

	Illiterate	primary	Intermediate	University degree	F	p
Excessive consumption and storage	3.25±0.35 ^a	2.51±1.15 ^a	2.2±1.01 ^a	2.72±1.11 ^a	12.682	<0.001**
Quantity of food	1.25±0.35 ^a	1.85±0.84 ^a	1.8±0.86 ^a	1.72±0.82 ^a	1.527	0.206
Personal attitude	2.17±1.18 ^a	1.95±0.78 ^a	1.84±0.68 ^a	1.97±0.69 ^a	1.969	0.117
Intention	2±0.71 ^a	2.13±1 ^a	1.91±0.9 ^a	2.08±0.97 ^a	2.413	0.65
Food access behavior	3.25±0.35 ^a	2.39±1.01 ^b	2.2±0.91 ^{ab}	2.54±0.99 ^{ab}	7.615	<0.001**
Environmental awareness	2.25±0.35 ^a	2.22±1.02 ^a	2.09±0.93 ^a	2.35±0.97 ^a	4.130	<0.006*

Table 16 One-way ANOVA of Education level

Source: Own construction

As table 14 shows, it can be observed that significant differences exist among groups with different education levels in three dimensions: excessive consumption and storage, food access behavior, and environmental awareness (with F values of 12.682, 7.615, and 4.130 respectively, all p values < 0.05). This indicates that education level has a significant impact on these aspects.

Analysis of Religious Belief Disparities

Religious beliefs play a significant role in shaping individual values and behavioral norms. Followers of different religious beliefs may have varying moral concepts and lifestyles, thereby influencing their perspectives on and approaches towards food. Analyzing disparities in religious beliefs helps uncover differences among different religious groups in terms of food waste behaviors, attitudes, and intentions. As indicated in Table 15, significant differences exist among groups with different religious beliefs in three dimensions: excessive consumption and storage, quantity of food waste, and environmental awareness (with F values of 53.79, 4.15, 26.49, and 13.4 respectively, all p values < 0.001); differences also exist in personal attitudes (F = 2.86, p = 0.014 < 0.05).

	Buddhism	Christianity	Islam	Hindusim	Other	No religious affiliation	F	p
Excessive consumption and storage	2.34±1.1 ^b	2.11±0.99 ^{bc}	1.96±0.98 ^c	1.84±0.68 ^c	2.31±1.15 ^b	3.19±0.92 ^a	53.79	<0.001**
Quantity of food	1.68±0.78 ^b	1.88±0.82 ^{ab}	1.9±0.85 ^{ab}	1.73±0.79 ^b	2±0.93 ^a	1.64±0.83 ^b	4.15	<0.001**
Personal attitude	1.88±0.69 ^b	1.9±0.77 ^b	1.87±0.76 ^b	1.65±0.49 ^a	1.99±0.8 ^b	2.01±0.64 ^b	2.86	0.014*
Intention	1.95±0.98 ^a	2.04±1.01 ^a	1.97±0.94 ^a	1.9±0.68 ^a	2.14±0.97 ^a	2.08±0.96 ^a	0.76	0.58
Food access behavior	2.4±0.94 ^b	2.13±0.94 ^{bc}	2.07±0.9 ^c	1.88±0.8 ^c	2.16±0.99 ^{bc}	2.84±0.9 ^a	26.49	<0.001**
Environmental awareness	2.18±0.99 ^b	2.06±0.99 ^b	2.03±0.9 ^b	1.69±0.58 ^c	2.23±1.04 ^b	2.55±0.93 ^a	13.4	<0.001**

Table 17 One-way ANOVA of Culture and religions

Source: Own construction

Analysis of Residential Environment Disparities

The residential environment has a profound impact on individual lifestyles and consumption habits. For example, residents of large cities may face a fast-paced lifestyle and high levels of stress, leading them to prefer fast food and takeout, resulting in more severe food waste. In contrast, in rural areas and small towns, people may rely more on self-sufficiency to obtain food, leading to a higher level of appreciation for food. As shown in Table 16, significant differences exist among groups with different residential environments in three dimensions: Excessive consumption and storage, Food access behavior, and environmental awareness (with F values of 11.575, 8.017, and 5.195 respectively, all p values < 0.001). This indicates that the residential environment significantly influences food waste issues. Therefore, through the analysis of residential environment disparities, more targeted food wastage management strategies can be developed for different regions to enhance management effectiveness, reduce resource wastage, and promote sustainable development.

	Metropolitan city	Suburban area	Small town	Rural area	F	p
Excessive consumption and storage	2.62±1.05 ^{ab}	2.22±1.12 ^c	2.8±1.1 ^a	2.44±1.11 ^b	11.575	<0.001**
Quantity of food	1.82±0.84 ^a	1.82±0.89 ^a	1.63±0.73 ^b	1.78±0.87 ^{ab}	2.625	0.049
Personal attitude	1.99±0.72 ^a	1.92±0.76 ^a	1.88±0.57 ^a	1.91±0.77 ^a	1.118	0.341
Intention	2.12±0.96 ^a	2.01±0.95 ^a	1.95±0.97 ^a	2.06±0.95 ^a	1.431	0.232
Food access behavior	2.42±0.97 ^b	2.22±0.99 ^c	2.66±0.93 ^a	2.34±0.98 ^{bc}	8.017	<0.001**
Environmental awareness	2.35±1.04 ^a	2.05±0.95 ^c	2.35±0.89 ^a	2.2±0.96 ^{ab}	5.195	0.001**

Table 18 One-way ANOVA of Area

Source: Own construction

Analysis of Income Disparities

Individual income levels directly influence their purchasing power and consumption habits regarding food. Lower-income groups may be more inclined to purchase inexpensive food items or prioritize the practicality of food, while higher-income groups may be more susceptible to indulgent consumption and excessive purchasing behavior, thereby increasing the likelihood of food waste.

	Low income	Middle income	High income	Prefer not to say	F	p
Excessive consumption and storage	2.55±1.13 ^b	2.44±1.06 ^{bc}	2.16±0.97 ^c	3.54±0.96 ^a	21.959	<0.001**
Quantity of food	1.8±0.87 ^a	1.71±0.81 ^a	1.86±0.78 ^a	1.75±0.89 ^a	1.103	0.347
Personal attitude	1.94±0.72 ^b	1.88±0.67 ^b	1.94±0.76 ^b	2.18±0.69 ^a	3.251	0.021*
Intention	2.1±1.01 ^b	1.92±0.85 ^b	2.05±0.96 ^b	2.4±1.16 ^a	5.438	0.001**
Food access behavior	2.47±1.01 ^b	2.38±0.93 ^b	2.08±1.01 ^c	2.81±0.91 ^a	7.141	<0.001**
Environmental awareness	2.27±1 ^b	2.18±0.88 ^b	2.07±1.08 ^b	2.84±1.02 ^a	9.353	<0.001**

Table 19 One-way ANOVA of Income level

Source: Own construction

As shown in Table 17, significant differences exist among groups with different income levels in five dimensions: Excessive consumption and storage, Food access behavior, Environmental awareness, Intention to reduce food waste, and Personal attitude (with F

values of 21.959, 7.141, 9.353, 5.438, and 3.251 respectively, all p values < 0.05). However, there are no significant differences in the Quantity of food waste.

Analysis of family Structure Disparities

Different family structures may have varying impacts on food waste. For instance, nuclear families (parents with children) may prioritize thriftiness and family sharing, while individuals living alone or single-person households may be more prone to excessive purchasing and wasteful behaviors. As indicated in Table 18, significant differences exist among different household structure types in four dimensions: Excessive consumption and storage of food, Food access behaviors, Intention to reduce food waste, and Environmental awareness (with F values of 4.944, 3.614, 2.257 respectively, all p values < 0.05). However, there are no significant differences in the Quantity of food waste or personal attitudes.

	Excessive consumption and storage	Quantity of food	Personal attitude	Intention	Food access behavior	Environmental awareness
Family type 1	2.91±1.01 ^d	2.53±1.09 ^a	2.53±1.12 ^c	2.63±1.13 ^a	2.16±0.95 ^c	2.51±1.25 ^b
Family type 2	1.82±1 ^{cd}	1.72±0.78 ^a	1.8±0.8 ^{bc}	1.76±0.83 ^a	1.71±0.74 ^{bc}	1.7±0.91 ^{ab}
Family type 3	2.13±0.69 ^{bcd}	1.86±0.66 ^a	1.94±0.68 ^{abc}	1.91±0.68 ^a	1.83±0.67 ^b	1.97±0.72 ^{ab}
Family type 4	2.32±1.08 ^{abc}	2±0.84 ^a	2.17±1.05 ^{abc}	1.95±0.9 ^a	2.06±0.82 ^{ab}	1.98±0.94 ^{ab}
Family type 5	2.74±0.92 ^{abc}	2.49±0.97 ^a	2.41±1.03 ^{abc}	2.39±0.97 ^a	1.94±0.78 ^{ab}	2.56±1.12 ^{ab}
Family ype 6	2.53±1.03 ^{abc}	2.2±0.93 ^a	2.31±1 ^{abc}	2.24±0.95 ^a	1.89±0.78 ^{ab}	2.38±1.16 ^a
Family type 7	2.91±1.01 ^{bc}	2.53±1.09 ^a	2.53±1.12 ^{ab}	2.63±1.13 ^a	2.16±0.95 ^{ab}	2.51±1.25 ^a
Family type 8	1.82±1 ^a	1.72±0.78 ^a	1.8±0.8 ^a	1.76±0.83 ^a	1.71±0.74 ^a	1.7±0.91 ^a
F	4.944	0.594	1.857	2.18	3.614	2.257
p	<0.001**	0.761	0.074	0.034*	<0.001**	0.028*

Table 20 One-way ANOVA of Family type

Source: Own construction

	Content
Family type 1	Single, living alone/单身，独自居住
Family type 2	Married, with a spouse/已婚，有配偶
Family type 3	Have a partner, but not married/有伴侣，但未婚
Family type 4	Nuclear family (parents and children)/核心家庭（父母与子女）
Family type 5	Extended household (living with other relatives)/扩展家庭（与其他亲属同住）
Family type 6	one-parent family/单亲家庭
Family type 7	Sharing or living together/合住或共同居住
Family type 8	Others _____ (please specify)/其他_____ 请注明）

Table 21Family constructure option correspondence table

Source: Own construction

4.4. Hypothesis Testing

Explanation of Research Relationships

In this study, we constructed a complex relationship model aimed at exploring the formation and driving factors of food waste behaviors. As illustrated in Figure 8, we consider Excessive consumption and storage of food, Food access behavior, and Quantity of food waste as outcome variables measuring food waste behavior. We take personal attitudes (towards resisting food waste) as explanatory variables in the model, Environmental awareness as a moderating variable, and we introduce "Intention " as a mediating variable to help explain the relationship between personal attitudes (towards resisting food waste) and food waste behaviors.

Specifically, we constructed a relationship model encompassing Excessive consumption and storage of food, Food access behaviors, Quantity of food, intention to reduce food waste, Environmental awareness, and Personal attitudes (towards resisting food waste). We utilized the respondents' regions (China and Europe) as heterogeneous elements to explore the individual-level reasons and driving factors for food waste among Chinese and European respondents.

In this structure of model in this study, the relationship pathways regulated by the moderating variable of Environmental awareness are: "Personal attitudes towards

resisting food waste -> Food access behavior," "Personal attitude towards resisting food waste -> Excessive consumption and storage of food behaviors," and "Personal attitudes towards resisting food waste -> Quantity of food" We investigate the research relationships between personal attitudes (towards resisting food waste), environmental awareness levels, and different food waste behaviors.

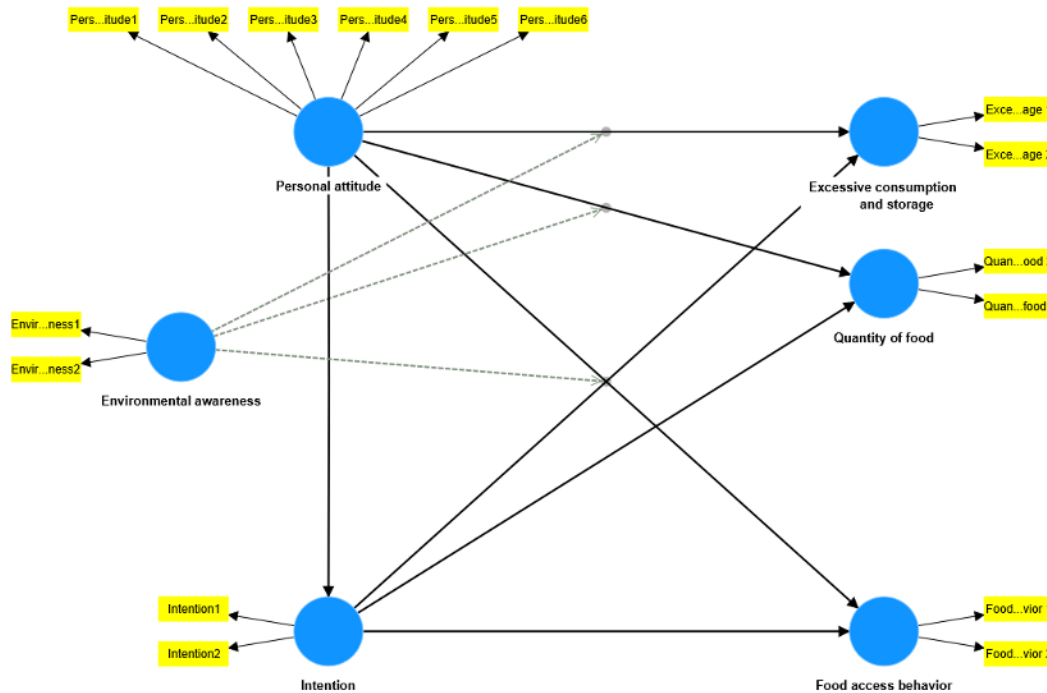


Figure 8 Research relationship between the level of environmental awareness and personal attitude and different food waste behaviors

Source: Own construction

Relationship Testing Analysis Represented by Chinese Respondents

(1) Direct Effects Analysis of Personal Attitudes Towards Food Waste and Different Food Waste Behaviors

Taking Chinese respondents as the representative research group, the direct effects relationship analysis between personal attitudes towards food waste and different food waste behaviors (as shown in Table 20) reveals that out of the 3 tested relationships, 1 hypothesis was rejected while 2 hypotheses were accepted. Combining with regression effect coefficient analysis, it is observed that among Chinese respondents, personal

attitudes towards resisting food waste positively promote their food access behavior (i.e., concern for the rationality of food packaging and whether to purchase food beyond the required quantity) ($B = 0.166$, $p = 0.013 < 0.05$). This positive effect may stem from several factors: firstly, the resistance attitude prompts individuals to pay more attention to the rationality of food packaging, preferring smaller packages to reduce food loss. Secondly, the resistance attitude may lead individuals to prefer purchasing smaller quantities of food to minimize waste.

Furthermore, personal attitudes towards resisting food waste among Chinese respondents have a significantly negative promoting effect on Excessive consumption and storage of food behavior ($B = -0.179$, $p = 0.003 < 0.05$). This indicates that the stronger the resistance attitude towards food waste, the more emphasis individuals place on reducing food waste and minimizing excessive consumption and storage behaviors.

These results demonstrate the significant role of personal attitudes towards resisting food waste in shaping food access behavior. Strengthening the cultivation and promotion of attitudes resisting food waste may help encourage individuals to adopt more sustainable and responsible food access behavior, as well as reduce food consumption and storage behaviors, thereby reducing occurrences of food waste.

Path	B	T	p	Result
Environmental awareness -> Excessive consumption and storage	-0.315	5.632	<0.001**	A
Environmental awareness -> Food access behavior	0.254	4.076	<0.001**	A
Environmental awareness -> Quantity of food	0.019	0.311	0.756	R
Intention -> Excessive consumption and storage	0.084	1.44	0.15	R
Intention -> Food access behavior	-0.076	1.228	0.219	R
Intention -> Quantity of food	0.017	0.273	0.785	R
Personal attitude -> Excessive consumption and storage	-0.179	2.928	0.003*	A
Personal attitude -> Food access behavior	0.166	2.472	0.013*	A
Personal attitude -> Intention	0.58	14.488	<0.001**	A
Personal attitude -> Quantity of food	0.145	1.865	0.062	R
Environmental awareness x Personal attitude -> Excessive consumption and storage	0.129	3.275	0.001**	A
Environmental awareness x Personal attitude -> Food access behavior	0.051	1.086	0.277	R
Environmental awareness x Personal attitude -> Quantity of food	0.232	4.311	<0.001**	A

Table 22 Analysis of path relationship effects among Chinese respondent group

Source: Own construction

(2) Analysis of the direct effect between environmental awareness and different food waste behaviors

When examining the direct effects relationship between environmental awareness and different food waste behaviors, out of the 3 tested relationships, 1 hypothesis was rejected while 2 hypotheses were accepted. Combining regression effect coefficient analysis, it is found that among Chinese respondents, environmental awareness has a positive promoting effect on their food access behavior ($B=0.254$, $p<0.001$), and a negative significant predicting effect on excessive consumption and storage of food behavior ($B=-0.315$, $p<0.001$).

This suggests that the level of environmental awareness among Chinese respondents influences their attention to the quantity of food purchases and the size of food packaging. This may be related to the virtue of thrift promoted in Chinese culture and the increasing awareness of environmental issues in Chinese society. People are becoming more conscious of conserving resources and protecting the environment, consciously choosing appropriate food packaging and quantities to reduce the

environmental impact of food waste. However, the level of Environmental awareness among Chinese respondents does not have an effect on Quantity of food ($p>0.05$). This indicates that the level of environmental awareness among Chinese respondents does not directly affect their behaviors such as food preparation and non-frugal food consumption. This is consistent with the high demands for gourmet cooking in Chinese culture, which is not directly associated with their level of environmental awareness.

(3) Analysis of the effects between Intention (food waste reduction intention) and different food waste behaviors

Taking the Chinese respondent group as the research object, their Intention towards their Food access behavior ($B=-0.076$, $p=0.219>0.05$), Excessive consumption and storage ($B=0.084$, $p=0.15>0.05$), and Quantity of food ($B=-0.017$, $p=0.273>0.05$) and other aspects of behavioral performance are not directly related. There is little connection between the food waste problem and the Chinese respondents' Intention. The Chinese respondents' Intention is not enough to directly affect their food waste behavior. This may be due to the cognitive and psychological gap between behavioral intention and actual behavior, the influence of social culture, as well as the lack of operability and implementation difficulty and other factors. Therefore, in order to improve the behavioral effect of reducing food waste, in addition to increasing intention, corresponding intervention measures need to be taken based on these factors to promote the conversion of intention-to-behavior.

(4) Moderating effect analysis

Through the analysis of the moderating effect of Chinese respondents, it can be seen that environmental awareness plays a moderating relationship between personal attitude towards food waste and excessive consumption and storage of food. The path effect of Personal attitude towards food waste has a negative impact on the Excessive consumption and storage of food ($B=-0.315$, $p<0.001$). However, There is a significant positive effect on the interaction term Environmental awareness x Personal attitude $\rightarrow$ Excessive consumption and storage has a positive and significant effect ($B=0.129$, $p=0.001<0.05$), indicating that Environmental awareness plays a significant positive moderating relationship between Personal attitude and Excessive consumption and

storage. In addition, in the moderating cross-relationship, the interaction term, environmental awareness $\times$ personal attitude $\rightarrow$ Quantity of food has a significantly positive impact ($B = 0.232$, $p < 0.001$), showed that environmental awareness plays a significantly positive moderating role between personal attitude and Quantity of food.

Relationship tests represented by the European respondent group

(1) Analysis of the direct effect between environmental awareness and different food waste behaviors

Taking European respondents as the representative group of the study, the analysis of the direct effect relationship between environmental awareness and different food waste behaviors shows that among the 3 research relationships, a total of 1 hypothesized relationship was rejected and 2 hypothesized relationships were accepted. Combined with the regression effect coefficient analysis, it can be seen that the level of personal Environmental awareness of the European respondent group has a positive effect on Food access behavior ($B = 0.173$, $p = 0.006 < 0.05$); that is, Environmental awareness has a positive role in promoting their behavior of paying more attention to the rationality of food packaging when shopping, purchasing appropriate amounts of food, and choosing packaging rationally; and the level of Environmental awareness of European respondents makes them Excessive consumption and storage have a negative significant effect ($B = -0.271$, $p < 0.001$). This shows that the higher the environmental awareness of European respondents, the more they will reduce excessive food waste behavior. This finding reflects the profound impact of the environmental protection concepts held by European consumers in their shopping decisions on actual behavior.

European respondents tend to value the importance of resource conservation and environmental protection, which prompts them to pay more attention to whether the food packaging they purchase is environmentally friendly and reasonable. When shopping, they are more likely to choose products with small packaging or recyclable materials to reduce food packaging waste. This behavior reflects European consumers' pursuit of sustainable development and recognition of environmentally friendly consumption patterns in their daily lives. Therefore, by encouraging consumers to pay attention to the environmental protection and rationality of food packaging, and

providing more product options with recyclable materials or small quantities of packaging, we can effectively reduce the waste of food packaging and promote the goal of environmentally sustainable development.

Path	B	T	p	Result
Environmental awareness -> Excessive consumption and storage	-0.271	3.493	<0.001**	A
Environmental awareness -> Food access behavior	0.165	2.772	0.006*	A
Environmental awareness -> Quantity of food	-0.054	0.985	0.325	R
Intention -> Excessive consumption and storage	-0.016	0.259	0.796	R
Intention -> Food access behavior	0.013	0.24	0.811	R
Intention -> Quantity of food	0.089	1.564	0.118	R
Personal attitude -> Excessive consumption and storage	-0.464	5.404	<0.001**	A
Personal attitude -> Food access behavior	0.449	4.991	<0.001**	A
Personal attitude -> Intention	0.776	37.368	<0.001**	A
Personal attitude -> Quantity of food	0.546	6.911	<0.001**	A
Environmental awareness x Personal attitude -> Excessive consumption and storage	0.049	0.824	0.41	R
Environmental awareness x Personal attitude -> Food access behavior	0.071	1.359	0.174	R
Environmental awareness x Personal attitude -> Quantity of food	0.132	2.914	0.004*	A

Table 23 Analysis of path relationship effects among European respondent group

Source: Own construction

(2) Analysis of the direct effect between personal attitude (resistance to food waste) and different food waste behaviors

Taking European respondents as the representative group of the research, based on the analysis of the direct effect relationship between personal attitude (resistance to food waste) and different food waste behaviors, a total of 3 hypothesized relationships were accepted in the 3 research relationships. Combining From the regression effect coefficient analysis, the personal attitude (resistance to food waste) of the European respondent group shows a positive promotion effect on their food access behavior (B=0.449, p<0.001). This is reflected in the fact that they pay attention to the size of food packaging and the quantity of food purchased when shopping. The stronger the personal attitude (resistance to food waste) of European respondents, the more they pay attention to the size and quantity of food purchased to avoid food waste. In addition, the

European respondent group's personal attitude (resistance to food waste) showed a significant negative correlation with excessive consumption and storage of food ($B=-0.464$, $p<0.001$), indicating that the stronger the Europe respondent's personal attitude (resistance to food waste), the more carefully he or she plans food consumption and reduces unnecessary purchases and wasteful behaviors during cooking; and the personal attitude (resistance to food waste) of the European respondent group plays a positive role in promoting the quantity of food waste ($B=0.546$, $p<0.001$). According to the questionnaire design rules, that is, the stronger the personal attitude (Personal attitude) of the European respondent group against food waste, the more careful they will be about not exceeding the required amount of food when buying food.

(3) Analysis of the effects between Intention (food waste reduction intention) and different food waste behaviors

Taking the European respondent group as the research object, their Intention their food access behavior ($B=0.013$, $p=0.811>0.05$), Excessive consumption and storage ($B=-0.016$, $p=0.796>0.05$) and Quantity of food ($B=0.089$, $p=0.118>0.05$) are not directly related. Among the European respondent groups, food waste behavior is not significantly related to food waste reduction intention (Intention) behavior to reduce food waste.

(4) Moderating effect analysis

Through the analysis of the moderating effect of European respondents, it can be seen that Personal attitude towards excessive consumption and storage behavior is negative impact, and Environmental awareness)has a positive effect on Food access behavior($B=0.165$, $p<0.001$), but the interaction term Environmental awareness x Personal attitude -> Food access behavior does not have a significant effect ($B=0.071$, $p=0.174>0.05$); in addition, the interaction term Environmental awareness has a positive and significant regulatory to relationship between Personal attitude)and Quantity of food($B=0.132$, $P=0.004<0.05$),indicating that environmental awareness plays an important role in personal attitude towards quantity of food waste

Analysis of the direct effect relationship of the overall model

(1) Analysis of the direct effect between personal attitude towards food waste and different food waste behaviors.

As analyzed through the path relationship model (Figure 11), it is evident that there are variations in the influence relationship between personal attitude towards food waste behaviors. Personal attitude towards Excessive consumption and storage of food behaviors shows a significantly negative impact ($B=-0.334$, $p<0.001$), indicating that the more positive personal attitude towards food waste is, the more resistant they are to purchasing and storing food beyond their needs, as well as engaging in non-conservative food behaviors.

Furthermore, there exists a significantly positive relationship between personal attitude towards quantity of food waste ($B=0.382$, $p<0.001$). According to the coding rules of questionnaire items, this suggests that the more positive personal attitude towards food waste is, the lower the percentage of food wasted weekly out of the total food, the lower the amount of food wasted weekly, and the lower the level of food wasted during the cooking process. Resistance attitude strengthens individuals' awareness of cherishing resources and their perception of moral pressure on wasteful behavior. Positive resistance attitudes can prompt individuals to plan food consumption more carefully and reduce unnecessary purchases and waste during cooking. Resistance attitudes may stimulate individuals' awareness of the value of food and encourage them to cherish food resources more, thereby reducing food waste.

There is a positive and significant relationship between personal attitude and food access behavior ($B=0.322$, $p<0.001$), indicating that the more positive personal attitude, the more attention they pay to the packaging size and purchase quantity of food. Avoid over-purchasing. The boycott attitude strengthens the individual's cherishment of resources and aversion to over-consumption. Pay more attention to the rationality of food packaging and avoid purchasing excess food, thereby reducing waste.

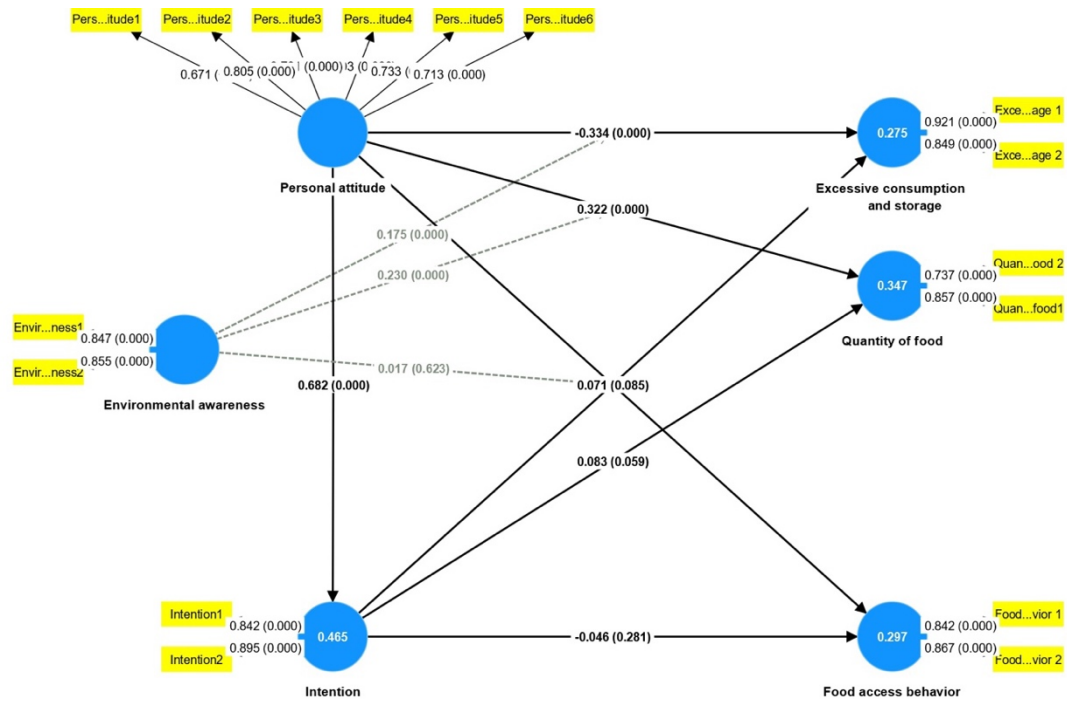


Figure 9 Overall path diagram

Source: Own construction

(2) Analysis of the direct effect between Intention (food waste reduction intention) and different food waste behaviors.

Through the analysis of the direct effects between Intention and different food waste behaviors, it can be seen that Intention → Food access behavior ($p=0.281$), Intention → Excessive consumption and storage ($p=0.085$) and Intention → Quantity of food ($p=0.059$) are not significant, indicating that the respondent group's intention to reduce food waste does not directly affect the following behaviors: careful selection of food packaging size, cleanliness of raw food during the cooking process Dealing with requests, appropriate over-preparation of food when entertaining guests, purchasing more food than one needs, and non-food-sparing behaviors, and the level of food wasted by respondents.

This shows that although people may have the intention to utilize food and reduce food waste, this level of intention does not directly translate into actual behavioral effects. There may be other factors or mechanisms such as habits, social pressure, economic

factors, etc. This also enlightens us that when designing interventions to reduce food waste, we need to consider the complex factors behind individual behaviors and adopt comprehensive strategies to guide individuals to change their food waste behaviors, thereby achieving more efficient use of food resources and reducing waste.

Path	Original Sample (O)	T-statistic (O/STDEV)	p-value	f-squared	VIF	Result
Environmental awareness -> Excessive consumption and storage	-0.421	10.985	<0.001**	0.125	1.952	A
Environmental awareness -> Food access behavior	0.295	7.097	<0.001**	0.063	1.952	A
Environmental awareness -> Quantity of food	-0.069	1.794	0.073	0.004	1.952	R
Intention -> Excessive consumption and storage	0.071	1.725	0.085	0.003	2.082	R
Intention -> Food access behavior	-0.046	1.078	0.281	0.001	2.082	R
Intention -> Quantity of food	0.083	1.885	0.059	0.005	2.082	R
Personal attitude -> Excessive consumption and storage	-0.334	6.712	<0.001**	0.055	2.798	A
Personal attitude -> Food access behavior	0.322	6.079	<0.001**	0.053	2.798	A
Personal attitude -> Intention	0.682	29.321	<0.001**	0.868	1	A
Personal attitude -> Quantity of food	0.322	5.375	<0.001**	0.057	2.798	A
Environmental awareness x Personal attitude -> Excessive consumption and storage	0.175	5.266	<0.001**	0.038	1.953	A
Environmental awareness x Personal attitude -> Food access behavior	0.017	0.491	0.623	0	1.953	R
Environmental awareness x Personal attitude -> Quantity of food	0.23	6.327	<0.001**	0.072	1.953	A

Table 24 Research analysis of the relationship between level of food waste, intention, environmental awareness, and food acquisition behaviors

Source: Own construction

(3) Analysis of the direct effect between environmental awareness and different food waste behaviors.

From the analysis of the direct effect relationship between environmental awareness and different food waste behaviors, among the three research relationships, a total of 1 hypothesized relationship was rejected and 2 hypothesized relationships were accepted. Combined with the regression effect coefficient analysis, Environmental awareness level has a positive promotion effect on Food access behavior ($B=0.295$, $p<0.001$); that is, the higher the environmental awareness, the more people pay attention to the rationality of food packaging when shopping and The behavior of purchasing an

appropriate amount of food and choosing packaging appropriately has a positive promotion effect; and the level of Environmental awareness has a negative and significant effect on the behavior of Excessive consumption and storage of food ($B=-0.421$, $p<0.001$). This shows that the higher the environmental awareness of respondents, the more they will reduce excessive food waste. But there is no significant impact on Quantity of food waste ($B=-0.069$, $p>0.05$).

The moderating effect relationship of the overall model

(1) Analysis of the moderating effect of environmental awareness on the relationship between Personal attitude and Excessive consumption and storage.

The moderation effect analysis of Environmental awareness on the relationship between Personal attitude towards Excessive consumption and storage of food was conducted. According to the results of the path analysis (Figure 12), it was found that environmental awareness significantly moderates the relationship between Personal attitude towards Excessive consumption and storage of food. Specifically, environmental awareness has a negative and significant impact on excessive consumption and storage of food behavior ($B=-0.421$, $p<0.001$). This means that higher environmental awareness strengthens personal attitude towards food waste reduction, thereby reducing occurrences of food waste behavior.

Furthermore, the interaction effect of environmental awareness and personal attitude towards Excessive consumption and storage of food exhibits a marginally significant positive impact ($B=0.175$, $p<0.001$). This indicates that environmental awareness moderates the relationship between personal attitude towards excessive consumption and storage of food behavior in a positively significant manner. In other words, the interaction effect between environmental awareness and personal attitude towards food waste significantly influences food waste behavior, emphasizing the higher level of environmental awareness strengthen personal attitude towards food waste reduction, thus reducing food waste behavior. Guided and motivated by environmental awareness, individuals are more inclined to take proactive actions to reduce food waste in their daily lives. High levels of environmental awareness encourage and motivate personal

attitude towards food waste reduction, thereby promoting more proactive actions to reduce food waste in daily life.

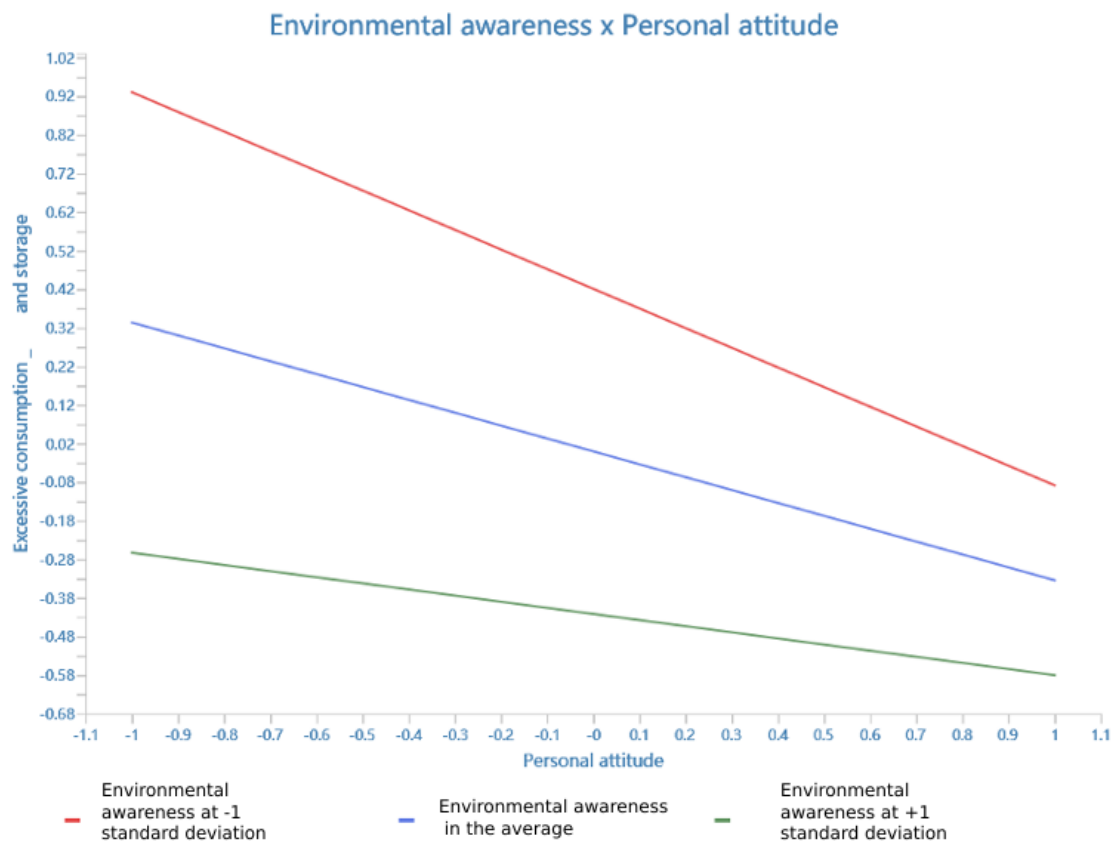


Figure 10 Moderating effect diagram of environmental awareness on the relationship between personal attitude towards food waste and Excessive consumption and storage

Source: Own construction

(2) Analysis of the moderating effect of environmental awareness between personal attitude and Quantity of food

Through the path test results, it can be seen that Environmental awareness has a marginally positive and significant impact on Quantity of food waste ($B=0.322$, $p < 0.001$), which indicates that the higher the level of environmental awareness, the more inclined individuals are to reduce food waste behaviors and thus behave more

cautiously in planning food consumption, reducing unnecessary purchases, and reducing wasteful behaviors during cooking.

In addition, the interaction term environmental awareness $\times$ personal (resistance to food waste) attitude $\rightarrow$ quantity of food waste also has a positive and significant effect ($B=0.23$, $p<0.001$), indicating that environmental awareness plays an positive and important role in personal attitude. towards quantity of food waste. This means that individuals with high environmental awareness are more likely to realize the preciousness of resources and the importance of the environment, and are therefore more inclined to adopt measures to reduce waste behaviors in daily life, such as planning food consumption more carefully, reducing unnecessary purchases, and Reduce wasteful behavior during cooking. Personal attitudes (resistance to food waste) are often closely related to environmental awareness.

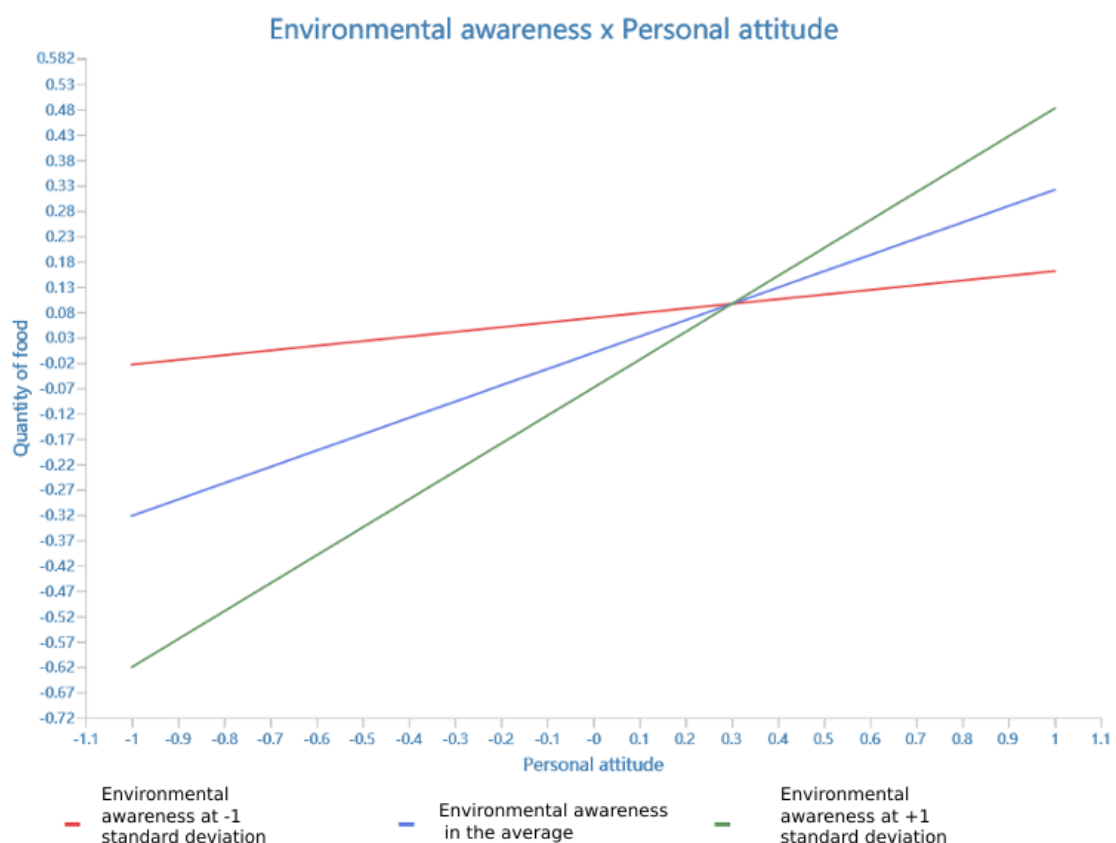


Figure 11 Moderating effect diagram of environmental awareness on the relationship between personal attitude towards waste and quantity of food

Source: Own construction

(3) Analysis of the moderating effect of environmental awareness on the relationship between Personal attitude and food access behavior

Through the path test results, it can be seen that environmental awareness has a moderating effect on the relationship between personal attitude and food access behavior. The path effect of personal attitude and food access behavior is positive significant ($B=0.295$, $p<0.05$), and the interaction term environmental awareness $\times$ personal resistance to food waste $\rightarrow$ food access behavior does not have a positively significant effect ($p>0.05$), which shows that environmental awareness does not have a moderating effect on the relationship between personal attitude and food access behavior. In other words, although personal attitude and environmental awareness have a certain impact on food acquisition behavior, an increase in the level of environmental awareness will not significantly change this impact relationship.

Although environmental awareness can affect personal attitude to a certain extent, it does not have a significant moderating effect on the relationship between personal attitude towards food access behavior. This finding contributes to a deeper understanding of the impact of environmental awareness on personal behavior and provides an important reference for developing more effective strategies to reduce food waste.

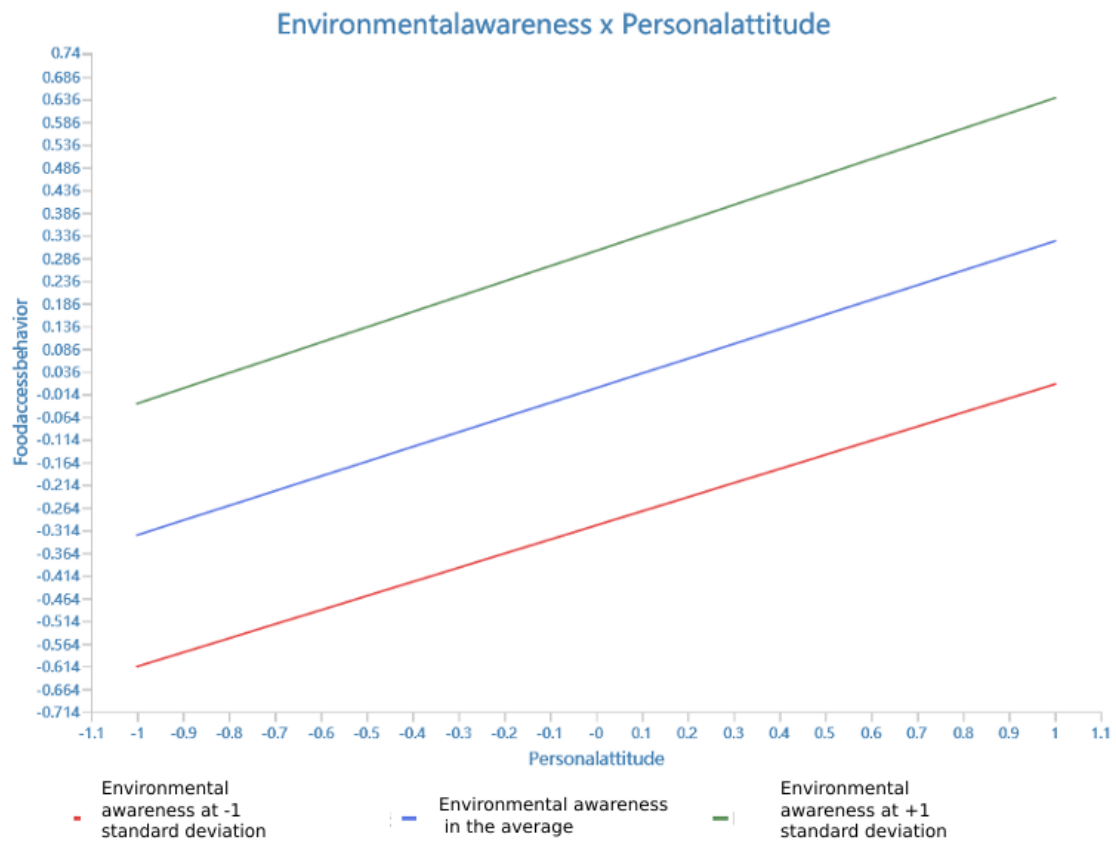


Figure 12 Moderating effect diagram of environmental awareness on the relationship between personal attitude towards waste and food access behavior

Source: Own construction

Multi-group effect relationship analysis

(1) Analysis of heterogeneity levels of environmental awareness and food access behavior

Through comparative analysis of the heterogeneous grouping results of Chinese and European groups, the positive relationship between environmental awareness and food access behavior is significant in both Chinese and European groups, and among the Chinese respondent groups, environmental awareness has a significant positive impact on food access behavior. The predicted impact relationship level with food access behavior is 0.254 ($p < 0.001$). In the European respondent group, the predicted impact relationship level between environmental awareness and food access behavior is 0.165 ($p < 0.001$). It shows that among the Chinese respondent groups, environmental

awareness has a higher positive effect on the cautiousness of food packaging size selection. The differences between regions also further illustrate the value concept that emphasizes saving and cherishing resources in Chinese traditional culture. Environmental awareness in China has a relatively deep foundation in society, so individuals are more inclined to show concern and respect for the environment in their daily lives. The Chinese government has always been committed to promoting environmental protection and sustainable development, and has increased the support through a series of policies and regulations. to promote environmentally friendly products and behaviors, thus enhancing personal recognition and practice of environmental awareness. At the same time, China's media and educational institutions are also vigorously promoting environmental protection concepts and strengthening the popularization and education of public environmental awareness, so that more people are aware of the impact of their personal actions on the environment, prompting them to choose food packaging sizes more carefully in their daily lives.

Path	China			Europe		
	B	T	p	B	T	p
Environmental awareness -> Excessive consumption and storage						
Environmental awareness -> Food access behavior	-0.315	5.632	<0.001	-0.271	3.493	<0.001**
Environmental awareness -> Quantity of food	0.254	4.076	<0.001	0.165	2.772	0.006*
Intention -> Excessive consumption and storage	0.019	0.311	0.756	-0.054	0.985	0.325
Intention -> Food access behavior	0.084	1.44	0.15	-0.016	0.259	0.796
Intention -> Quantity of food	-0.076	1.228	0.219	0.013	0.24	0.811
Personal attitude -> Excessive consumption and storage	0.017	0.273	0.785	0.089	1.564	0.118
Personal attitude -> Food access behavior	-0.179	2.928	0.003	-0.464	5.404	<0.001**
Personal attitude -> Intention	0.166	2.472	0.013	0.449	4.991	<0.001**
Personal attitude -> Quantity of food	0.58	14.488	<0.001	0.776	37.368	<0.001**
Environmental awareness x Personal attitude -> Excessive consumption and storage	0.145	1.865	0.062	0.546	6.911	<0.001**
Environmental awareness x Personal attitude -> Food access behavior	0.129	3.275	0.001	0.049	0.824	0.41
Environmental awareness x Personal attitude -> Quantity of food	0.051	1.086	0.277	0.071	1.359	0.174
	0.232	4.311	<0.001	0.132	2.914	0.004*

Table 25 Multigroup Analysis

Source: Own construction

(2) Heterogeneity level analysis of environmental awareness and excessive food consumption and storage behaviors

Through comparative analysis of the heterogeneous grouping results of Chinese and European groups, there are differences in the negative impact relationship between environmental awareness and excessive food consumption and storage behaviors among Chinese and European groups, and among Chinese respondent groups, the predicted impact relationship level of environmental awareness and excessive consumption and food storage behavior is -0.315 ($p < 0.001$). In the European group, the predicted impact relationship level of environmental awareness and excessive consumption and food storage behavior is -0.271 ($p < 0.001$). Compared with the European group, the Chinese group is more resistant to excessive food consumption and storage based on their level of environmental awareness, and cherishes food resources more.

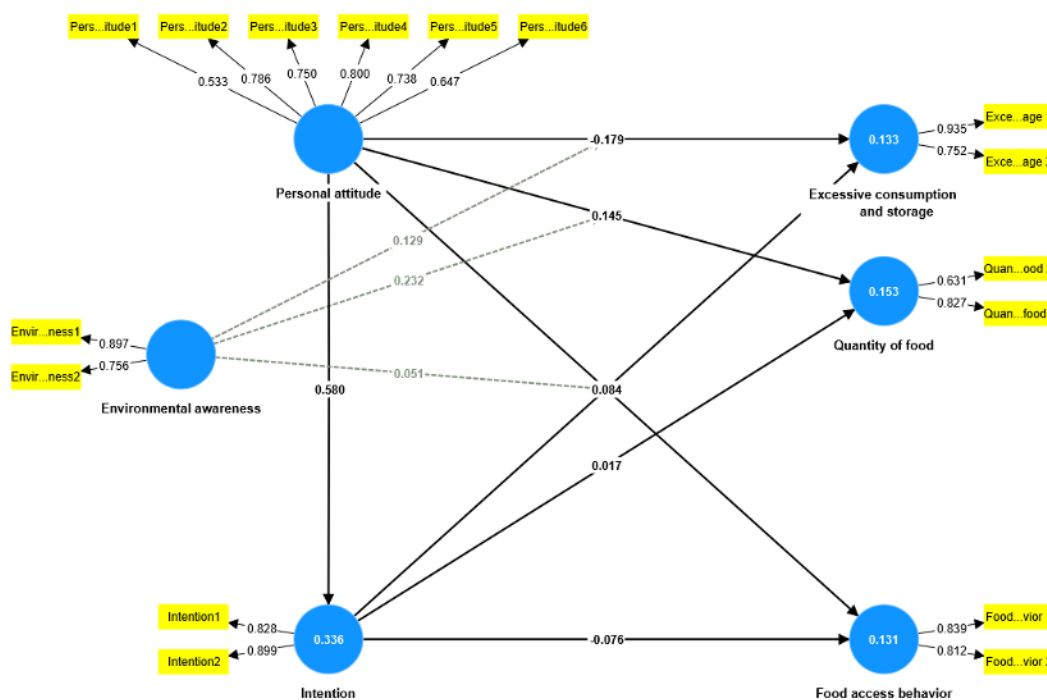


Figure 13 Path coefficient analysis for China respondents

Source: Own construction

(3) Heterogeneity level analysis of Personal (resistance to food waste) attitude and Intention (to reduce food waste)

Comparative analysis of the heterogeneous grouping results of Chinese and European respondent groups shows that there are differences in the positive relationship between personal attitude and intention in Chinese and European groups, and in Chinese respondent group, the predicted impact relationship between personal (resistance to food waste) attitude and intention to reduce food waste is 0.58 ($p < 0.001$). Among European respondent groups, the predicted impact relationship level between personal attitude and intention is 0.776 ($p < 0.001$). Compared with the Chinese respondent group, the European respondent group feels more tired or guilty about wasting food based on their personal resistance to food waste. The European respondent group has a stronger personal attitude, moreover, they are more likely to have the intention to reduce food waste, and individuals are more likely to regard food waste as a violation of environmental and social responsibilities, thus triggering stronger feelings of guilt and fatigue. mood.

(4) Heterogeneity level analysis of personal (resistance to food waste) attitudes and the amount of food waste

Through comparative analysis of the heterogeneous grouping results in China and Europe, there are differences in the positive relationship between personal (resistance to food waste) attitude and the amount of food waste among the Chinese and European respondent groups, and in China, the predicted impact relationship between personal attitude and quantity of food waste is 0.145 ($p > 0.05$). In the European respondent group, the predicted impact relationship between Personal attitude and Quantity of food is 0.546 ($p < 0.001$). Compared with the Chinese respondent group, the European respondent group has a direct impact on quantity of food waste based on personal (resistance to food waste) attitude. The stronger the personal (resistance to food waste) attitude, the proportion of food wasted per week will be lower.

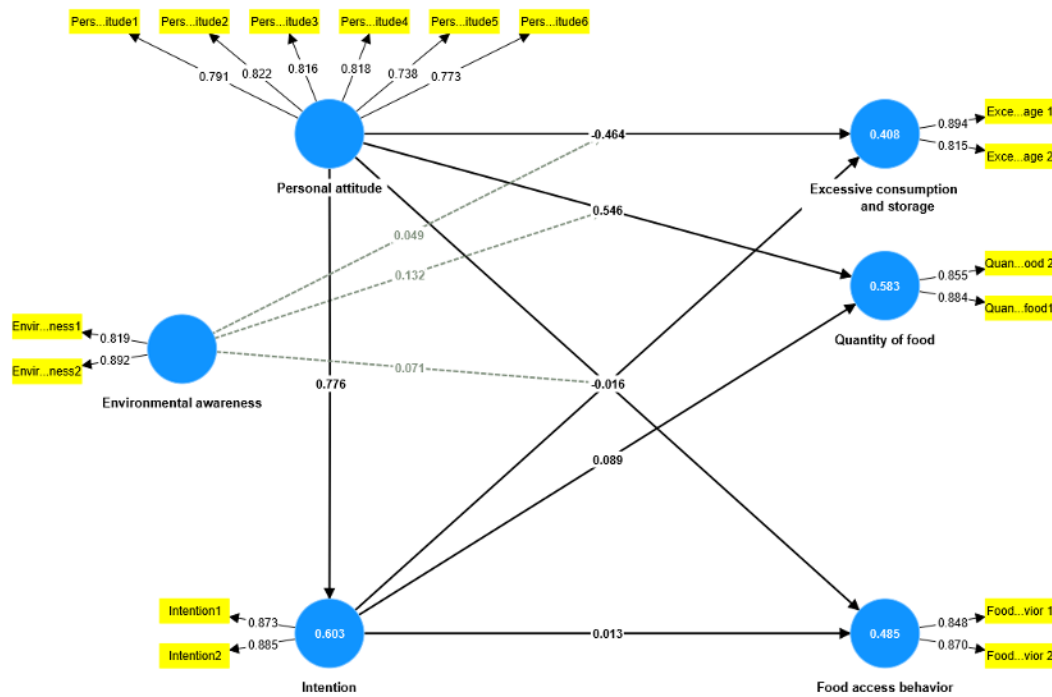


Figure 14 Path coefficient analysis for EU respondents

Source: Own construction

4.5. Food attributes and causes of food waste

By analyzing the causes of food waste among Chinese and European interview groups based on food attributes, it can be seen that there are some significant differences in the causes of food waste between the two places. Among Chinese respondents, food spoilage is considered the main reason, accounting for 62.676%. This may reflect certain deficiencies in food storage and management among some domestic consumers, which results in food spoiling prematurely and being wasted. In contrast, among European respondents, food spoilage is also an important reason, accounting for 85.874%. This may be due to the fact that some European families pay more attention to fresh ingredients, but it may also be related to excessive purchasing or unreasonable storage.

Item	Area (%)		Total (n=872)
	China (n=426)	Europe	
Food spoilage	267 (62.676)	383 (85.874)	650 (74.541)
Food expired	204 (47.887)	205 (45.964)	409 (46.904)
Food not tasty	205 (48.122)	264 (59.193)	469 (53.784)
other	45 (10.563)	17 (3.812)	62 (7.110)
Chi-Square Test: $\chi^2=27.231$ p=0.000			

Table 26 proportion of reasons for food waste generation among surveyed China and EU respondent group

Source: Own construction

In addition, European respondents pay more attention to the freshness and shelf life of food, and have higher requirements for food quality. This may be closely related to consumer culture and food safety awareness in Europe. They are more inclined to choose higher quality food and pay more attention to the freshness of food, so they have stricter requirements for the shelf life of food. The relatively low proportion of Chinese respondents in this regard may reflect that some Chinese consumers pay less attention to food quality and freshness when purchasing and eating food, and do not strictly manage the shelf life of food.

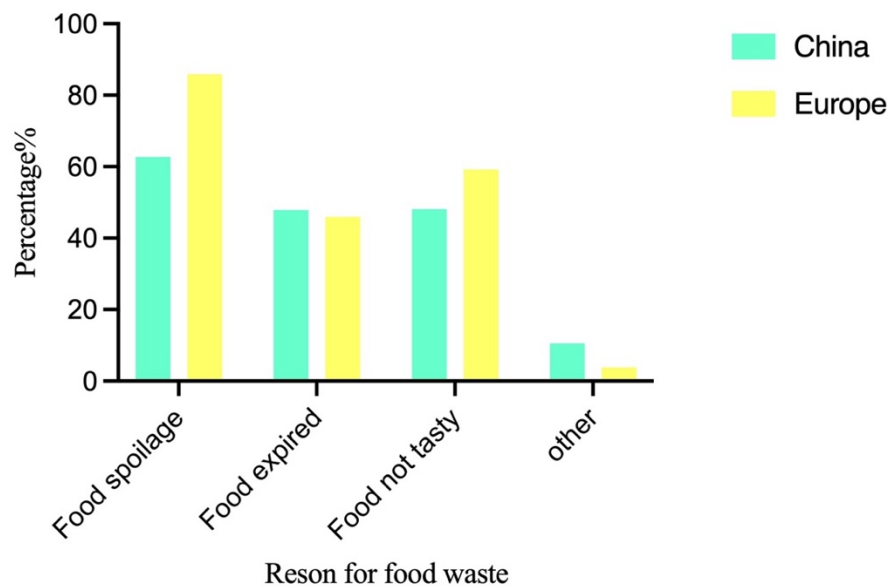


Figure 15 Proportion of food waste generation among China and EU respondent group

Source: Own construction

In addition, when it comes to food expiration, there is not much difference in the proportion of respondents from the two places. However, when it comes to poor food taste, the European group has a significantly higher proportion of reasons than Chinese respondents. This may reflect that European consumers pay more attention to the taste and quality of food and are more reluctant to eat food with poor taste, making it easier to waste food.

In general, Chinese respondents are more likely to waste food due to spoilage, while European respondents pay more attention to food taste and freshness. This reflects the cultural differences and consumption habits of consumers in different regions in food waste behaviors, and also reminds us that we need to take regional characteristics and consumer needs into consideration when formulating strategies to reduce food waste. Therefore, formulating targeted food waste reduction policies and measures for consumers in different regions can help reduce the occurrence of food waste more effectively.

4.6. Hypothesis testing

872 valid questionnaires were analyzed and it has good reliability and validity. Several hypotheses were tested after exploring the impact of consumers' attitudes toward food waste behavior, intention to reduce food waste, and environmental awareness on their behavioral performance. Through investigation and analysis of Chinese and European interview groups, the following conclusions are drawn:

Hypothesis	result
Hypothesis 1: Consumers' personal attitude towards reducing food waste is related to different food waste behaviors.	proved
Hypothesis 2: There is a correlation between consumers' intention to reduce food waste and food waste behavior.	rejected
Hypothesis 3: High environmental awareness has a positive and significant effect on personal attitude and food waste behavior	proved
Hypothesis 4: Religiosity is relevant to food waste reduction behaviors.	rejected
Hypothesis 5: The Chinese respondent group has a higher positive impact of personal environmental awareness on food acquisition behavior than the European respondent group.	proved
Hypothesis 6: In terms of food attributes, European respondents are more concerned about whether food has spoiled than Chinese respondents.	rejected
Hypothesis 7: Factors such as supply chains, retail links, and food donation policies in the food system will influence consumer food waste.	proved

Table 27Hypothesis check

Source: Own construction

5. Discussion

Through this work exploration, we found that food waste can be attributed to internal factors, that is, problems in the food system itself, such as production supply chain packaging and storage, retail links, food spoilage, food excess in the catering industry, etc.; as well as external factors, such as natural, political, economic or socio-cultural factors and environmental factors.

The distribution of demographic variables (gender, age, education, religious beliefs, living environment, income level, etc.) in the questionnaire was analyzed into six different dimensions of food waste: excessive consumption and storage, amount of food waste, personal resistance to food waste, and food reduction. Difference analysis was conducted on waste intention, food access behavior, and environmental awareness, and it was found that there were significant differences in excessive consumption and storage, food access behavior, and environmental awareness in different demographic variables (except gender). This provides us with a basis for formulating targeted management strategies. Therefore, governments, enterprises and all parties in society can formulate corresponding policies and projects based on the characteristics of people from different backgrounds to minimize food waste and improve resource utilization efficiency, thereby achieving the goal of sustainable development.

We analyzed the causes of food waste in China and Europe respectively. Environmental awareness and personal attitudes have a significant impact on food waste behavior at different levels. Among them, respondents from China are more significantly affected by environmental awareness, and respondents from Europe are more significantly affected by their personal attitudes. Our overall analysis of the respondents in the two regions found that environmental awareness has a significant impact on food access behavior and excessive consumption and storage of food behaviors ($p < 0.001$); while personal attitude has a significant impact on food access behavior, excessive consumption and storage, and the impact of waste quantity is significant; however, the impact of intention is not significant in this analysis and does not constitute a direct impact. This may be because although people may have the intention to reduce food waste, they use and reduce food waste, but this level of intention does not directly

translate into actual behavioral impacts. There may be other factors or mechanisms such as habits, social pressure, economic factors, etc. This also enlightens us that when designing interventions to reduce food waste, we need to consider the complex factors behind individual behaviors and adopt comprehensive strategies to guide individuals to change their food waste behaviors, thereby achieving more efficient use of food resources and reducing waste. Environmental awareness plays a mediating role between personal attitude to food waste and food waste behaviors. Specifically, increasing environmental awareness can strengthen personal resistance attitudes and reduce food waste behaviors. This moderating effect further highlights the importance of personal attitude and environmental awareness in shaping food waste behavior, while also highlighting individuals' concern for the environment and cherishing resources. Interestingly, after analyzing the questionnaire results, we found that although the impact of religious beliefs on food waste behavior has been mentioned in many literatures, our research results show that religious beliefs do not have a significant impact on food waste behavior.

In addition, we have found that there are differences in the impact of personal attitude and environmental awareness on behavior among Chinese and European groups, which may be related to differences in regional culture and policy environments. In terms of analysis of the causes of food waste at the level of food expense attributes, Chinese respondents are more likely to waste food due to spoilage, while European respondents pay more attention to the taste and freshness of food. This reflects the cultural differences and consumption habits of consumers in different regions in food waste behaviors, and also reminds us that we need to take regional characteristics and consumer needs into consideration when formulating strategies to reduce food waste.

The effective management of food waste is an extremely complex and wide-ranging issue that requires the participation of all sectors of society. We are faced with many challenges in food waste management and require comprehensive measures to solve them. Detailed measurement of the extent of food waste along the food supply chain can help us design effective responses to reduce food waste. Due to standardization of measurement methods and data collection has not been fully achieved, we don't know enough about the extent of food waste. The introduction of new technologies and tools,

such as the use of blockchain technology to track food supply chains, can be an important tool to address the challenge of measuring food losses in real-time on a commodity-specific basis (Antonucci et al., 2019). Strengthening the measurement and data collection of food waste and adopting more accurate and comprehensive methods to improve the reliability and transparency of data are a major future research direction.

Additionally, the overall food system and cost-effectiveness evaluation of interventions to reduce food waste is a challenge, and understanding how food waste relates to the overall food system is critical (Cattaneo et al., 2021). How food waste reduction at one stage of the food value chain affects market conditions upstream and downstream in the supply chain. When designing policies, the interactions and impacts of food waste with the overall food system need to be considered. Whether food waste is targeted specifically or as an ancillary goal of wider policies to improve the efficiency and sustainability of the entire system is critical to developing effective strategies. Therefore, a better understanding of the impact of food waste management on food safety and the private benefits and costs is a key element for policy as well as technology implementation. Whether food waste is targeted specifically or as an ancillary goal of wider policies to improve the efficiency and sustainability of the entire system is critical to developing effective strategies. Different policies and measures can have complex impacts that require comprehensive consideration of losses, waste and possible environmental and economic impacts.

Finally, there is the challenge of identifying and managing different levels of participants. Different participants are involved in all aspects from production to consumption, and their behaviors and decisions directly affect the occurrence and extent of food waste. Farmers, producers and suppliers face many challenges on farmland and in the production chain, such as seasonal yield fluctuations and transportation losses. They need to consider factors such as market demand, supply chain reliability and cost-effectiveness. Therefore, in order to effectively manage food waste, producers need to be identified and worked with to encourage them to take measures to reduce loss and waste in the production process. Secondly, middlemen and retailers in the supply chain are also important players. Their inventory management, purchasing decisions and sales strategies directly affect the occurrence of food waste. Faced with uncertainty and

demand fluctuations in the supply chain, middlemen and retailers need to develop more flexible and sustainable inventory management policies to reduce food waste caused by over-purchasing or unreasonable promotions. Additionally, consumers play a crucial role in food waste management. Their purchasing behavior, food storage and handling habits directly affect the lifespan and waste level of food. Therefore, there is a need to strengthen consumer education and awareness-raising to encourage them to adopt more frugal and sustainable consumption habits and reduce unnecessary food waste.

6. Conclusion

This study uses secondary literature and some official surveys to analyze the current status of food waste management in China and Europe, as well as the causes of food waste in food systems and innovative ways to reduce food waste. Secondly, primary data were collected mainly through questionnaires (see Appendix 1), and convenient online sampling techniques were used for data collection. Participants in China and Europe were surveyed on the causes of food waste. The aim is to understand the attitudes of Chinese and European citizens towards food waste at an individual level and to explore the causes of food waste.

After surveying Chinese and European consumers, this paper found that personal attitude and environmental awareness play a key role in the food waste problem. Personal attitude has a negative relationship with food waste behavior, and environmental awareness plays a moderating role in the relationship between personal attitude and food waste behavior. Consumers with a high degree of environmental awareness are more likely to take actions to reduce food waste. In addition, regional culture also produces differences in individual food waste behaviors and personal attitudes, so it is particularly important to formulate policies and measures to reduce food waste in different regions. There is no direct correlation between intention, cultural and religious beliefs and food waste behavior, which requires further in-depth research in the future. In addition, after exploring through the literature review, it was found that innovation in food waste management requires social innovation and technological innovation to be promoted together. Mainly including using technology to improve supply chain management, increasing consumer awareness, adopting sustainable production and packaging methods, etc.

In summary, food waste management involves multiple challenges, including shortcomings in measuring the extent of food waste, the complexity of overall food system assessments, difficulties in assessing the cost-effectiveness of interventions, and the identification and management of different actors. Addressing these challenges requires interdisciplinary collaboration, policy innovation, and social consensus to promote more efficient food resource utilization and waste reduction goals. Through collaboration and innovation, we can gradually reduce food waste and promote sustainable food production and consumption patterns.

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ANNEXES 1

Questionnaire for food waste management.

This questionnaire was conducted separately for the respondents living in China, Europe and other countries. And there are two different languages, Chinese and English.

论文调查问卷/**Thesis survey**

在个人层面食物浪费的原因及驱动因素的探究。An exploration of the causes and drivers of food waste at an individual level.

您好，我是一名在匈牙利在读的研究生，我的论文是关于在个人层面食物浪费的原因及驱动因素的探究，恳请您用几分钟时间帮忙填答这份问卷。本问卷实行匿名制，所有数据只用于统计分析，请您放心填写。题目选项无对错之分，请您按自己的实际情况填写。非常感谢您的帮助。

Hello, I am a student studying in Hungary. My graduation thesis is about exploring the causes and driving factors of food waste at the individual level. Please take a few minutes to help fill in this questionnaire. This questionnaire is anonymous and all data will only be used for statistical analysis. Please feel free to fill it out. There are no right or wrong question options. Please fill in the questions according to your actual situation. Thank you for your help.

1. 您的现居住国家或地区/Your current living country or region: *

☐ 中国/China

☐ 欧洲/EUROPORE

☐ 其他: Others: _____ *

2. 年龄/Your age: *

☐ <20

☐ 20-29

☐ 30-39

☐40-49

☐50-59

☐ >59

3.性别/Your gender: *

☐Female/女性

☐Male/男性

☐Prefer not to say/保密

4.学历/Your highest education: *

☐Illiterate/文盲

☐primary/初级

☐Intermediate/中级

☐University degree/大学

5. What is your religious affiliation,if any?/您是否有宗教信仰

☐Buddhism/佛教

☐Christianity/基督教

☐Islam/伊斯兰教

☐Hindusim 印度教

☐Other/其他: _____

☐No religious affiliation/无宗教信仰

6. What best describe your current living environment/最能描述您目前居住环境的是? :

☐ Metropolitan city/大都市城市

☐ Suburban area/郊区

☐ Small town/小城镇

☐ Rural area/乡村

7. What is the type of the family and your status!/? 您的家庭状况或结构是以下哪种类型?

A. Single, living alone/单身, 独自居住

B. married /已婚, 有配偶

C. Have a partner, but not married/有伴侣, 但未婚

D. Nuclear family (parents and children) /核心家庭 (父母与子女)

E. Extended household (living with other relatives) /扩展家庭 (与其他亲属同住)

F. one-parent family/单亲家庭

G. Sharing or living together/合住或共同居住

H. Others _____ (please specify) /其他_____请注明)

8. How many people are there in your household, including yourself?/? 您的家庭有多少人, 包括您自己? (Open-ended: _____人)

9. What is the primary source of income for your household?/? 您家庭的主要收入来源是什么? (Multiple choices:

☐ Employment/就业

☐ Business/经商

☐ Agriculture/农业

☐ Other/其他: _____

☐ No primary income source/没有主要收入来源)

10. What is your approximate annual income range?/? 您的年收入大致在哪个范围内? (Multiple choices:

☐ Below €5,000/人民币 5 万以下

- ☐ €5,000- €15,000/人民币 5 万 - 10 万
- ☐ €15,000 - €40,000/人民币 10 万 - 30 万
- ☐ Above €40,000/人民币 30 万以上
- ☐ Prefer not to say/不愿透露)

11. How would you describe the overall economic status of your household?/ 您如何描述您家庭的整体经济状况?

- ☐ Low income/低收入
- ☐ Middle income/中等收入
- ☐ High income/高收入
- ☐ Prefer not to say/不愿透露)

12. How often do you buy food?/您购买食物的频率?

- ☐ Buy every day/每天
- ☐ Buy once a week/一周一次
- ☐ Purchase once a month/一月一次
- ☐ Purchase less frequently/不经常买
- ☐ Never buy/从不购买

13. Do you regularly buy more food than you need?/ 您是否经常购买超出需要的食物?

- ☐ Often exceeds demand/经常超出
- ☐ Sometimes more than needed/有时超出
- ☐ Moderately exceeding needs/适度超出
- ☐ Rarely more than needed/很少超出
- ☐ Never exceed needs/从不超出

14. When you buy food, would you rather buy --?/当您买食物时，你更愿意买——?

- Strongly prefer large packaging/非常偏好大包装
- Prefer large packaging/偏好大包装
- It doesn't matter/不在意
- Prefer small packages/偏好小包装
- Strong preference for small packages/非常偏好小包装

15. Have you ever saved food only to end up not using it?/ 您是否曾经节省食物却最终不使用它？

- Very often/非常频繁
- Often/经常
- Moderate/适度
- Rare/很少
- Never happens/从不发生

16. How much food do you have waste each week?/ 您每周浪费多少食物？

- <500g
- 500-1,000g
- 1,000-5,000g
- >5,000g

17. What percentage of total food do you waste each week? /您每周浪费的食物总量占多少百分比？

- 0-25%
- 26-50%

○51-75%

○76-100%

○No food wasted/没有食物浪费

18.Do you often cook more to get more food than you and your guests can eat?/ 您是否经常做更多的食物来获得比您和您的客人能吃的更多的食物?

○Often/经常如此

○Sometimes/有时候会

○Occasionally/偶尔如此

○Rarely do this/很少如此

○Never do this/从不这样做

19. How much food do you waste during cooking?/ 您在烹饪过程中浪费了多少食物?

○Rare/很少

○Less/较少

○Moderate/适中

○More/较多

○Wasting a lot or not cooking/大量浪费

○Not cooking/不做饭

20. multiple choice/多选题: You waste food because:/ 您浪费食物是因为:

○Food spoilage/食物变质

○Food expired/食物过期了

○Food not tasty/食物不好吃

○Others, ____/其他____

21. In your opinipn,food wast is : ____/ 在您看来食物浪费是一种____

○Absolutely not/完全不应该

○Sometimes it should/有时候应该

○Occasionally should/偶尔应该

○Totally should/完全不应该

22.Do you feel unhappy when uneaten food is thrown away? 当没吃完的食物被扔掉时，你会感到沮丧吗？

○Often feel unhappy/经常感到不快

○Sometimes feel unhappy/有时候感到不快

○Rarely feel unhappy/很少感到不快

○Never feel unhappy/从不感到不快

23.Throwing away food affect you?/ 扔掉食物不会影响你吗？

○Often have an impact/经常有影响

○Sometimes it has an impact/有时候有影响

○Little impact/很少有影响

○Never affected/从不有影响

24.Are you concerned about food waste? /您会关心食物浪费吗？

- Very concerned/非常关心
- Sometimes concern/有时候关心
- Little concerned/很少关心
- Don't care much totally/完全不在意

25.Would you like to proactively learn about food waste?/ 您想主动了解食物浪费吗?

- Very willing to learn more about/非常愿意深入了解
- Willing to know something/愿意有所了解
- Sometimes follow/有时会关注
- Little attention/很少关注
- Not willing to understand at all/完全不愿意了解

26.Do you think food waste awareness campaigns influence your decision-making?/ 您认为食物浪费意识活动会影响您的决策吗?

- Often influence decisions/经常对决策产生影响
- Sometimes it has an impact/有时会有影响
- Rarely affects decision-making/很少影响决策
- Never influence decisions/从不影响决策
- Uncertain/不确定

27. Do you know that food waste is bad for the environment?/ 您知道食物浪费对环境有害吗? (add: approximately 35-45% of food we loose, and food waste in the case of

individual consumers can be 15-25%!) / (补充：我们损失的食物大约有 35-45%，而个人消费者的食物浪费可能达到 15-25%!)

○Fully understand the hazards/完全了解危害

○Have some understanding/有一定了解

○Know little about/了解很少

○Don't understand at all/完全不了解

○Uncertain/不确定

28. Does your culture or religious belief prohibit food waste?/ 您的文化或宗教信仰禁止食物浪费吗？

○Totally prohibited/完全禁止

○Sometimes it is emphasized that prohibition/有时候强制禁止

○Less emphasis on prohibition/不太强调

○No emphasis on prohibition at all/w 安全不强调

○Not applicable/no religious affiliation/不适用/无宗教信仰

29.Does your culture or beliefs influence your food choices and attitudes?/ 您的文化或信仰会影响您的食物选择和态度吗？

○full impact/完全影响

○Have a certain impact/有一定影响

○Not much impact/不太影响

○Doesn't affect at all/无安全不影响

○Not applicable/no religious affiliation/不适用/无宗教信仰

30. Have you ever proactively thought about how you use food in your daily life and reduce food waste?/ 您是否曾主动思考过自己在日常生活中对食物的使用，以及是否减少食物浪费？

○Yes, I often reflect and make an effort to take measures to reduce food waste./ 是，我时常反思，并努力采取措施来减少食物浪费。

○Yes, I occasionally think about it but haven't taken specific actions/是，我偶尔会考虑，但并未采取特别的行动。

○No, I rarely think about or pay attention to my food waste behavior./ 否，我很少思考或关注自己的食物浪费行为。

○No, I have never specifically paid attention to or reflected on my use and waste of food in daily life./ 否，我从未特别关注过或反思过自己在日常生活中对食物的使用和浪费。

○Uncertain/不确定

31. Are you tired or guilty of wasting food?/ 您是否感到疲倦或因浪费食物而感到内疚？

○Often feel/经常

○Sometimes feel/有时

○Rarely feel/很少

○Never feel/从不

○Uncertain/不确定

32.Are there any specific strategies or habits that help you reduce food waste?/ 您有具体的策略或习惯可以帮助您减少食物浪费吗?

○Very much/非常有

○There are some/有一些

○There is a little/有少许

○No/没有

○Uncertain/不确定