


Review

Research Hotspots, Research Frontiers, and Management Significance: A Bibliometric Analysis and Review of Global Food Waste of Students Research Based on CiteSpace

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Abstract: Reducing food waste in the student population is important for promoting sustainable economic, social, and ecological development. In this paper, with the help of CiteSpace software (versions 6.1.R6 and 6.2.R4), we visually analyze the literature related to the food waste of students in the WoS core collection database. It is found that (1) scholars are paying increasing attention to the field of student food waste research, with the United States being the country with the largest total amount of research in this field, the greatest academic influence, and the most frequent cooperation with other countries. (2) Research in this field can be broadly divided into three phases: the starting period (2000–2010), the exploration period (2011–2015), and the development period (2016–2023). The research on student food waste involves multiple fields of knowledge, such as statistics, behavior, psychology, management, nutrition, etc. It is divided into three research hotspots, namely student food waste quantity measurement, student food waste influencing factors, and student food waste behavioral interventions, as well as three cutting-edge themes, namely student food waste in developing countries, student food waste and dietary intake and nutritional health, and student food waste from the perspective of behavioral science. (3) Scholars from different countries/regions have different research focuses. Research in the United States focuses on the development of student food waste interventions and the investigation of students' and teachers' knowledge, attitudes, and barriers to intervention in student populations; European scholars focus on researching this area from a behavioral perspective; developing countries in Asia focus on quantifying the level of food waste among college students and exploring the impact of demographic factors on student food waste; and developed countries in Asia focus on surveys of teachers, dietitians, and other parties to explore the impact of food education on food waste and propose food education interventions based on the recommendations of various parties. Based on the above findings, future research directions are proposed to provide references for subsequent research on food waste among students.



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1. Introduction

Saving food and reducing food waste are not only effective ways of ensuring food security, relieving pressure on resources and the environment, avoiding economic losses, and fostering a good social atmosphere, but also inevitable requirements for building a green lifestyle and an ecological civilization, holding great significance in promoting the sustainable development of the economy, society, and the ecological environment. In recent years, natural disasters and the impact of the COVID-19 pandemic have adversely affected global food security. Statistics from the Food and Agriculture Organization of the United Nations (FAO) show that about 783 million people were in a state of hunger globally in 2022, amounting to one-ninth of the global population [1]. By 2050, the global population is

expected to reach 9.8 billion, and the current global food production will need to increase by 50–70% to feed this growing population [1]. However, against this backdrop, 1.3 billion tons of food is still wasted globally each year, representing one-third of total food production [2]. The United Nations reported in 2021 that the weight of global food waste from households and the retail and food service sectors was about 931 million tons, accounting for 17% of total global food production, with an estimated 79–118 kg of food waste generated per capita per year [3]. Studies have shown that food waste has a significant negative impact on ecological and economic sustainability, contributing to large carbon, water, and ecological footprints, generating about 8% of the global greenhouse gas emissions annually [4] and causing direct economic losses of about USD 1 trillion per year globally [5].

Against the backdrop of this global food waste situation, the situation regarding the food waste produced by the student population is also not optimistic and has attracted much attention from scholars [6]. According to the survey results, the amount of food wasted in the United States is about 90 billion pounds per year, accounting for 40% of its total food supply [7]. The average American college student wastes 88 g of food per meal [8], and each American student loses 1200–1400 calories of energy and 33 g of protein per day due to food waste [9]. In Europe, the level of food waste varies from country to country, but the overall level of food waste remains high. In France, the average weight of food wasted per student per meal is 70 g [10]; in Sweden, the average weight of food wasted per student per meal in student canteens is 75 g, which is equivalent to 23% of the total lunch supply in school canteens [11]; in Italy, the total food wasted by students accounts for about 20–29% of the total weight of food [12,13]. Among developing countries in Asia, about 19% of edible food in China is wasted at the consumption stage, with an annual economic loss of USD 188.48 per capita due to food waste [14]. The annual amount of food waste produced by Chinese urban residents is equivalent to about $440 \times 10^8 \text{ m}^3$ of water resources and $460 \times 10^4 \text{ hm}^2$ of land resources [15]. Chinese college canteens produce about 1.74 million tons of food waste annually, generating 195.8 million m^3 of biomethane [16]. The per capita food waste per meal produced by Chinese college students is 67.55 g, with a per capita waste rate of 14.54%. The foodstuffs with the top three waste rates are vegetables (16.79%), rice products (14.54%), and soybean products (13.25%), and those with the top three waste amounts are pasta (43.03 g), rice products (33.99 g), and vegetables (31.07 g) [17]. In Vietnam, the average amount of food wasted per student at lunchtime is 23% of the total food (about 85 g), which is estimated to be the equivalent of about 15.3 kg of food per person per school year [18]. Among the developed countries in Asian, Japan wastes 6.43 million tons of food per year, which is equivalent to 1.7 times the amount of food aid provided by the World Food Programme (WFP) in 2016 (about 3.8 million tons) [19]; in terms of student food waste, the amount of food wasted by students in Japan accounts for about 6.9% of the total amount of food [20]. There are few recent surveys and studies on the status of food waste in Africa. Some studies show that the per capita food waste in sub-Saharan Africa is 6–11 kg per year [4]; for food waste in the student population, researchers measured the food waste in the canteen of Rhodes University in South Africa and found that each student produced about 555 g of food waste per day [21].

According to UNESCO statistics, in 2022, the proportion of students worldwide in relation to the total global population reached 33.4%, comprising one-third of Earth's total population, which indicates that against the backdrop of serious food waste around the world, the total amount of food waste produced by the student population is huge, having a huge negative impact on the sustainable development of the economy, society, and the ecological environment, and thus the serious problem of food waste produced by the student population needs to be solved urgently. At the same time, students are in a critical period for their consumer behavior formation, and thus strengthening the study of food waste in students not only helps to cultivate students' good eating habits but also plays an important role in the establishment of young students' values and the formation of good social customs. At present, international political and academic circles have paid extensive attention to food waste, and the research contents focus on the measurement of the food

waste level of residents, the analysis of food waste influencing factors, and other aspects, and some of the literature has reviewed and analyzed the food waste measurement and assessment methods, the driving mechanisms and so on [22,23]. The research perspectives and results are relatively rich, and the number of studies is growing rapidly. However, a comprehensive and systematic compendium of research on student food group waste has not yet been established. Therefore, in this paper, we use CiteSpace scientometric software to systematically sort the literature related to student food waste and visually present the research hotspots and cutting-edge distributions in this field, with the aim of providing references for the subsequent research on student group food waste. Based on this purpose, we designed the questions addressed in this paper as follows:

- What are the publication trends in the field of food waste in student populations, the countries/regions where the articles are published, and the overall historical process of research in the field?
- What are the research hotspots in the field of food waste in the student population? What are the main research areas in each country/region?
- What are the frontiers of research in the field of food waste in student populations?

2. Research Methodology

Bibliometrics and visual analytics allow for a more comprehensive and objective analysis of the literature. With the rapid growth in the number of studies in the field of food waste in student populations, the one-sidedness of the systematic literature review method of summarizing the current state of research through a subjective approach is increasingly apparent. In order to ensure the scientific validity of our research review, this paper used econometrics and knowledge mapping methods to analyze and visualize the research field of food waste in student populations and to systematically describe the current situation regarding the research field of food waste in student populations around the world [24].

2.1. Use of Scientometric Analysis Software

The Web of Science Core Collection Database (WoSCC) is recognized by scholars as a high-quality bibliographic database. It is the best database for bibliometric analysis [25]. In order to present more comprehensive results of econometric analysis, taking into account the quality of the literature and other factors, this paper took the abstract-type database WoS Core Collection Database as the data source.

CiteSpace is a Java-based application for visualizing and analyzing the hotspots and research frontiers of the scientific literature in a discipline or field of knowledge over a certain period of time through econometrics, co-occurrence analysis, and cluster analysis [26]. In this paper, we used the CiteSpace (versions 6.1.R6 and 6.2.R4) visual analysis tool to visualize and map the literature information, analyze the current research status in this field, and provide suggestions and prospects for future research. In the mapping, N denotes the number of network nodes, E denotes the number of connections, Density denotes the density of the network, and Modularity is the evaluation index of network modularity (the larger the value of Modularity Q , the better the clustering effect of the network, and a value of Modularity $Q > 0.3$ indicates that the obtained network association structure is significant) [26]. The color and size of the nodes represent different citation years and the number of citations. Word frequency refers to the number of times a word appears in the analyzed literature—the greater the word frequency, the larger the node, reflecting the core research hotspots in the field [27]. The Burst function of the CiteSpace software can indicate the situation that the frequency of the use of titles, abstracts, and keywords in a short period of time presents explosive growth, and the high-intensity emergent keywords represent the academic frontier and hotspots within a certain period of time.

2.2. Data Collection and Exclusion

In this paper, meta-analysis (PRISMA) [28] was used for data collection in order to obtain scientifically high-quality literature studies. The specific process is shown in Figure 1.

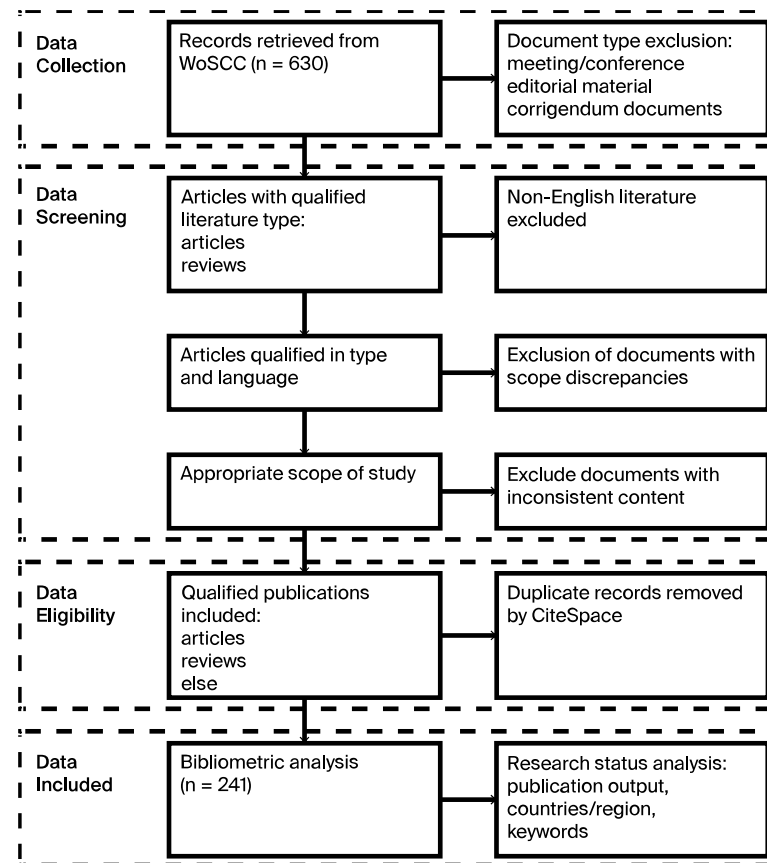


Figure 1. Data collection process.

In order to encompass a more comprehensive breadth of the literature, the search formula was set as subject = “students or adolescents” AND “food wast* or (leftover food or wast*)”, where “*” indicates the inclusion of all waste-related words such as waste, wasting, wastage, etc., to ensure complete search coverage. The search found that scholars focused on food waste in the student population after 2000, so the time span was set from 1 January 2000 to 31 December 2023. As of 27 January 2024, a total of 630 articles were retrieved.

In order to improve the quality of the analyzed literature, we screened the 630 documents retrieved from WoSCC according to the following steps:

- Literature type screening: taking into account the credibility of the academic literature and the depth of research, we excluded works other than articles, review articles, and papers in press.
- Language selection: CiteSpace requires consistency in the language of the literature in the database to ensure the degree of accuracy in the co-citation analysis and other aspects. Therefore, we excluded non-English studies.
- Scoping of the study: as the study area was food waste in the student population, we included studies from disciplines such as management, consumer behavior, and food engineering related to food waste in order to collect research from different disciplinary perspectives on a variety of topics related to the quantitative assessment of food waste in the student population, the development of interventions, valuation, and recycling, and many other aspects of food waste.
- Review of study titles and abstracts: we excluded articles that were clearly less relevant to the field of food waste in the student population by reading the study titles

and abstracts. During the exclusion process, since we could not accurately obtain a definitive answer as to whether to keep the article or not just by reading the study title and abstract, we scored the article (2 = definitely keep, 1 = unsure about keeping, 0 = definitely do not keep) once we understood its content. The researcher would discuss the articles with a score of 1, and if the discussion still resulted in disagreement, the article was excluded. During this process, it was kept in mind that the main focus of the study was food waste in the student population in order to more accurately exclude all articles that did not fall within the scope of this research area.

- Software de-duplication: duplicates among the remaining studies were de-duplicated using CiteSpace. Finally, 241 eligible articles were obtained.

2.3. Data Analysis

The 241 studies collected during the above process were imported into CiteSpace, and the mapping parameters were adjusted according to the clarity and readability of the spectrograms. In the CiteSpace graphs, N denotes the number of nodes, the size of the nodes reflects the citation or frequency of occurrence of the data involved, and the lines between nodes indicate the existence of connections between nodes. In order to systematically describe the current state of research in the field of food waste in the student population, this study analyzed the following four main areas.

- Basic situation analysis of the research field of food waste in the student population. We statistically analyzed the time of publication and publication trend of the literature in the field of food waste in the student population, the country/region of publication, and the overall research process in order to understand the overall overview of published articles in this field.
- Content analysis of food waste research in the student population. By constructing keyword clustering and literature co-citation analysis mapping, we summarized the hot topics of research in this field.
- Analysis of future research trends in food waste in the student population. By constructing a time-series mapping of keywords, the research frontiers (future research trends) in the field were inferred.
- Comparative analysis of research themes on food waste among students in different geographical regions. Combined with the analysis of countries/regions where the articles were published and the analysis of research hotspots and frontiers, we compared and analyzed the similarities and differences in the themes in the field of research on food waste in student groups in different countries/regions, so as to present the current status of the research themes in this field more clearly and comprehensively from the viewpoint of geographic subregions.

3. Results of the Bibliometric Analysis

3.1. Publication Trends

The number of studies related to student food waste research published in international core journals from 2000 to 2023 was analyzed to obtain the overall progress of research in this field. Twenty-seven articles were published from 2000 to 2013, with an average of less than five articles per year. The number of articles began to show a general rapid upward trend in 2014, reaching a peak of 34 articles in 2021. A total of 213 articles were published during or after 2013, accounting for 88.38% of the total statistical literature (Figure 2). This indicates that more scholars have begun to pay attention to the problem of student food waste because of the increasing attention on the areas of student dietary intake and nutritional health and economic, social and ecological sustainable development.

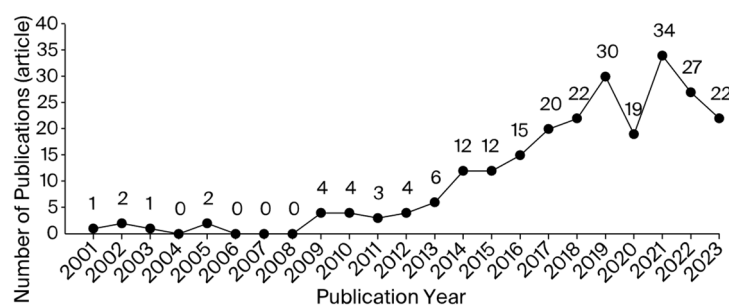


Figure 2. Annual publications in the research literature.

3.2. Areas of Issuance and Analysis

CiteSpace software is used to visualize and analyze the region of origin of published articles. Taking “Country” as the network node, the Pruning option selects Pruning sliced networks and the Minimum Spanning Tree, and the rest of the parameters are set as the default values to ensure the clarity and readability of the graphs. The graph contains 49 country or region nodes and 50 connecting lines. D (network density density) = 0.0425, the network density is high, and the cooperation between countries is relatively close. The knowledge graph is adjusted to obtain the graph of the number of articles issued by each country/region (Figure 3). The size of each node in the graph represents the number of articles published in the corresponding country/region, and the larger the node, the larger the number of articles sent.

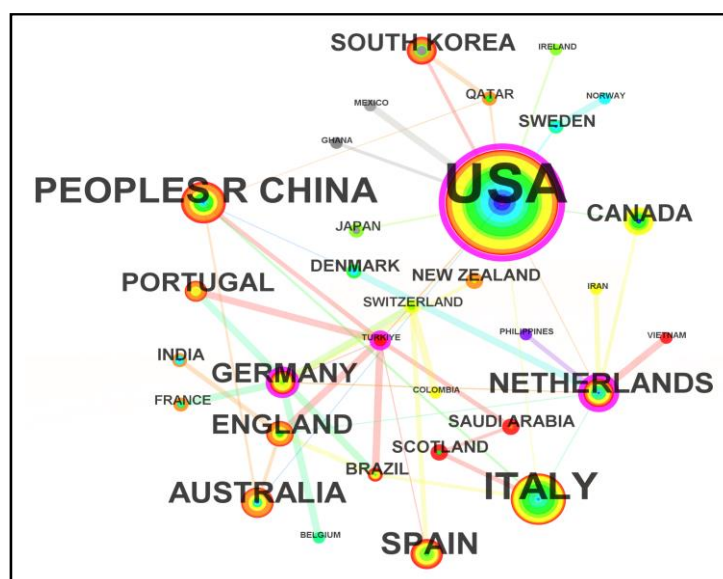


Figure 3. Overview of country/territory distribution.

We used CiteSpace’s statistical function to organize Table 1, presenting the volume and centrality of the top five countries/regions in terms of the volume of articles. Among the top five countries/regions, the United States ranked first with 110 articles, followed by China (excluding Hong Kong, Macao, and Taiwan, the same below) with 19 articles, Spain with 14 articles, Italy with 12 articles, and Australia with 9 articles. As can be seen from the comprehensive data on the number of articles and centrality, most of the developed countries/regions in Europe and the United States have a higher number of articles and centrality in this field, reflecting the fact that these countries/regions pay more attention to the food waste produced by student population, and their scientific research strengths are also stronger, forming a strong academic influence in this field.

Table 1. Top 5 Countries and regions in terms of number of articles and centrality.

Arrange in Order	Volume of Publications	Centrality	States
1	110	0.64	USA
2	19	0.09	PEOPLES R CHINA
3	14	0	SPAIN
4	12	0.05	ITALY
5	9	0	AUSTRALIA

In terms of cooperation, the connecting lines between the nodes in Figure 3 indicate the existence of cooperation between the countries/regions represented by nodes, and a higher number of connecting lines between two nodes indicates greater cooperation between the two countries. The United States, Turkey, and the Netherlands are the three countries with the most cooperation with other countries/regions, indicating that these three countries have good cooperative relationships with other countries/regions, respectively, indicating that these three countries have good cooperative relationships with more countries/regions and undertake more comprehensive and in-depth research in this field. In general, the cooperation of scholars from different countries/regions in this field is closer, laying a good foundation for more in-depth research in this field in the future.

3.3. Content of the Study

3.3.1. Trends in the Evolution of Research Content

These data were extracted by creating a data extraction form and entering data into a Microsoft Excel worksheet. The articles were categorized according to the authors of the study, the geographic region and the time of publication, and the analysis of the relevant policies enacted worldwide; the number of annual publications and keywords shows that the research in this field can be roughly divided into the starting period (2000–2010), the exploration period (2011–2015) and the development period (2016–2023).

(1) Start-up period (2000–2010)

In 1999, the UN Committee on Economic, Social, and Cultural Rights developed the concept of The Right to Adequate Food, which guides the UN's approach to global food security governance [29]. In 2000, the United Nations Millennium Declaration was issued at the Millennium Summit, calling on states to take action in areas related to poverty reduction, sustainable development, and fighting against hunger and disease [30]. Against this backdrop, food waste among students has come to the forefront, with food waste being the most important keyword at this stage, and research has focused on measuring the amount of food waste produced by students and developing interventions from the perspectives of school education, food provision, and food variety.

(2) Exploratory Period (2011–2015)

The number of articles in this phase increased steadily. The Healthy and Hunger-Free Kids Act was enacted in 2010, and the National School Lunch Program (NSLP) was implemented in the USA in 2012–2013. Influenced by these policies, a large number of European and American scholars began to quantitatively measure and comprehensively assess student food waste and explore its influencing factors from a more novel perspective. At that stage, modern technologies such as digital imaging were introduced to quantify student food waste. The keywords plate waste and school lunch began to appear. As the topics of ecological environment and sustainable development have received closer attention, academic and political circles have begun to link research in this field with ecological and environment issues. In 2013, the Food and Agriculture Organization of the United Nations (FAO) released the report “Food Waste Footprint: Impact on Natural Resources”, which, for the first time, analyzed the consequences of food waste on the climate, soil, and water use, etc., from the perspective of environmental protection. The signing of the Paris Agreement in 2015 laid down the legal basis and basic framework for a reduction in greenhouse gas emissions by the international community, directly giving rise to the goal of “carbon neutrality” at the global and national levels and providing strategic

guidance for scholars in various countries to strengthen their research on combatting food waste and to promote the sustainable development of the economy and ecological environment.

(3) Development Period (2016–2023)

In 2016, the United Nations issued the 2030 Agenda for Sustainable Development, which clearly states that reducing food waste is important for food security and that countries should take measures to prevent food waste. The issue of food security has received widespread attention due to the impact of the COVID-19 pandemic and the Russian–Ukrainian conflict. The Global Food Waste Survey Report 2021, published by Waste Watcher International Observatory, proposed a generalized approach to curbing global food waste as well as more universal interventions for student food waste interventions. During this period, scholars began to analyze the impact of mealtime emotions, Confucian culture, food-theme education, menu types, familiarity with food, and food the types of food offered on students' food waste, with a rapid increase in keywords and publications, and the trend of interdisciplinary research began to emerge, with research further deepening and refining.

3.3.2. Research Hotspots

Keyword clustering is a network cluster formed by keywords belonging to the same research topic in a research area, which can clearly present the topic categories to which the research hotspots in the area belong. CiteSpace software was used for the visualization and analysis of the issuing regions, the database time span was set as 2000–2024, and the time slice was selected as 1 year. Taking “Keyword” as the network node, in order to ensure the clarity and readability of the mapping, the threshold was set to TopN = 60, i.e., the keywords with the top 60 occurrences in a year formed the network mapping, and the rest of the parameters were set to their default values. The log-likelihood ratio (LLR) algorithm of CiteSpace was applied to generate keyword clustering labels (Figure 4) to present the distribution of hot topics of research in the field. The knowledge graph was adjusted to obtain the keyword clustering analysis visualization graph of the field (Figure 4). There are 275 keyword nodes and 541 node links in the graph; the network density is 0.0144. The Modularity Q and average profile value (S) in the graph are two indicators that can be used to test the trustworthiness of clustering; in general, clustering with a Modularity Q above 0.3 and S above 0.5 is considered reasonable, and clustering with an S above 0.7 is considered efficient and very plausible [31]. In the figure, the Modularity Q value is 0.6813, and the S value is 0.9538, which indicates that the network association structure obtained is significant and the clustering results are highly credible.

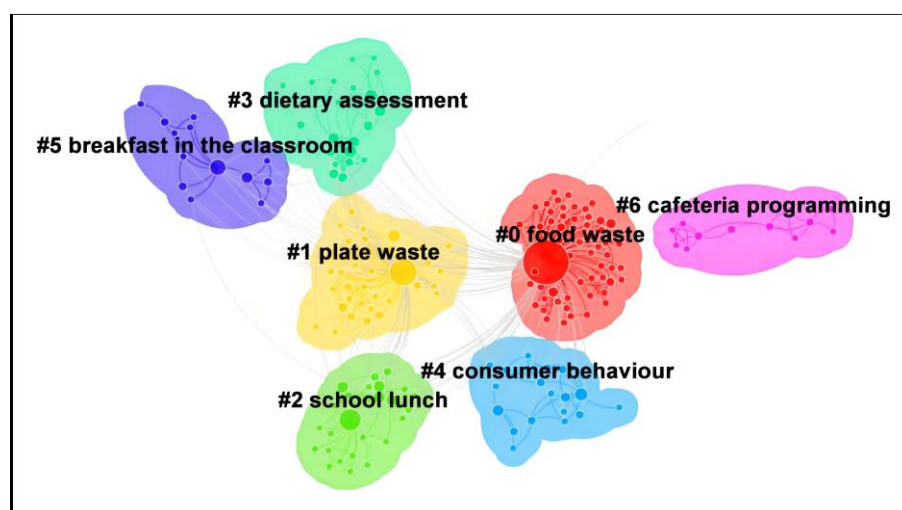


Figure 4. Keyword cluster analysis and visualization mapping.

As can be seen from Figure 4, keywords in this domain can be categorized into seven clusters, with smaller cluster labels indicating that they contain more keywords. The clusters are as follows: #0 food waste, #1 plate waste, #2 school lunch, #3 dietary assessment, #4 consumer behavior, #5 breakfast in the classroom, #6 cafeteria programming.

Co-citation analysis can present studies that contribute most to the research in this field, while co-citation emergence analysis can present the studies that experience a sudden increase in the number of citation volume in a short period of time, reflecting the works that contribute more to the field in different periods of time, thus reflecting the shift in research focus. A sudden increase in the number of co-citations of an article in a certain year indicates that it has suddenly received a lot of attention in that year.

Taking “Reference” as the network node, the statistical analysis of studies’ co-citation information was carried out on the basis of a literature co-citation analysis. In order to ensure the clarity and readability of the results, the Pruning option was set to select Pruning sliced networks and the Minimum Spanning Tree, $f(x) = \alpha e^{-\alpha x}$, $\alpha_1/\alpha_0 = 1.0$, $\gamma = 0.5$, and the rest of the parameters were set to their default values. A total of five co-cited emergent studies were obtained, as shown in Table 2.

Table 2. Top 3 studies with the highest co-citation emergence intensity.

Author	Year of Publication	Title	Citation Breakout Starting Year	Citation Breakout Termination Year	Burst Strength
Cohen JFW [32]	2013	School Lunch Waste Among Middle School Students: Nutrients Consumed and Costs	2014	2018	9.07
Schwartz MB [33]	2015	New School Meal Regulations Increase Fruit Consumption and Do Not Increase Total Plate Waste	2016	2019	6.8
Cohen JFW [34]	2014	Impact of the New US Department of Agriculture School Meal Standards on Food Selection, Consumption, and Waste	2015	2019	6.72

As shown in Table 2, the articles with the highest burst intensity were written by Cohen, JFW, and other scholars. This study was the first to quantify the nutritional loss caused by students’ food waste in a precise way [32], presenting the negative consequences on students’ nutritional intake and health. This article’s long duration of emergence from 2014 to 2018 and the difference in its emergence intensity compared with the article in second place suggests its significance in encouraging scholars to enhance research on food waste in student populations in relation to their dietary intake and nutritional health.

The article with the second highest emergent intensity was authored by Schwartz, MB, and other scholars. This study found that since the enactment of the Healthy, Hunger-Free Kids Act in 2010, main dish waste among students at mealtime has decreased by nearly 20%, and entree waste has decreased as well [33], demonstrating the important role of macro-policy interventions in reducing student food waste.

The article ranked third in terms of strength of emergence was published by Cohen, JFW. The emergence period lasted four years, from 2015 to 2019. This article found that policies dedicated to improving the quality of young people’s meals increase youth food waste [34]. The conclusion has a strong practical significance for policy making.

Upon combining the analysis of the keywords with a high frequency of occurrence and the literature co-citations included in each cluster, it was found that the field of student food waste is an interdisciplinary research area related to many fields, such as statistics, behavior, psychology, management, nutrition, etc., with the following three major categories:

(1) Measurement of student food waste

The accurate measurement of the amount of food waste is the prerequisite and foundation for the formulation of food waste mitigation policies. As scholars have paid more

attention to the field of student food waste research, scholars have begun to try to apply simpler and more accurate methods to measure the amount of student food waste. For example, Wallen et al. found that the use of the Day in the Life Questionnaire-Colorado can better measure the amount of food waste produced in the dining process of fourth-grade students [35]. Panizza et al. used the Mobile Food Record to investigate the amount of plate waste and how it was disposed of by adolescent girls, making it less difficult to quantify, thus representing a useful tool for measuring plate waste throughout the day [36]. Taylor et al. found that digital imaging was highly reliable in assessing children's consumption of fruits and vegetables during the school lunch period and that this method could significantly reduce the time and labor costs required to measure food waste levels with essentially no change in the precision of the measurements [37]. Chapman et al. found that categorizing wasted food and then measuring the weight of wasted food in each category provided a better estimate of the weight of food wasted on individual plates [38]. Malefors et al. developed and used a new automated waste quantification tool to more accurately quantify the level of student food waste, with a 10% increase in accuracy over traditional measurements [39]. In addition to quantifying the amount of food wasted by students, some articles have also quantified the ecological and economic impacts of student food waste. For example, Wang et al. found that Chinese university cafeterias produce about 1.74 million tons of food waste annually, generate 195.8 million m³ of biogas, indicating the negative impacts of students' food waste on ecological and economic sustainability and providing basic data for understanding the current situation of food waste in the student population and designating intervention measures.

(2) Factors affecting students' food waste

The factors that drive students' production of food waste include both individual student characteristics, such as age, gender, and disposable income, as well as external factors, such as mealtime, mealtime environments, quantity and type of food, and the availability of specific foods. Regarding the influencing factors directly related to students themselves, Pandey et al. found that attitude towards food waste, self-efficacy, and concern for the environment significantly influenced the behavioral intention and, ultimately, behaviors related to reducing food waste; students' positive emotions and familiarity with food significantly influenced food waste behavioral attitudes, while familiarity with food significantly influenced food waste behavior [40]. Ozanne et al. found that the most important factor contributing to food waste among college students was a lack of meal planning and food consumption planning (e.g., not making a shopping list before shopping, not meal planning, etc.) [41]. In terms of influences that are not directly related to students themselves, Blondin et al. found that factors such as the palatability of the food and the ease with which students could access the food had an impact on students' food waste the level of food waste [42]. Chapman et al. found that the introduction of reverse breaks (rescheduling lunch break from after lunch to before lunch) was associated with an increase in fruit consumption and that eating lunch earlier was associated with a decrease in the consumption of entrees and milk while delaying lunch was associated with a decrease in the consumption of entrees and milk [43]. This provides new ideas for exploring how meal times affect the level of food waste among students.

(3) Students' food waste behavior intervention measures

How effective are the implementations of programs related to reducing student food waste? How can they be evaluated, and how can effective policy recommendations be formulated? Scholars have developed and implemented measures to reduce student food waste based on multiple dimensions. For example, Prescott et al. found that enhanced food education, such as sharing food knowledge with peers, could reduce students' food waste [44]. Adams et al. designed an experiment to evaluate the relationship between the introduction of salad bars in schools and the level of fruit and vegetables wasted during students' lunches and proposed reducing the level of students' food waste by offering specific food items [45]. Connors et al. found that increased education on food purchasing, cooking, and storage practices was effective in reducing student food waste [46]. Wansink

et al. found that changing the shape of trays (e.g., avoiding rectangular trays in favor of square or pentagonal trays) or reducing the size of trays could reduce student food waste [47]. Dogdu et al. found that the design of packaging in terms of shape, size, depth, width, and material may increase the level of food waste if it increases the ease with which the consumer can consume the food [48]. Zhao et al. conducted a more systematic study on barriers to and factors influencing food waste among students and proposed interventions such as improving food quality and taste, extending meal times, and allowing students to choose their own lunch and to share and save leftovers [49]. Qian et al. found that watching food-saving videos, as opposed to traditional posters, slogans, and logos, could increase the effectiveness of food waste promotion campaigns and, in turn, reduce the levels of food waste [50]. Shanks et al. found that high school students preferred nonfat flavored milk in their milk consumption and that milk waste could be reduced by making nonfat flavored milk more widely available to high school students [51]. Malefors et al. found that 60% of the total food waste was generated by a minority group of 20% of students and that halving the amount of food waste generated by this group could cause a 31% reduction in total food waste. Interventions should, therefore, be tailored to the high-food-waste group rather than applied consistently to all students [39].

3.3.3. Research Frontiers

On the basis of keyword clustering (Figure 4), in order to ensure the clarity and readability of the map, $k = 20$ in the g-index was adjusted to produce Figure 5, which presents the time sequence of research keywords in this field. The keyword frequency and centrality analysis, keyword clustering analysis, and categorizing the themes belonging to the keywords appearing in Figure 5 in recent years (2022 and 2023), as well as the research frontier in the field of student food waste, can be analyzed.

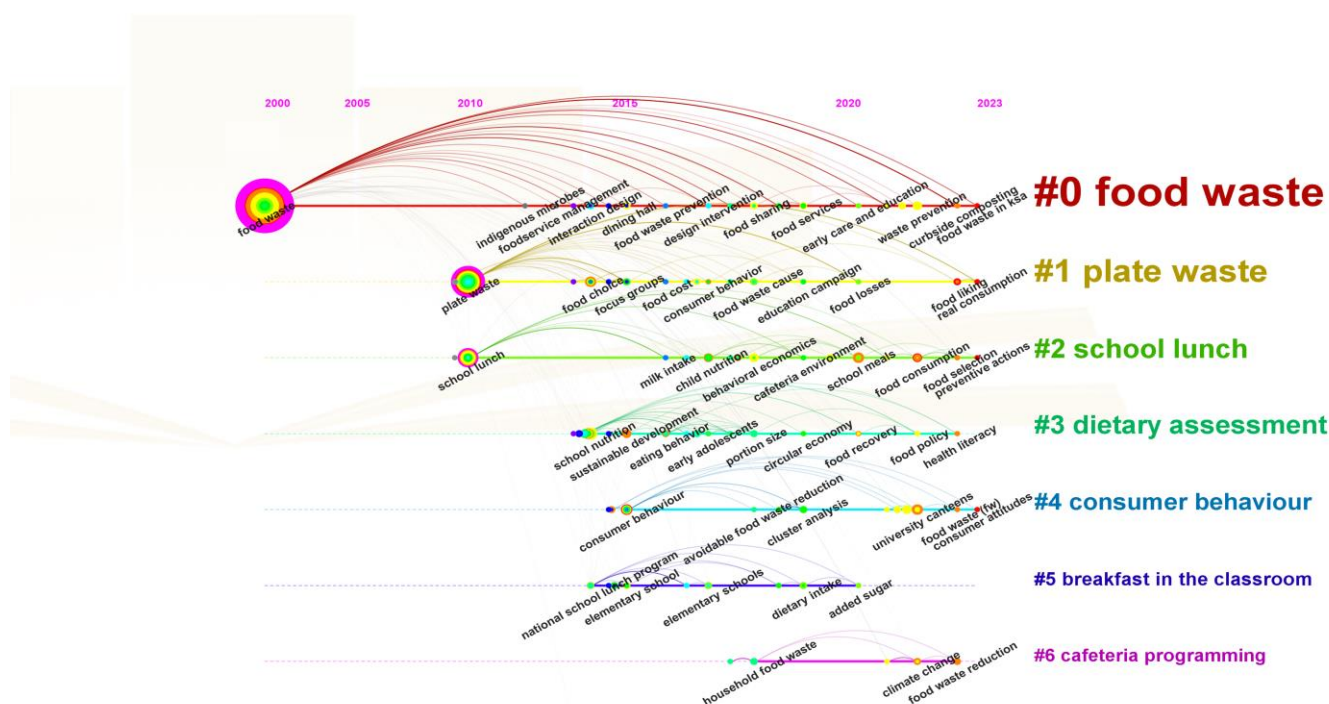


Figure 5. Keyword timing map.

The research frontiers in this field in recent years are mainly reflected in the following three areas:

(1) Food waste among students in developing countries

Since the field of student food waste first began to receive academic attention, most studies have focused on developed countries. With the rise in income levels in developing

countries, food waste is becoming more and more serious, having a certain impact on the sustainable development of the social ecology [27]. For this reason, more and more scholars have begun to pay attention to the food waste of student groups in developing countries, and they have mainly carried out basic research on the quantification of food waste in student groups, the exploration of demographic factors influencing food waste, and the assessment of loss costs. For example, Wang et al. estimated the methane generated from food waste produced by 2344 universities in 353 cities in China. Their results showed that campus canteens produce 1.74 million tons of food waste annually, produce 195.8 million m³ of biomethane, and reduce 0.77 million tons of CO₂-eq [16]. Malibari et al. conducted a survey on the food waste of college students in the Kingdom of Saudi Arabia and found that 68% of the respondents leave plate waste when they have a meal, more than 70% of the respondents have a positive attitude towards reducing food waste, and at least 25% of the respondents believe that packing unused food and bringing it back is a good food waste intervention [52]. Nguyen et al. found that Vietnamese primary school students wasted an average of 85 g during lunch. In the main course, the amount of rice waste was the smallest, and the amount of vegetable waste was the largest; boys' food waste levels were lower than girls, and reducing portion sizes and improving the taste and quality of food could reduce food waste among primary school students [18]. Qian et al. found students in southern China who consumed rice-based diets had higher levels of food waste than students in northern China who consumed wheat-based diets [53].

(2) Student Food Waste and Dietary Intake and Nutritional Health

The enactment of the Healthy Hunger-Free Kids Act (HHFA) and the National School Lunch Program (NSLP) in the USA sparked social concerns about student meals and their dietary health. Academics have begun to examine the issue of food waste among students to understand their true dietary intake and to target interventions to improve their health by addressing dietary deficiencies. For example, Appelhans et al. used a technology-based system to collect data and generate feedback on student food choices and plate waste and built on the standards set for school meals by the Healthy Hunger-Free Kids Act to keep parents, schools, food service providers, and teachers informed about school meals, particularly with regard to student plate waste and true nutritional intake [54]. Student plate is an important criterion for evaluating student nutritional intake [55]. Ilic et al. hoped to improve the implementation of meal nutrition policy standards by reducing the amount of waste from standardized school meals, and found that food types, personal preferences, and food availability all had an effect on the amount of food wasted by primary school students, with personal preferences having the most significant effect [56]. In 2020, the government-funded Healthy School Lunch Program was implemented in schools in more economically disadvantaged areas of New Zealand. McKelvie-Sebileau conducted interviews with student's family members, students themselves, and school principals to assess the impact of the introduction of the school lunch programs on students' level of food waste. This study found that nutritional loss or the inadequate absorption of nutrients by students was also classified as food waste. This study highlights the essential involvement of students and their family members in the design of school lunch programs in specific school settings [57].

(3) Behavioral Perspectives on Student Food Waste

In recent years, academics have begun to combine behavioral theories to conduct more in-depth research on the mechanisms that generate students' food waste behaviors from the perspectives of behavioral control, cognition and consciousness, individual and group decision-making, and behavior and attitude. For example, Piras et al. found that food education programs only have a short-term effect on reducing students' food waste and that students' food waste levels are affected by the food waste behaviors of their peers around them [58]. Banna et al. investigated the relationship between cognitive constraints, behavioral control, emotional eating, and food waste among girls aged 9–13 years old [59]. Pandey et al. found that while improving students' self-efficacy, improving students' attitude toward food waste and increasing their concern for the environment may

reduce their food waste behavior [40]. Theories from behavioral disciplines, such as the Theory of Planned Behavior and its extended model and Social Practice Theory, have been incorporated into cutting-edge research in the area of student food waste. Academics have begun to pay more attention to the relationship between students' food waste, individual decision-making behaviors, and other people's food consumption behaviors in the specific context of school cafeterias. Interdisciplinary research has become one of the most important avenues for in-depth studies in this field [60].

3.3.4. Research Priorities by Country/Region

The field of food waste research in student populations has received increasing attention from scholars due to policy drivers, growing ecological concerns, and other drivers. Currently, scholars from the United States, Europe, Asia, and even African countries/regions have conducted research in this area. However, due to the different research levels and perspectives in different regions, the focus of the research is also different. In order to compare and analyze the similarities and differences in the themes of different regions in the field of food waste research in the student population, we categorized the articles according to the authors of the studies, the geographic regions, the types of research, and the topics of research by creating a data extraction form and entering the data into a Microsoft Excel worksheet. Based on the above analysis of research hotspots and frontiers, we further summarized the past research focuses of scholars in each country/region in this field and presented a clearer and more comprehensive picture of the current status of research topics in this field from the perspective of geographic subdivisions.

(1) The USA's Research Priorities

Specifically, in the USA, due to the enactment of the Healthy Hunger-Free Kids Act in 2010 and the implementation of the National School Lunch Program (NSLP) in 2012–2013, research is mainly targeted at elementary and middle school students, driven by these two important policies. Currently, there are more studies in this field in the USA, and the research perspectives include the quantification of food waste in student groups, the exploration of influencing factors, the assessment of costs and loss, and the analysis of the attitudes of students and food providers, which are relatively novel and in-depth. The current research in this field in the United States focuses mainly on the design and evaluation of measures to reduce food waste among students. For example, Wansink et al. found that although growing vegetables in school gardens can increase students' knowledge of diet and nutrition and their purchasing of salads made with vegetables grown in school gardens, students did not consume all of the vegetables they purchased, thus significantly increasing the amount of wasted salads, which could be reduced by improving the appearance of these foods and pairing them with other popular foods [61]. Alattar and Morse developed, piloted, and evaluated a cafeteria food waste diversion program that was successful in reducing student food waste by having them personally observe and weigh plate waste [62]. In addition, scholars in the United States have investigated and studied food waste in terms of knowledge, attitudes, and barriers to interventions in student populations. For example, Alattar and Morse found that the interviewed students had a certain understanding of the effects of food waste, and had a positive attitude towards reducing food waste [62]; Mitchell et al. found that there were gaps in the knowledge and attitudes about the environment and food system among students of different races, with white students scoring significantly higher on their combined knowledge of food waste and climate change and food stewardship [63]; Zhao et al. conducted a survey on current barriers to reducing plate waste among student populations, and their results showed that the main barriers to reducing plate waste in schools were the low-level support of school policies, low food quality, and poor food taste, which led to the development of interventions such as improving food quality and taste, providing more time for students to finish their lunches, allowing students to choose their own food for lunch, and allowing students to share and save leftovers themselves [49]. The United States is the leading country in this area of research, with more innovative perspectives on both the influencing

factors and the development of interventions compared with studies in other countries. A survey on the attitudes and knowledge of the student population about food waste prior to the development of food waste interventions for the student population would be helpful in developing more targeted interventions.

(2) European Research Priorities

The focus of research varies across European countries. For example, Sweden focuses on food waste among student populations of all ages, while the rest of the European literature on food waste in schools focuses mainly on elementary schools [64]. In general, European scholars focus more on the behavioral perspective in this field. For example, Principato et al. examined the factors that influence changes in food waste behavior among student groups. The results of this study showed that the greater the students' awareness of food waste, the more likely they were to reduce food waste; the greater their concern for food freshness, the higher the level of food waste; and the greater their awareness of the consequences of food waste, the greater the likelihood of having food purchases on their shopping lists, which can help to reduce the irrational consumption of food and food waste [65]. Piras et al. found that students' food waste levels were consistent with the food waste levels of students sitting near them, suggesting that students' food waste levels were influenced by the food waste behaviors of those around them due to observation and imitation behaviors [58]. Lorenz et al. found that college students' behavioral intention to reduce food waste was closely related to their food waste levels; behavioral intentions to reduce food waste were determined by attitudes, behavioral control, and subjective norms to reduce food waste [60]. As the discipline of behavioral science develops, the field of student food waste will become increasingly rich in its perspectives and in-depth analyses of the causes of food waste in student populations.

(3) Asian Research Focus

In Asia, there is a difference in research focus between developing Asian countries (e.g., China, Vietnam, and Malaysia) and developed Asian countries (e.g., Japan and South Korea).

Scholars from developing countries in Asia have mostly focused on quantifying the level of food waste among university students and exploring the factors that influence it. In terms of quantifying the level of food waste among students, Qian et al. conducted a questionnaire survey among 9192 students in China and found that 74% of the students had generated food waste in the university cafeteria, and each student generated 61.03 g of food waste per meal, with wheat (25.78%), rice (20.36%) and vegetables (18.61%) taking up the largest proportion [1]. Liu et al. used a combination of physical weighing, a questionnaire survey, and a semi-structured interview to quantify the level of food waste produced from school lunches in Beijing, China. The results of this study show that the average amount of food waste generated by school students in Beijing in 2014 was 130 g/meal, which accounted for 21% of the total meals, with staple food and vegetables accounting for the highest proportion, at 43% and 42%, respectively [66]. Nguyen et al. measured the plate waste among approximately 1700 primary school students in suburban areas of Vietnam and found that, on average, 23% of the food was wasted per student at lunchtime (about 85 g), which corresponds to 15.3 kg of food wasted per student over the course of a school year. This study provides basic data on food waste among student populations in low- and middle-income countries [18]. As for the investigation of the factors affecting students' food waste, Wu et al. found that plate waste was significantly related to grade and economic status; the lower the education level and the higher the disposable income, the higher the level of food waste, and male students wasted significantly less staple food than female students [67]. Zhang et al. found that the level of food waste of students in universities was significantly correlated with the age and gender of the students; for example, the level of food waste of senior students was higher than that of freshmen, and the food waste level of male students is lower than that of female students [68]. Qian et al. found that there is a correlation between students' body size and food waste. That is, the lower the body mass index (BMI) value, the higher the level of food waste. The association between

BMI and food waste was greater for males than for females, and the association between BMI and food waste was greater for people from northern China than for people from southern China [69]. Some scholars also focus on the influence of the dining environment on students' food waste levels. For example, Liu et al. found that the amount of student food waste caused by buffets was smaller than that caused by boxed lunches. The food supply mode, cafeteria service quality, eating habits, and knowledge of food production are the main factors affecting the level of food waste among students [66]. Zhang et al. found that improving the quality of food and appropriately reducing the quantity of food can reduce the level of food waste among students [68]. Currently, developing countries have begun to emphasize the sustainable development of the economic and social ecology and advocate for a green and low-carbon lifestyle and consumption [27], and the number of studies in this field is rapidly increasing. However, in general, the total number of studies in developing countries in Asia is relatively small, and the research perspectives are still relatively homogenous. The research in this area needs to be deepened.

Scholars from developed Asian countries have conducted fewer studies on food waste among students, focusing on the factors affecting food waste among primary and secondary school students and the development of related interventions. Compared with developing countries in Asia, scholars in developed Asian countries have conducted more surveys on students, teachers, and dietitians to explore the impact of school dietary education on food waste and to propose food education interventions based on the recommendations of various parties. For example, Izumi et al. used interviews, observations, literature reviews, and other methods to investigate students, teachers, and other people, explored the factors affecting the food waste produced by elementary school students in Tokyo, and found that optimizing menu design, increasing students' knowledge of unfamiliar and disliked foods, incorporating food and nutrition education into the school curriculum, and extending the students' mealtime were effective in reducing students' food waste [70]. Baik et al. found that students with food waste habits usually have poor behaviors such as an insufficient intake of vegetables, choosing foods based on preference only, poor table manners, and eating street food and biscuits/drinks/fast food, and concluded that parental food education practices play an important role in shaping the diets of students and reducing the level of food waste [71].

In general, research on student food waste has focused on primary school students, followed by secondary school students and university students [64]. These research efforts involved quantifying and assessing the level of student food waste, exploring the factors affecting student food waste and intervention measures, quantifying the impact of student food waste on the sustainable development of the economy and the ecological environment, and investigating the attitudes and perceptions of students, teachers and other relevant key groups on food waste, etc., cultivating a relatively rich research perspective and providing a more comprehensive perspective and research basis for future scholars' research in this field.

4. Discussion

4.1. Findings

Against the backdrop of increasing global scarcity of arable land resources, reducing food waste is essential to improving future food supplies and achieving sustainable food systems [23]. As a complex, multidisciplinary, and international issue, food waste has received increasing attention from scholars. In this context, this paper reviews 241 articles related to student food waste research with the help of CiteSpace bibliometric analysis software. First, based on the analysis of the overall trend of food waste articles in the student population, this study maps the volume of articles and analyzes the national and regional partnerships. Second, the evolution process of research in the field of student food waste is broadly categorized into the starting, exploratory, and developmental periods. Third, combining keyword and co-citation analysis, three hotspots of research in the field are identified, namely measurement of student food waste, exploring the influencing factors

of students' food waste, and developing interventions for students' food waste behavior, while three frontiers are identified, namely student food waste in developing countries, student food waste and dietary intake and nutritional health, and the food waste of students from behavioral perspectives. Fourth, the research focuses on three countries/regions, namely, the United States, Europe, and Asia, which were organized and summarized.

This study has the following three levels of marginal contributions:

First, the existing literature has been reviewed from the aspects of food waste behavior [72] and food waste intervention measures [73], etc., and we found that there are fewer systematic analyses of the food waste behavior of student populations in the literature. With the help of CiteSpace software, this study systematically reviewed the academic progress in student food waste research since 2000 and revealed the intrinsic linkage mechanism of the three phases of academic food waste research. This addresses the problem with previous reviews of food waste research, which did not adequately reveal temporal changes.

Second, this study identifies the research on food waste in the student population from multiple dimensions, such as research hotspots and research frontiers. With the help of charts and graphs to achieve the expansion of the analysis, as well as an in-depth discussion of the current situation and the development trend of research in the field of student food waste, the results of this study can provide direction and ideas for subsequent research.

Third, this study conducted a comparative analysis of the current status of food waste research in the student populations in the United States, Europe, and Asia from the perspectives of research perspective, research methodology, and research content, and the results of this study can provide lessons and references for student food waste research and policy development in different regions.

4.2. Research Gaps and Suggested Directions

First of all, different countries and regions have different economies and cultures, and different students' dietary patterns are also quite different [68,69], so the focus of research on food waste among students in different countries/regions is also different. The next step in food waste research can be to explain the background and regional effects of food waste among students from the perspective of cultural anthropology and other theoretical perspectives, such as the level of economic development and differences in culture and customs, in order to reveal the internal mechanism of producing food waste among students in different regions and to provide a reference for the formulation of targeted anti-food waste policies.

Second, in some countries and regions, the nutritional intake of students exceeds their nutritional requirements, resulting in over-nutrition, which has led to a high rate of obesity among students. From the perspective of dietary health, food intake in excess of physiological needs should also be regarded as a kind of waste, described as "hidden food waste". Existing research lacks a systematic exploration of "hidden food waste". In this context, improving our understanding of "hidden food waste", scientifically measuring the amount of "hidden food waste", and exploring the influencing factors of "hidden food waste" from the theoretical perspectives of economics, nutrition, and behavioral science are of great significance in reducing unreasonable food demand, improving the reasonable diets of the student population, and promoting the sustainable development of the food system.

Third, according to the above, the existing research on food waste in student groups mostly focuses on the consumption side, and there are few discussions on student food waste from the perspective of the food supply chain. Subsequent studies can be broadened to include the production and distribution of student meals so as to explore the root causes of reducing food loss and waste in student groups from the perspective of the whole chain and to provide support for the formulation of a more comprehensive and targeted anti-food waste policy.

Finally, in the era of the digital economy, social media is the main channel for communication, obtaining information, and self-expression among student groups, especially middle school and college students. In this context, the influence of social media, such

as Facebook and WeChat, on the food waste produced by student groups has become a new issue of concern. Elucidating the mechanism by which information on social media influences students' eating behaviors provides theoretical support for creating a healthy eating atmosphere, formulating food waste intervention measures, and guiding students to develop good eating habits.

In this paper, we obtained relevant studies from the WoSCC database to develop a knowledge graph visualization and analysis, presenting the current status, hotspots, and trends of research in the field of food waste in the student population in a more comprehensive way. However, the following limitations exist:

First, this paper uses the WoSCC database as the data source, but the literature in this database is mainly in English, meaning that it cannot summarize the research on mobile libraries in all countries and regions, so there may be some partiality in the selection of the research samples. Second, the screening of the retrieved articles was performed manually, which is not 100% accurate due to human subjectivity, so there may be some errors in the literature data.

5. Conclusions

Due to reasons policy-driven reasons, scholars are paying increasing attention to students' dietary intake, nutrition, health, sustainable development of the ecological environment (e.g., the sustainable use of resources and environmental protection), sustainable development of social economy (e.g., rational consumption and reduction of economic losses) and other fields, and more scholars have begun to pay attention to students' food waste. This field is receiving increasing attention from academic circles. The United States is the country with the largest amount of research in this field, the greatest academic influence, and the most frequent cooperation with other countries.

In terms of research content, first, from the perspective of the research process, the research in this field can be roughly categorized into the starting period, the exploration period, and the development period. Second, from the perspective of research hotspots and research frontiers, scholars' studies in this field are divided into three research hotspots: namely, the measurement of students' food waste, the exploration of influencing factors for students' food waste, and students' food waste behavioral interventions, as well as three frontier topics, namely student food waste in developing countries, student food waste and dietary intake and nutritional health, and the food waste of students from behavioral perspectives. In terms of the content of the research focus of scholars in this area, the focus of scholars in each country/region is different. Scholars in the United States mainly focus on primary and secondary school students in this field and also pay more attention to the knowledge and attitudes of students, teachers, student food service workers, and other relevant people regarding food waste in the student population, as well as their views on the main obstacles to intervening in student food waste, and the research perspectives they choose are relatively new, making the USA the leading country in this field of research. Europe focuses on behavioral research and the development of interventions in this area. Scholars from developing countries in Asia focused on quantifying the level of food waste among college students and exploring the factors that influence food waste. Scholars from developed Asian countries focused on exploring the factors that influence food waste among primary and secondary school students and developing interventions. Scholars from developed Asian countries have also proposed food education interventions based on surveys of students, teachers, and dietitians, as well as gaining recommendations from a variety of sources.

Based on the results of the above research, this paper proposes that future research seeks to explain the background and regional effects of student food waste from the perspective of cultural anthropology and other theoretical perspectives and reveal the internal mechanism of student food waste in each region, pay attention to the "hidden food waste" of students from an interdisciplinary perspective, explore the food loss and waste produced by students from the perspective of the whole chain of student meal production

and distribution, clarify the mechanism of information on social media such as Facebook and WeChat influencing students' eating behavior, and use social media scientifically to guide students to develop good eating habits, further deepen the research in this field.

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