Toward food waste reduction at universities

Walter Leal Filho, Priscilla Cristina Cabral Ribeiro, Andréia Faraoni Freitas Setti, Fardous Mohammad Safiul Azam, Ismaila Rimi Abubakar, Julen Castillo-Apraiz, Unai Tamayo, Pinar Gokcin Özuyar, Kamila Frizzo, and Bruno Borsari

Abstract

Food waste is a serious problem, which undermines the achievement of many sustainable development goals (SDGs), despite their consideration in the agendas of many countries and companies. Notoriously, food waste (FW) causes different kinds of pollution that affect public health and social justice, while contributing to economic losses. This waste phenomenon has causes, drivers, and impacts that require rigorous assessments and effective approaches to mitigate its noxious effects, which are a serious concern for universities. Within these institutions, reducing food waste becomes a circular economy strategy, which is being utilized to assist in promoting sustainable development. However, there is a need for urgent attention to the specific causes of food waste and for consistent actions to reduce it, while boosting awareness in the campus community and triggering a change in students' eating habits. The purpose of this study is to analyze what can be done to reduce the levels of food waste at universities. To achieve this, a review of the theme's state of the art, which is inclusive of an overview of food waste production at universities around the world, is presented. The study employed a qualitative methodology where a comprehensive review of the literature and case studies analyses from selected world regions were considered. The data indicate that a broad variance exists in producing food waste among universities, from 0.12 to 50 kg/capita/day. More factors influence the problem (e.g., gender, age, season, consumer behavior), as well as strategies to solve and prevent it (e.g., composting, recycling, new designs of packages,

trayless meals, education), and benefits leading toward food waste reductions from 13 to 50%. Also, four priority actions were identified to reduce food waste at universities, and these consist of planning and awareness, food preparation and storage, services, and direct waste reuse. With appropriate adaptations, these recommended actions should be deployed as means for reducing food waste at universities around the world, while expanding learning and education in sustainability.

Keywords: Sustainable development, Food waste, Food consumption, Universities, Preventive actions

Introduction

Food waste (FW) denotes a complex topic within the global food industry, affecting many countries of the world, including developing ones. Thus, FW has become a top priority on the agendas of governments and economic sectors in the pursuit of achieving the UN Sustainable Development Goals (SDGs) (Costa et al., 2022). Actually, FW has become an increasing concern in the last decades due to its environmental impacts, from greenhouse gas emissions to soil, water, and air pollution, thus worsening the effects of climate change. In addition, FW intensifies food insecurity, may cause health problems and leads to economic losses (Shafiee-Jood & Ximing, 2016; Wang & Yuan, 2021). Its gravity is exemplified by the fact that climate change undermines various sustainable development goals (SDGs), such as SDG 1 (No Poverty), SDG 2 (Zero Hunger), SFG 12 (Sustainable Consumption and Production), and SDG 13 (Climate Action). Figure 1 outlines the dimensions of the problem.

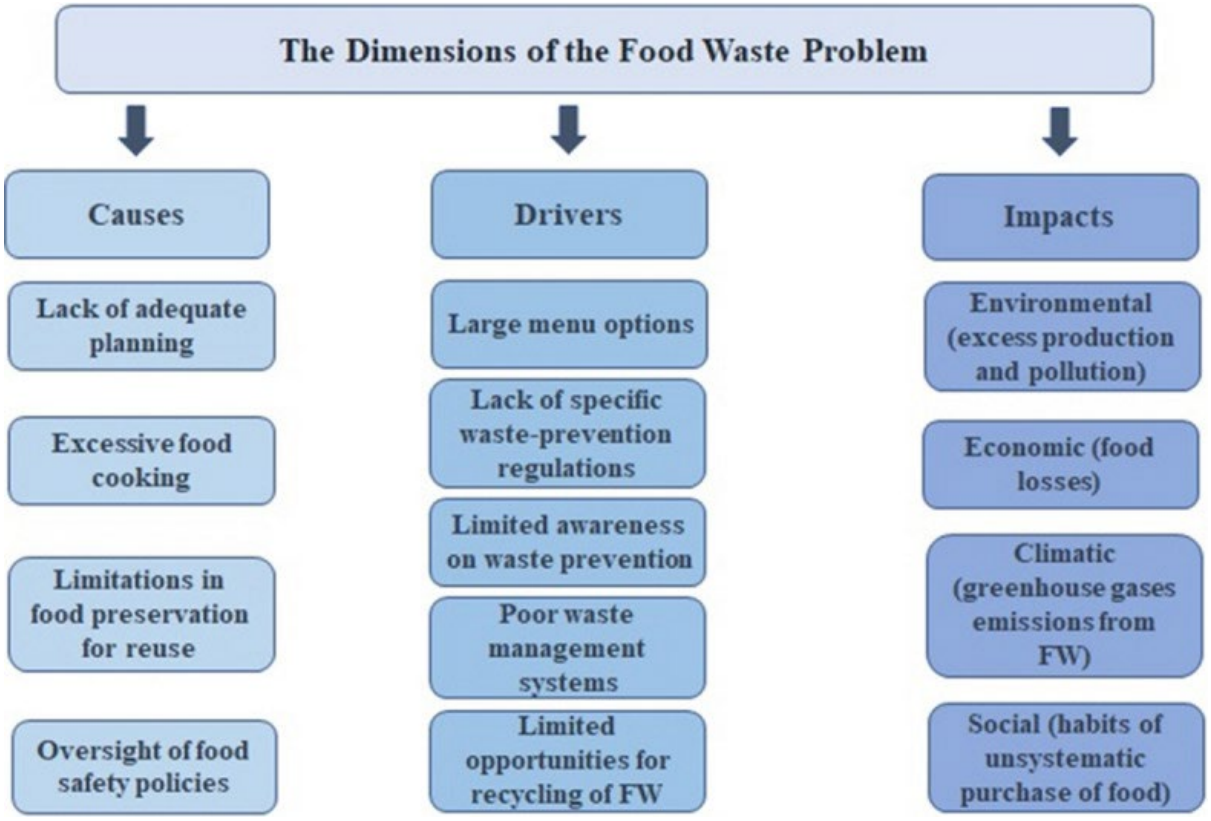

Fig. 1

Key dimensions of the FW problem

Universities, which may be comparable to mini-cities or large businesses, are places where FW remains a significant problem (Lazell, 2016; Leal Filho et al., 2021). They may host hundreds, or even thousands of students depending on their capacity while processing and serving every day large volumes of food, thus contributing to the worldwide problem of FW (Kaur et al., 2021). Wasteful behaviors of university communities, plus excessive cooking, over-purchasing, and ineffective food planning and management (e.g., poor transportation, deficient inventory, and inadequate food storage and preservation), are among the significant causes of FW at universities (Lazell, 2016; Leal Filho et al., 2021).

Decision-makers at many universities have been undertaking efforts to prevent and reduce FW and also to spur a positive image of institutional commitment to environmental protection and sustainability on their campuses (Shafiee-Jood & Ximing, 2016; Wiriyaphanich et al., 2021). Reducing FW is also a social responsibility of universities and an avenue for creating a positive public image when several people, including some of their students, are food-insecure (Kaur et al., 2021). FW is central to global sustainability efforts, making universities that enhance their environmental stewardship through initiatives to reduce FW and conducting research about reducing it, attractive to students interested in sustainability and environmental programs (Li et al., 2021). Therefore, involving students in the sustainability education process through applied and cooperative approaches to resolve the FW problem can become transformative for their education, independently from any future career path these may take. There is a need for more research in this field, especially studies aiming at identifying ways to reduce, or even eliminate FW. The scarcity of studies focusing on FW generated at higher education institutions that intersect with global food production reiterates the need for urgent actions to help address this problem.

When universities operate as living labs, they have the potential to bring new approaches and development ideas for feasible solutions that could assist also with the challenges posed by FW (Leal Filho et al., 2022). The urgency for identifying and implementing sustainable methods of FW management is compelling, and universities as microcosms of learning and innovations can play a more active role in reducing and/or recycling FW. However, this effort requires systemic and strategic actions, because it is a complex task that implies monitoring and controlling waste against set targets. In fact, cultural, political, economic, geographic, and sociodemographic factors may also be related to FW behavior (Thyberg & Tonjes, 2016). Therefore, attempts to address this problem need to take all these elements into account, in a comprehensive and holistic manner.

There are many and varied FW sources that can potentially amplify the magnitude of this phenomenon, such as overproduction, unnecessary losses in inventory or inappropriate

transportation and storage (Leal Filho et al., 2021). Recent studies have provided an overview of the determinants of FW generation in cafeterias (Qian et al., 2021) and dining halls (Deliberador et al., 2021; Deliberador, César & Batalha, 2021), whereas others have been focusing on what influences students' FW behavior (Wang et al., 2022). For instance, Zhang et al. (2021) found out the reasons that contribute to FW increases at their university and proposed valuable solutions for this problem.

Possible changes toward more sustainable food production and consumption, such as the technology-based solution proposed by Vázquez et al. (2020), or specific guidelines as those proposed by Leal Filho et al. (2021), appear to be effective and applicable to other contexts. It should be made clear, however, that FW and losses are critical political issues that possess tangible implications for the entire supply chain, from crop production to disposal of food remains. This issue needs to be properly addressed by universities and demands the implementation of innovative, responsive, and sustainable solutions to the problem.

Our primary motivation for conducting this study consisted in lessening the existing gap between the relevance of FW research and real efforts made by universities to reduce FW. The originality of our study lies in the fact that we adopt a pragmatic approach to identify achievements from the field, while proposing precise actions that may become applicable elsewhere, with appropriate adaptations. Hence, our objective is to analyze what can be done to reduce the levels of FW at universities, whereas our main contribution lies in suggesting where actions should be taken.

There is still a lack of studies that identify areas of improvement and suggest initiatives to tackle waste management at universities. Through a qualitative study, we aim to: (i) present the most updated overview of FW at institutions of higher learning, (ii) analyze the approaches and methods that have been used by these to reduce FW, and (iii) propose initiative areas that, if pursued, could effectively help to reduce FW at universities. We seek to move this topic forward by understanding

the challenges, opportunities, and nuances of FW management and disposal at higher education institutions, while proposing effective, sustainable practices.

Material and methods

This work employed a two-pronged, qualitative methodology. One focused on a literature review of recent studies about FW at universities, whereas the other was directed at an analysis of selected case studies from countries representative of North America (Canada and USA), Asia (China and Qatar), and southern Europe (Spain).

The rationale guiding the selection of articles for the literature review analysis consisted of their close relationship with the topic under study and also the fact that these illustrate real examples of experiences in FW management at universities. These articles were searched on the Scopus database using filters such as year of publication (2020–2023), type of documents (journal articles and conference papers), and language (English) while employing keywords like "food consumption, food waste" and "university", and the initiative areas. They were read thoroughly and their content was summarized and discussed as qualitative data in the literature analysis review of this study. Its focus was on understanding how FW is generated and disposed of at dining halls canteens and cafeterias. In addition to this, nuances were sought to learn what approaches, if any, were in place at institutions of higher learning to develop awareness and impart education in reducing FW on campus. Both methods here employed (literature review and the analysis of case studies) complemented each other in reciprocity. For example, Patten (2004) pointed out that a literature review can assist qualitative and/or quantitative researchers to identify trends or research voids, in any field of inquiry. Case studies instead are descriptive endeavors that shed light on problem solutions achieved in specific research contexts thus, blending a variety of data gathering techniques, over time (Creswell & Creswell, 2018). Through this approach, researchers may tackle case studies from a variety of epistemological angles, employing a variety of definitions to address the researchers' roles in the process of collecting, analyzing, and interpreting data (Compton-Lilly, 2012).

Also, Miles (2015) conceded that additional advantages of using case studies consist of the fact that these provide a better context for the topic being studied. Therefore, both methodological strategies, although non-experimental, can offer valuable information to describe a distinctive research context, or event, which may inspire more studies along the same trajectory, with appropriate adaptations, or adoptions, depending on the characteristics embodied by a new study environment (Patton, 1990). The study approach used is described in Fig. 2.

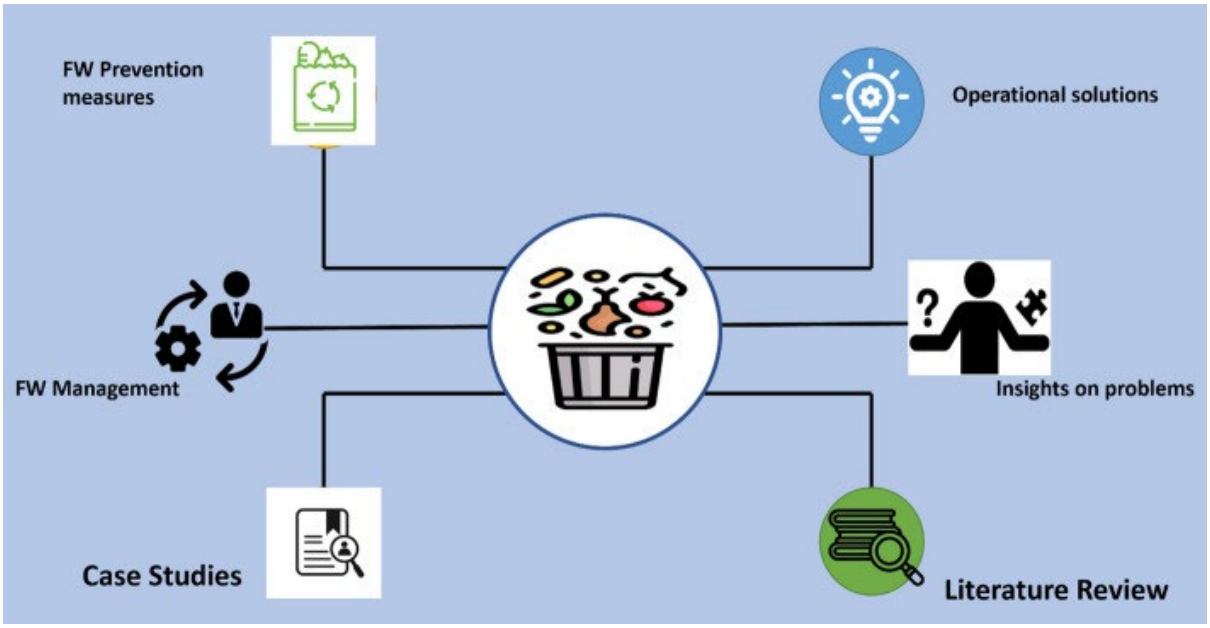

Fig. 2

Schematic view of the study approach used

Our methodology proved to be effective in understanding challenges and opportunities about FW management and disposal at university campuses, despite the diversity of cultures and operational approaches employed by institutions of higher education. The investigators sought to find relationships between the two qualitative methods used for their data collection because according to Popham (1993), these have the potential to enhance the trustworthiness of assessment studies.

Results and discussion

Literature review: Food waste at universities: the state of art

Solid waste becomes a nuisance when disposed off indiscriminately, such as along streets, rivers or dumped into the sea. These practices generate a lot of hazards and are dangerous to the well-being of humans and the environment (Adeniyi & Afon, 2022). FW is one of the most concerning solid waste issues, especially when considering the current hunger problems affecting humanity, preceding and following the COVID-19 pandemic. It also creates Carbon Footprints (CFs) that may significantly worsen the effects of global warming (Qian et al., 2022a). For any hypothetical country in the world, FW is the third largest source of carbon gas emissions in the world (UNEP, 2021). University dining halls are places where waste-reducing actions are urgently needed. Therefore, campus dining sustainability programs are expected to play a critical role in educating future leaders about environmental stewardship, through effective FW reduction approaches. To this end, the Green Restaurant Association (2020) has proposed eight standards for green restaurants and these are: (a) water efficiency, (b) waste reduction and recycling, (c) sustainable food, (d) sustainable, durable goods and building materials, (e) energy, (f) reusable and environmentally preferable disposals, (g) chemical and pollution reduction, and (h) transparency and education that may be feasible also for implementation at universities and more institutions.[query section].

Reasons and factors behind FW generation

According to Kasavan et al. (2021), there is a high FW at the consumer level in developed countries due to over-purchasing of perishable foods, like fruits and vegetables, meats and dairy products, whereas the post-harvest and production processes constitute major causes of FW in developing countries. Considering that at universities, FW occurs mainly from the cooking and preparation of dining halls and consumers' behavior, Deliberador et al. (2021) discussed the reasons for FW at campus eateries, such as food quality, portion size, satiety, time, and attitudes. Another factor to be considered is the seasonal influence on the characteristics and quantity of FW, which is not a common topic discussed within universities, nor is part of research agendas, or standard for urban

land use (Adeniyi & Afon, 2022). Qian et al. (2022a) in their survey of 29 universities, which engaged 9,192 students, found some reasons related to generating FW, such as the mass of FW, gender, age, education, ethnicity, religious beliefs, being the only child in a family, daily waste habits, family origin (city, small town, or rural area), household size, family wealth, lunch or dinner, weekdays or weekends, presence of commensals, time pressure, differences in how food is served, food expenditure, meal costs, food taste satisfaction, and awareness.

Also, Yoon et al. (2023) pointed out that gender is another factor for variability in food consumption and sustainable behavior. According to these authors, female consumers have a higher tendency to patronize environmentally friendly restaurants, are more likely to purchase sustainable products, hold stronger attitudes toward environmental issues, and pay more for sustainably produced foods when compared to their male counterparts. These gender differences and perceptions of sustainable practices are similar to those experienced by campus dining services at a large southeastern university in the USA.

Spatial characteristics affect FW. For example, in a survey at Chinese universities, Qian et al. (2022b) discovered that regional economic development influences FW in China. The lower carbon food print regions are concentrated in Northeast and Northwest China, where rice and meat have less demand and wheat instead is the staple food. This may be because the south is more affluent and most people have a higher purchasing powers that allow higher levels of consumption and waste (rice and meat), as substantiated by a previous study by Qian et al. (2022a).

Zhang et al. (2021) conceded that FW per meal, per capita, differs based on some factors such as personal attributes (age and gender), and additional reasons related to consuming behavior (excessive purchasing, tasteless food, personal preference for gourmet, rather than staple food, undesired accompaniments, selection of disposable tableware, cheap food, and large-sized portions).

Quantifying the FW volume

Accurate calculations of FW are necessary to identify waste hotspots and strategies for implementing effective waste reduction plans. To accomplish these computational tasks, employment of key performance indicators such as FW per capita (total FW generation divided by the total population in each school) and FW per portion (percentage of FW generated at the consumption level) is recommended (Kasavan et al., 2021). In an international study with a sample of 52 higher education institutions, Leal Filho et al. (2021) discovered that more than half of the universities (60%) do not measure the amount of FW generated by their canteens. Hence, it is not possible to fully understand to what extent FW is being generated and its impacts in terms of waste and related costs to dispose of it. Measurable indicators yield real numbers and these data can encourage preventive FW measures, detect operational inefficiencies, and especially, establish realistic targets for improvement.

An employment of the Material Flow Analysis (MFA) and System Dynamics (SD) approaches at the Ateneo de Manila University (Philippines) revealed that the total mass of rice waste was 49.48 kg/day and that large sources of waste originated in the cafeteria, involving the cooking and serving of rice—the reason of this FW was the surplus of cooked rice that was not consumed (Favis et al., 2022).

A study at Obafemi Awolowo University (OAU) in Nigeria showed that the average solid waste generated per person per day is 0.042 kg., which cumulatively yields 2.98 tons/day (Adeniyi & Afon, 2022). In a recent survey in a public North American university, Cavazos et al. (2023) estimate that diners serving themselves once during lunch, on average leave on their plate 0.4 kg/day during a five-day week, leading to individual amounts of FW of 6.7 kg., during the typical sixteen-week semester period. In a survey with 7000 students at a Portuguese university, 4,374 meals were prepared using 1599 kg of food during this study period (10 days). From this initial mass, 189.5 kg of food was wasted, 164.1 kg as plate waste (what is in the dishes), and 25.3 kg as leftovers. The high

FW values (about 13.4%), determine a monthly economic loss of €3.080, an ecological footprint of 2.8 global hectares (gha), and a total FW of 417 kg (Martinho et al., 2022).

In another survey from Chinese universities, vegetables ranked first (46.80% of total plate waste) in FW, grain waste ranked second (36.23% of total plate waste), meat ranked third (13.91% of total plate waste), and the waste of eggs and aquatic products was the lowest (1.55 and 1.52% of the total FW, respectively) (Qian et al., 2022b). At a university in Northern Portugal with 7000 students, Martinho et al. (2022) compared the total FW from soup and main course options (meat, fish, pasta, and ovolactovegetarian meal) and found that FW was higher for meat (78.1 kg), whereas the lowest FW was measured for the ovolactovegetarian option. Considering daily meal prices and FW, researchers estimated that there is a daily economic loss of €140. Considering the length of the Portuguese academic year (200 days), this equates to almost €28,000/per year.

Tucho and Okoth (2020) found that leftovers (dominated by Injera, rice, and spaghetti), generated by students at an Ethiopian university accounted for 82% of the total FW in a one-year timeframe, whereas onion counted for 10% and potato peels 6%, yielding cumulatively, 680 tons of FW.

In three canteens of a Chinese university, considering environmental and cost impacts, Li et al. (2021) found that the total amount of FW with 22,000 students was 246.75 t/year, the carbon footprint caused by FW was 539.28 t CO2-eq, and the cost was €647,348.94. The staple food (cooked wheat-based foods and rice products) is the highest (46.14%) contributor to the FW in this sample, whereas the remainder consists of vegetables and soy products (28.34%). The authors explained that the carbon footprint of FW in university canteens in China derives mainly from the use of electricity and natural gas (68.71%) during the cooking phase. This requires the use of more energy-efficient electrical appliances in university canteens, attention to energy conservation, and considerations about sourcing renewable energies. The cost of FW in university canteens occurs primarily from the purchase of livestock and poultry meats in the procurement phase (26.04%), and labor costs in the cooking phase (38.17%). This calls on students to reduce meat consumption and waste and adopt a

more balanced diet. Labor wages are stable and unlikely to change. In a national survey conducted among Chinese universities, Qian et al. (2022b) found that FW correlates with high carbon footprints, and that meat waste accounts for 13.91% of the total plate waste weight, which generates 46.28% of the total carbon footprint. On the contrary, vegetables account for 46.80% of the total plate waste, but only 10.65% of the total carbon footprint. Hence, reducing the FW of high-carbon-footprint foods like those derived from animals is effective for reducing carbon emissions.

Strategies for preventing and controlling FW

Alternatives for universities to search for organic production by dining halls, canteens, and cafeterias are available, however, and these consist of:

- − installing composting bins in every building thus, eliminating trash pickup for janitors;
- − employing earthworms and establishing vermicomposting facilities as an alternative to common composting practices;
- − composting the food via anaerobic digestion to yield methane and compost—that can be turned into valuable organic fertilizers, which can be used for the university gardens and animal feed or sold FW to worm farms (Da Rocha Ramos et al., 2022; Feil et al., 2020; Grech et al., 2020; Kasavan et al., 2021; Leal Filho et al., 2021).

These composting practices could be assessed by considering variables such as supplier selection, after-sale support, composting method performance (Al-Aomar et al., 2022), and compost/vermicompost quality.

Another action proposed by Grech et al. (2020) is related to packages, minimizing their use, and recycling them. Following this idea, the trayless initiative is an infrastructural action to reduce FW, plus a cultural one (Davison et al., 2022). Concerning reducing FW, Grech et al. (2020) and other authors suggest that canteens could be reducing plate and utensil sizes, go trayless, adjust quantities of food made available to trends of consumption, menu options (focusing on the reduction of

animal-based products availability, and inclusion of local and seasonal products that prioritize fresh and minimizes consumption of processed foods), catering styles (table service placing self-service buffet), adoption of an online prebooking meal system, development of digital applications for continuous FW monitoring, composting, and donations (Cavazos et al., 2023; Davison et al., 2022; Martinho et al., 2022; Musicus et al., 2022; Zhang & Kwon, 2022).

Related to the trayless strategy, Zhang and Kwon (2022) noticed that, in their sample, this initiative did not result in unhealthy food choices as some authors attested, but rather the consumption of fat and caloric intake decreased, improving the quality of the consumers' diet. Although there were some changes in the students' diets, the authors did not find FW reductions significant because one-third of the sample did not leave any plate waste before the trayless implementation. Besides, the number of individuals leaving large portions of FW did not change. Although the trayless strategy did not have the impact expected by the university, some issues stood out, such as the dissatisfaction with trayless related to the building layout (walking between people in the dining center), safety (dropped food while moving from a food area to another), and hazards (burnings of students' hands). Leal Filho et al. (2021) found that some canteens prioritize the use of single-use food boxes still, and even though students might be willing to pay the full price of a dish and receive a smaller portion, staff would still serve the full one.

In accordance with the infrastructure of a canteen/cafeteria/dining hall, during the food processing, revisions of the standard operating procedures made in the processes of the cafeterias and maintenance or updating the equipment are recommended, with regular measurements of FW in these campus facilities (Favis et al., 2022; Leal Filho et al., 2021).

Faezirad et al. (2021) noticed that the reduction of FW at one of the major universities in Tehran, Iran was based on decreasing the number of unclaimed meals, and to implement this approach, a simultaneous balance between minimizing waste cost and shortage penalty was considered. Besides, the authors proposed an artificial neural network-based model designed for demand prediction by a

students' reservation system that supports meal planning. Hence, choosing two types of food, each as an alternative or a supplement to the other, promotes the model's efficiency. Although students have already set their preferences when making the reservation, they may still face shortage; in this case, it may be possible to replace food 1 with food 2 or vice versa, at a new price. This idea would realize the objective of FW reduction.

Some authors described the implementation, in some 'target areas' like ethical procurement and sustainable food consumption strategies, to change students' behavior, in line with the cultural differences and strategies that educate students and the university community about FW reduction. Governments and universities aimed to embed sustainability into institutional activities such as teaching and research, or by encouraging freshmen students to study sustainability, collaborating with the community, staff development, branding, reducing carbon emissions, and transforming campuses in all activities and resources (water, grounds, FW, procurement and purchasing) in a perennial commitment to sustainability (Cavazos et al., 2023; Davison et al., 2022; Grech et al., 2020; Martinho et al., 2022).

Even though these strategies are essential to reduce FW, Musicus et al. (2022) identified some barriers to donating FW and/or composting it. About the first strategy, they found that a lack of labor, liability concerns, infrastructure, lack of recipient partnerships, and state or municipal policies can become tangible constraints. Related to composting the barriers found were lack of infrastructure, knowledge/experience, labor, and financial concerns. The main concern is the lack of labor that can be overcome by students and community volunteer groups.

Benefits of investing in FW reduction

When universities decrease FW they gain economic benefits (tangible and intangible cost of waste management from purchase to disposal), social benefits (enhance food security), and environmental benefits (improve natural resource use efficiency, while reducing greenhouse gas emissions) (Kasavan et al., 2021).

In a recent study by Davison et al. (2022) in Indian and UK, university canteens, they found COVID-19-related changes, such as from self-service to table service, as well as reduced menu choices and improved estimation of the number of students requiring meals. Surveys and focus groups were conducted with students to better understand their attitudes about FW, while interviews were carried out with university staff to better understand FW management. The study in the UK university canteen revealed that introducing table cards, posters, and signs led to food waste reductions of 13%. Meanwhile, the study in the Indian university canteen indicated that institutional interventions and COVID-19 impacts led to food waste reductions of 50%. Concerning food waste-related differences between the UK and India, culture and food preferences were key reasons for FW in India, with 40.5% more participants stating that they wasted food because the 'food didn't taste good'. A summary matrix of the points discussed thus far is presented (Table (Table11).

Table 1

Constructs of literature review and their sources

Constructs	**Sources**	**Summary**
	Deliberador et al. (2021)	Quality, portion size, satiety, time, and emotion
Reasons and factors behind FW generation	Adeniyi and Afon (2022)	The seasonal influence in the characteristic and quantity of FW
	Qian et al. (2022a)	The weight of FW, education, ethnicity, religious belief, the only child of a family, daily waste habits, family origin (city or town or rural area), household size, family wealth, lunch or dinner, weekdays or weekends, presence of others eating, time pressure, differences in

Constructs	Sources	Summary
		how food is served, food expenditure, the cost of this meal, food taste satisfaction, and awareness campaign
	Qian et al. (2022a) and Zhang et al. (2021)	Age
	Yoon et al. (2023), Qian et al. (2022a) and Zhang et al. (2021)	Gender
	Qian et al. (2022b)	Spatial characteristics
	Zhang et al. (2021)	Consuming behavior
Quantity of FW	Favis et al. (2022)	Ateneo de Manila University (rice waste)—49.48 kilos/day
	Adeniyi and Afon (2022)	Obafemi Awolowo University (OAU)—0.12 kilos/day/per capita
	Martinho et al. (2022)	Portuguese university—18.9/day
	Qian et al. (2022b)	Diverse Chinese universities—0.146 kilos/day/per capita
	Tucho and Okoth (2020)	Jimma University—0.115 kilos/day/per capita
	Li et al. (2021)	Taiyuan University of Technology—0.68 kilos

Constructs	Sources	Summary
	Kasavan et al. (2021), Grech et al. (2020), Feil et al. (2020), Da Rocha Ramos et al. (2022), Leal Filho et al. (2021) and Al-Aomar et al., (2022)	Recycling, recovering resources, composting, and assessment of composting alternatives
	Grech et al. (2020)	Packages
Strategies to solve and prevent	Davison et al. (2022), Martinho et al. (2022), Cavazos et al. (2023), Musicus et al. (2022), Zhang and Kwon (2022) and Leal Filho et al. (2021)	Infrastructural strategies—trayless, reduction of plate and utensil sizes, change menu options, single-use food boxes, adoption of an online prebooking meal system, FW monitoring, composting, and donation
	Favis et al. (2022) and Leal Filho et al. (2021)	Dining halls/cafeteria/canteens maintenance and their FW measurement
	Faezirad et al. (2021)	Minimize waste cost and shortage penalty
	Grech et al. (2020), Davison et al. (2022), Martinho et al. (2022)	Cultural strategies—education

Constructs	Sources	Summary
	and Cavazos et al. (2023)	
	Musicus et al. (2022)	Barriers to FW donation and composting
Benefits of investing in FW reduction	Kasavan et al. (2021)	Economic, social, and environmental benefits
	Davison et al. (2022)	FW reductions from 13 to 50%

Case studies: actions to reduce food waste at universities

Reducing FW requires multifaceted initiatives, involving multiple actors. Alongside governments and the private sector, other stakeholders such as universities have become increasingly accustomed to defining their impacts on climate change and taking adaptation measures (Valls-Val & Bovea, 2021). New products, technologies, and ideas are necessary to satisfy the food supply needs of the global population. Within this frame, universities can help to find solutions to reducing the footprint of products, systems, and technology by allocating more capacity to multidisciplinary research endeavors, while devising innovative curricula to educate students in reducing their own FW impacts (Abdelaal et al., 2019). For example, an electronic food rescue program was developed for university students in the USA to obtain good quality excess food that would otherwise have been wasted (Frank, 2022). Students enrolled in the program receive alerts about the source, type, quantity, and location of the available food, which contributes to enhancing students' food security.

Several universities have acknowledged the potential impact of FW on climate change (Mu et al., 2017; Zhou et al., 2021). Because of this, reducing and repurposing FW on university campuses represent promising means by which to reduce agricultural-related greenhouse gas emissions, reduce food insecurity, and save money (Musicus et al., 2022). Some universities are implementing

food recovery programs where excess food is donated to local organizations such as food banks and charities that serve the poor (Goral, 2018). As plate waste is among the drivers of FW in several universities, encouraging students to decrease their portion sizes and take only what they can eat will help cut food over-supply and reduce the overall FW (Abdelaal et al., 2019; Musicus et al., 2022).

Therefore, several institutions have launched studies to evaluate, monitor, and trace the process of FW, while implementing strategies to reduce it (Mu et al., 2017; Zhou et al., 2021). A sample of action plans and approaches to reducing FW, with case studies from selected institutions is summarized in Table Table22.

Table 2

Actions undertaken by a set of selected universities to handle FW

Country	**Action Plan**	**Outcomes**	**Sources**
USA	A freshman course entitled "Food: A Lens for Environment and Sustainability" was introduced at the University of California, Los Angeles	Students reduced their dietary carbon footprint by reducing significantly their consumption of meat	Jay et al. (2019)
China	Production of biogas and other alternatives from non-edible FW collected from the campus canteens of Huazhong University of Science and Technology	Climate change impact can be reduced by anaerobic digestion of the FW that is converted into electricity and compost	Zhou et al. (2021)
Spain	The University of La Corũna established a decentralized composting service for	Lower cost management of FW by fostering partnerships	Torrijos et al. (2021)

Country	Action Plan	Outcomes	Sources
	vegetable gardens to treat FW generated by canteens	among stakeholders to produce compost for campus gardens	
Qatar	The Qatar Foundation's 14km^2 Education City Campus discovered that overproduction, rather than consumer waste, was the primary source of excessive FW	Reduction of waste in food delivery and consumption channels	Abdelaal et al. (2019)
Canada	Auditing and planned FW sorting at the University of Northern British Columbia	Improve FW categorization for easier recycling in composting	Rajan et al. (2018)

Our analysis of selected case studies revealed that a variety of approaches and methods have been used by universities to reduce FW, which consider the particularities and features of individual institutions. In addition to this, when it comes to tackling FW at universities, it is important to take their specific management, culture, and logistic contexts into account.

Beyond education, instruction on ‘‘how-to” and following the example of others are usually the most effective tools to reduce wastage. Rather than feeling guilty about wasting food, people should feel a sense of responsibility and become aware that by making small adjustments in their everyday food consumption habits, they can contribute to improving the lives of people who are currently hungry (Pinto et al., 2018). Reducing FW at universities helps save money, donate food to the needy or food banks, and generate biogas for energy production and compost for gardening and landscaping (Mu et al., 2017; Reynolds et al., 2019). Thus, reducing FW on campus is now a top priority for universities worldwide.

The way forward in food waste reduction at universities

One of the UN's goals for 2030 is to reduce, by half, the global FW and loss per capita, from production to consumption. Every year the world loses, or wastes between a quarter and a third of all food produced. This volume amounts to about 1.3 billion tons of food, which includes 30% of cereals, 40–50% of roots, fruits, vegetables, and oilseeds, 20% of meat and dairy products, and 35% of fish (UNEP, 2021).

Achieving food security requires a continuous process of educating, training, and raising people's awareness about the importance of consuming consciously, while reducing waste. The interface between sustainability and food is where universities play the role of knowledge 'lighthouses', and experimentation 'sources', but also as outside leaders in public engagement, enabling conversations and intersectoral actions (Corbari et al., 2021) to guide the food system toward ensuring food and nutrition security.

For universities to become vectors of development, they must commit to their core activities—teaching, researching, and extension programs—but also to non-core ones, such as internal policies, aiming to strive for sustainability and decrease waste management. In this sense, they must produce knowledge and develop skills, values, and actions to address and hopefully resolve the intertwined challenges of the present world, including climate change, hunger, poverty, and inequalities.

Reckoning the fact that universities are institutions that produce waste, should inspire these to promote more multidisciplinary education, scientific, and technological research—through a holistic approach—to foster the necessary skills and changes in habits when handling the problem of FW.

Most importantly, campuses should become testbeds where strategies for waste prevention are designed and implemented, preferably against a larger framework of carbon footprint decrease, and through academic collaborations and outreach programs. Within this framework, we envision four initiative areas presented in Table Table33 and the countries and/or regions where they were applied that, if more broadly pursued, could expand further reductions of FW at universities. These are:

1. planning and awareness,
2. food preparation and storage,
3. services, and
4. direct waste reuse.

Table 3

Initiative areas and countries/regions

Countries/Region	Initiatives areas	Measure analyzed/deployed	Sources
Brazil	Planning and awareness; Food preparation and storage; Services	Consumer perceptions of the meals and FW in a Brazilian university dining hall	Deliberador, César and Batalha, (2021)
China	Direct waste reuse	Assess the technical and environmental feasibility of producing energy from non-edible FW on an anaerobic digestion plant, through LCA, produced by 29 canteens at Huazhong University of Science and Technology (HUST)	Zhou et al. (2021)
	Planning and awareness; Food preparation and storage	The study deployed at Taiyuan University of Technology intended to identify the link between FW and university canteens and provide measures to reduce their	Li et al. (2021)

Countries/Region	Initiatives areas	Measure analyzed/deployed	Sources
		environmental (carbon emissions) and cost impact	
Croatia	Planning and awareness	Demographics and behavioral characteristics of university students who contribute to the generation of FW and factors related to knowledge, awareness, and concern	Knezevic et al. (2019)
EUA	Planning and awareness; Food preparation and storage; Services; Direct waste reuse	An overview of the FWd in food service establishments in educational institutions	Kaur et al. (2021)
Finland	Planning and awareness; Food preparation and storage; Services; Direct waste reuse	In a project that promotes a circular food system in the city of Turku, Finland, the aim is to reduce FW in restaurants in the Turku University Campus, recycling the nutrients by composting FW, and reusing them in the process of urban farming	Erälinna and Szymoniuk (2021)
Global	Planning and awareness; Food preparation and	Strategies to reduce FW were analyzed, and mapping the impacts of these strategies on all stages revealed a lack of	Vizzoto et al. (2021)

Countries/Region	Initiatives areas	Measure analyzed/deployed	Sources
	storage; Services; Direct waste reuse	strategies aimed at curbing leftover and serving waste	
	Planning and awareness; Services; Direct waste reuse	Universities' policies and strategies, best practices, and deficiencies that are seen in preventing FW	Leal Filho et al. (2021)
	Planning and awareness; Food preparation and storage; Services; Direct waste reuse	Reduction and repurposing food strategies, and perceived barriers to these strategies among US university food service representatives	Musicus et al. (2022)
Italy and Russia	Planning and awareness; Direct waste reuse	The waste management system in two Italian universities and one Russian university	Rada et al. (2020)
New Zealand	Planning and awareness; Food preparation and storage	FW produced by university students living in shared apartments in an inadequate shopping and inappropriate disposal	Ozanne et al. (2022)
Portugal	Planning and awareness; Service	The School of Agriculture at the University of Lisbon implemented a simple and inexpensive education	Pinto et al. (2018)

Countries/Region	Initiatives areas	Measure analyzed/deployed	Sources
		campaign to raise awareness of reducing plate waste, by establishing the connection between FW and personal behavior	
Spain	Direct waste reuse	There are different composting technologies used at the University of A Coruña (UDC), their investment and operational costs, and the monitoring process	Torrijos et al. (2021)
	Direct waste reuse	Decentralized composting which produces high-quality organic fertilizers for university urban gardens was described and analyzed through the experience of the University of ACoruña (UDC)	Vázquez et al. (2020)

In Table Table33 we realize that various initiatives have been implemented according to different priority needs and the availability of resources for specific universities, from around the world. In the first initiative, a university could give preference to fresh, seasonal, organic, or whenever possible, locally sourced food (Li et al., 2022; Vizzoto et al., 2021) as part of their planning strategies. Introducing some menus which may be cooked on demand, at short time intervals (e.g., pasta, rice, flatbreads, panini, pizzas, and more bakery foods), may help to minimize FW while satisfying variations on demand. This approach may also help to promote a healthier diet, encourage university canteens and restaurants to reduce their CO_2 emissions, and could help universities to reduce the

use of plastic packaging. Planning and awareness initiatives demand studies about the characteristics of university students by dining hall managers and university offices that aim to be more sustainable (Knezevic et al., 2019).

The second initiative (food preparation and storage) demands 'ad hoc' training for service staff to acquire the necessary food preparation and storage skills to make full use of food products, reduce the waste of fresh produce, and ensure adequate space for the preservation of foodstuff. Students are another group at universities campus that require education to become more conscious about their food buying habits, training for meal preparation, and sustainable food disposals (Ozanne et al., 2022). There is also a demand for training dining hall employees about planning for production and disposal support in the management of FW (Erälinna & Szymoniuk, 2021). According to some drivers (functional, behavioral, contextual, and demographic), Kaur et al. (2021) divided into pre-consumer (production waste) and post-consumer (consumption waste) stages of FW and found some strategies to decrease it.

The third initiative is about services, as universities should implement procedures to offer choices of healthier food options and adequate portion sizes. Dining halls can strategize campaigns to educate their patrons to take what they want to eat, in a sufficient amount (Deliberador, César & Batalha, 2021), thus preventing the need to dispose of leftover foods, besides launching educational campaigns to promote a connection between FW and personal behavior (Pinto et al., 2018).

The fourth initiative, direct waste reuse, recycling can be useful, along with the provision of specific bins for selective waste collection to allow composting and anaerobic digestion at a later stage (Leal Filho et al., 2021; Vázquez et al., 2020). Furthermore, some types of waste can be converted into various forms of renewable energy. For example, cooking oil can be used to make biodiesel, while FW can be turned into biogas and/or heat (Zhou et al., 2021). The dissemination of source separation criteria within the community and the sharing of good practices between universities play a key role in improving the level of sustainability in the education sector (Rada et al., 2020). Universities can

also donate their excess food to non-profit organizations, provided they comply with food safety procedures and legislation to prevent the risk of foodborne diseases, or even donate to animal feed production and use the waste for composting by technologies created for this purpose (Goral, 2018; Torrijos et al., 2021). Despite implementing these and many other initiatives, there are several barriers to achieving sustainable FW management, as Musicus et al. (2022) reported from studying this problem at universities in the USA.

Conclusions

This paper has shown that FW is a matter of significant concern to universities, and urgent efforts are needed to address it while developing effective approaches aimed at reducing it. Key drivers of FW at universities include over-supply of food, plate waste, inefficient food management practices, and lack of awareness of FW prevention.

This issue has major ecological and socioeconomic implications, including a high environmental footprint, economic loss, and food insecurity for increasing segments of society, even in affluent countries. Reducing FW via food recovery, enhancing the efficiency of the food supply chain, and educating the university community to adjust their daily lifestyle to reduce FW can help create environmentally sustainable campuses and a more equitable society.

This paper has some limitations, however. The first one is related to the fact that the sample of universities considered in the case study analysis cannot be regarded as comprehensive. This is because it is aimed at providing a profile of current trends, and not a worldwide overview. The second limitation is the scope of the study, which examined FW without expanding into the various aspects of food production. Yet despite these limitations, the paper provides a needed addition to the literature since it tackles a matter of distinctive relevance to universities while considering a problem that has notable, ethical implications.

Ultimately, the best way to handle FW is by preventing it in the first place. To achieve this goal it is very important to engage all students (at every level of instruction) in active learning focused on growing food whether this occurs on campus, or not. Obviously, a campus demonstration farm, or at least, a modest size garden are ideal spaces to foster food systems education (Sottile et al., 2016). These may act as living labs around which all curriculum subjects can be connected because the frame of instruction at these sites is supportive of ecocentric learning (Borsari, 2012). In a university garden, students have numerous opportunities to develop skills in growing their food, while understanding stewardship values and restorative practices, that cannot be taught from lectures only, within the walls of a classroom setting. In addition, in a university garden, the compost site becomes the keystone space where learners realize that there is no waste in nature because everything is part of a continuous cycle, Thus, crops stubbles, rotten fruits, and similar residues are not waste, but rather resources that, if properly composted, will regenerate ecologically soil fertility, which contributes to a sustainable, food growth (Borsari, 2020). Even a one-time-only exposure to this and similar hands-on activities can become transformative in the education of all learners and contribute effectively to expanding awareness about FW reduction while pursuing human and planetary health (Borsari & Vidrine, 2022).

In this context, the design of zero waste programs may be very helpful, even though their implementation can be challenging. In a world where many countries face poverty and hunger, it is a paradox that FW continues to occur. There is no space for FW in a sustainable world! Universities should invest more funds and resources in getting this message across to society through efforts (often spurred by some students' clubs), to convert campus open space into (prairie, herbs, edible, vegetables, pollinators, rain, and more) gardens. Campus landscape diversification has the potential to reconnect human beings with nature, food, and associated resources to grow it. A re-establishment of these vital links is sorely needed to remediate excessive, consumptive habits that should become superseded instead by a culture of NO waste and sustainability. This end goal will be achieved only when more universities will tie their study programs to a more sustainable design and

management of their open space supported by ecocentric instruction, where food systems studies have emerged as keystone themes of curricula.

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Authors' contributions

W.L.F. contributed to conception of article, structuring, coordinating, and quality control; P.C.C.R. performed writing and reviewing; A.F.F.S., F.M.S.A., I.R.A., J.C.A., U.T., P.G.O., and K.F. performed writing; B.B. contributed to writing, reviewing, and quality control.

Data Availability Statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflict of interest

The authors declare no competing interests.

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