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Research Article

Assessing and addressing plate waste in university dining: A dual-design study at Brescia University College in Ontario, Canada

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Abstract

In Canada, approximately 35.5 million metric tonnes of food are wasted annually, with avoidable food loss and waste costing Canada $49.5 billion (Nikkel et al., 2019). The volume of food waste in Canada harms environmental sustainability and leads to economic inefficiency and social inequality (Soma, 2022). This study at Brescia University College explored methods to reduce plate waste in a university restaurant. Using two research designs, this study first analyzed and categorized all plate waste, finding non-food waste predominantly during breakfast (59.8 percent) and lunch (54.3 percent). Edible waste was highest during dinner (51.0 percent); carbohydrates contributed to the most waste (54.5 percent) and plant-based protein (3.1 percent) the least.

The second design involved student participation in waste weighing and completing questionnaires. Results showed a median edible waste of 19.0g, with fullness, poor taste, large portion size, and inability to bring home leftovers as the main reasons for waste. Meal plan students had a significantly higher amounts of plate waste than non-meal plan students ($p<0.001$).

Recommendations include serving smaller portions, improving food taste, and offering storage solutions for leftovers.

Keywords: Consumer attitudes; consumer behaviours; food waste; plate waste; university dining hall; university restaurant; university students

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Résumé

Au Canada, environ 35,5 millions de tonnes métriques d'aliments sont gaspillées chaque année ; les pertes et le gaspillage alimentaires évitables coûtent 49,5 milliards de dollars au Canada (Nikkel et al., 2019). Le volume de déchets alimentaires au Canada nuit à la conservation de l'environnement et conduit à l'inefficacité économique et à l'inégalité sociale (Soma, 2022). Cette étude menée au Brescia University College a exploré les moyens de réduire les restes d'assiette jetés dans un restaurant universitaire. Suivant une première méthode de recherche, nous avons d'abord analysé et catégorisé tous les restes d'assiette jetés. Nous avons constaté que les déchets non alimentaires prédominaient au déjeuner (59,8 %) et au dîner (54,3 %) ; les déchets comestibles étaient les plus nombreux au souper (51,0 %) ; les glucides y contribuaient le plus (54,5 %) et les protéines d'origine végétale (3,1 %) le moins.

La seconde méthode de recherche a impliqué des étudiants et étudiantes dans la pesée des déchets et le remplissage de questionnaires. Les résultats ont montré que la médiane des déchets comestibles était de 19,0 g. Les principales causes de gaspillage étaient la satiété, le mauvais goût, la grande taille des portions et l'impossibilité d'apporter les restes à la maison. Les étudiants bénéficiant d'un menu préconçu jetaient une quantité de restes significativement plus élevée que les étudiants n'en bénéficiant pas ($p<0,001$).

Les recommandations qui découlent de l'étude sont de servir des portions plus petites, d'améliorer le goût des mets servis et de proposer des options de conservation pour les restes.

Introduction

Food waste has received increased global attention in the past few years due to its high volume and adverse environmental, economic, and social consequences (Wu et al., 2019). Globally, approximately one-third of all food produced for human consumption is lost or wasted (Tarczyńska et al., 2023). Food waste relates to land use, greenhouse gas emissions, and water consumption (Wu et al., 2019). In Canada, approximately 35.5 million metric tonnes of food is wasted annually, with avoidable food loss and waste costing Canada $49.5 billion (Nikkel et al., 2019). The volume of food waste in Canada negatively affects environmental sustainability and leads to economic inefficiency and social inequality (Soma, 2022). Almost 60 percent of the environmental footprint created by the food industry comes from food loss and waste, of which a significant portion is avoidable. Discarded food in landfills produces methane gas, which is 25 times more damaging to the environment than carbon dioxide (Nikkel et al., 2019). Not only does food waste in Canada affect Canadian consumers, it also impacts global agriculture (Soma, 2022). Therefore, two key issues of food supply chain management are the reduction and prevention of food waste (Tarczyńska et al., 2023).

One definition of plate waste is "the uneaten quantity of edible food remaining on the consumer's plate after a meal" (Wu et al., 2019). This preventable waste depends on consumer characteristics such as appetite, preference, adequacy of portion size, and a meal's sensory attributes (Martinho et al., 2022). Food waste is categorized as edible or inedible and can be both avoidable or unavoidable (Wu et al., 2019). Avoidable food waste is

considered edible under normal circumstances, whereas unavoidable food waste, such as bones and peels, is inedible under normal circumstances (Deliberador et al., 2021a). Effective food waste prevention strategies must target avoidable food waste (Deliberador et al., 2021a). However, what is considered edible and inedible under normal circumstances differs between individuals and is impacted by culture, religion, and various social norms (Filho et al., 2021).

Determining the amount of food and plate waste can lead to effective intervention implementation, resulting in financial savings and having a beneficial effect on environmental sustainability (Deliberador et al., 2021a**).** According to the Food and Agriculture Organization of the United Nations, a sustainable food system is "a food system that delivers food security and nutrition for all in such a way that the economic, social, and environmental bases to generate food security and nutrition for future generations are not compromised" (FAO, 2018). A key component of sustainable food systems is the reduction and redistribution of food waste to provide access to food to those experiencing food insecurity. Food waste encompasses nutrition loss as the foods most often wasted are those with a higher nutritional profile. One of the most wasted food items is fruits and vegetables (Brennan & Browne, 2021). Therefore, food waste reduction is crucial to create sustainable food systems that ensure food security and provide all populations with access to sufficient nutrients (Martinho et al., 2022).

Research indicates that in developed countries, most food waste occurs at the consumption stage, while in developing countries, it primarily results from losses during production (Qian et al., 2021). Previous research has also shown that individuals between the ages of 18 and 24 years tend to waste more food compared to individuals from other age groups, making university students a vital population for study (Tarczyńska et al., 2023). University canteens in various countries report high food and plate waste with values ranging from 25 to 135 g of plate waste per consumer per meal (Martinho et al., 2022). These high waste values make university restaurants a primary target of waste reduction strategies. University canteens also significantly contribute to students' out-of-home food consumption (Martinho et al., 2022; Zhao & Manning, 2019). Wiriyaphanich et al. (2021) highlight the importance of investigating common drivers of students' food choices and waste behaviours in university dining settings as they begin to form independent long-term food habits. Students' behaviours and perceptions can help inform which food/plate waste reduction strategies could be incorporated into students' long-term food habits (Wiriyaphanich et al.; 202, Zhao & Manning, 2019). University restaurants are also viable locations for food waste research as both meal and waste occur in one location (Wilkie et al., 2015).

Food waste behaviours are complex; an understanding of consumer perspectives is needed to inform prevention strategies (Wiriyaphanich et al., 2021). Plate waste reduction solutions require an in-depth understanding of the factors that influence consumer food loss behaviour (Filho et al., 2021). Globally, developed countries have greater food and plate waste than developing countries (Filho et al., 2021). Many solutions to Canada's food waste crisis have been implemented (Soma, 2022), including educational approaches such as the Love Hate Waste Canada awareness campaign and policy approaches such as Ontario's Food and Organic Waste Framework Action Plan (Soma, 2022). However, many universities in Canada lack consumer food waste prevention strategies (Soma, 2022).

Wu et al. (2019) find a significant portion of food wasted at a consumer level can be attributed to the large volume of plate waste generated by university students.

A study by Ellison et al. conducted in 2019 finds that students from American universities waste approximately 88.2 g of food per meal. Plate and food waste on university campuses mainly occur in student restaurants/canteens (Qian et al., 2021). Menu variety, composition, and daily variation in the number of consumers impact both consumer demand and level of food waste and are affected by the weather, holidays, and student activities, making this a very complex issue (Martinho et al., 2022). Filho et al. (2021) estimate that universities generate 540 million tons of food waste worldwide each year. Within universities, plate waste is the most significant contributor to the amount of food waste at the consumer level (Filho et al., 2021). Decreased options, palatable special dishes, and reduced portion size are all shown to minimize plate waste (Filho et al., 2021). Large amounts of food waste are shown to indicate an operational deficiency and may result from poor quality or taste of food, inappropriate portion size, or menu inefficiency (Deliberador et al., 2021a).

Previous studies examine university students' behaviour and food waste awareness, but few are conducted in Canada (Tarczyńska et al., 2023). Despite increased investigation into student plate waste in university canteens, research specific to Canada is lacking (Qian et al., 2021). Previous studies were conducted in China, Poland, Portugal, the United States, Brazil, Switzerland, Thailand, and Germany (Qian et al., 2021; Wu et al., 2019; Tarczyńska et al., 2023; Martinho et al., 2022; Aires et al., 2021; Wiriyaphanich et al., 2021; Deliberador et al., 2021b; Visschers et al., 2020; Thongplew et al., 2021; Gabriel et al., 2021).

Many universities conduct food waste audits for statistical and economic purposes. Conversely, this study did not simply evaluate how much food was wasted but sought to establish why students wasted food, which student characteristics were associated with plate waste, and which meals generated the most waste. This study aimed to answer how dining halls could minimize plate waste and asked students directly what their dining hall could do to reduce plate waste. Because this research occurred in a developed country, plate waste was the primary waste of interest.

This study had two objectives: The first was to quantify and compare estimated food plate waste during major meals at the dining hall. The second was to identify causes and factors related to plate waste at the dining hall and student demographics associated with increased individual edible plate waste. Specifically, the study looked at differences in the amount of plate waste between meal plan and non-meal plan students and between food and nutrition students and non-food and nutrition students.

Methods

This study was conducted at Brescia University College, an affiliate of Western University in London, Ontario, Canada. Brescia University College is a women's university founded in 1919 and is committed to the educational development of women (*Food Services—Brescia University College,* n.d.). Research took place in Brescia's dining hall at the Clare Hall residence building (WR), the Mercato (*Food Services—Brescia University College*, n.d.). The Mercato consists of a salad bar, stone pizza oven station, grill, rotisserie, sandwich station, and a global station that offers different cultural dishes every day (*Food Services—Brescia University College*, n.d.).

Meal options include vegetarian, vegan, gluten-free, dairy-free and halal (*Food Services—Brescia University College*, n.d.). Each station offers students a customizable meal of the day where they can choose their own protein, fruits, vegetables, and grains.

Students living in residence must purchase the meal plan, whereas students living off campus can choose to buy it if they wish. The meal plan is valid for any item purchased at the Mercato or at the Brescia Starbucks kiosk.

This study consisted of two separate study designs, each conducted at different times. Data collection for both excluded weekends and reading weeks as many students were off campus during these times.

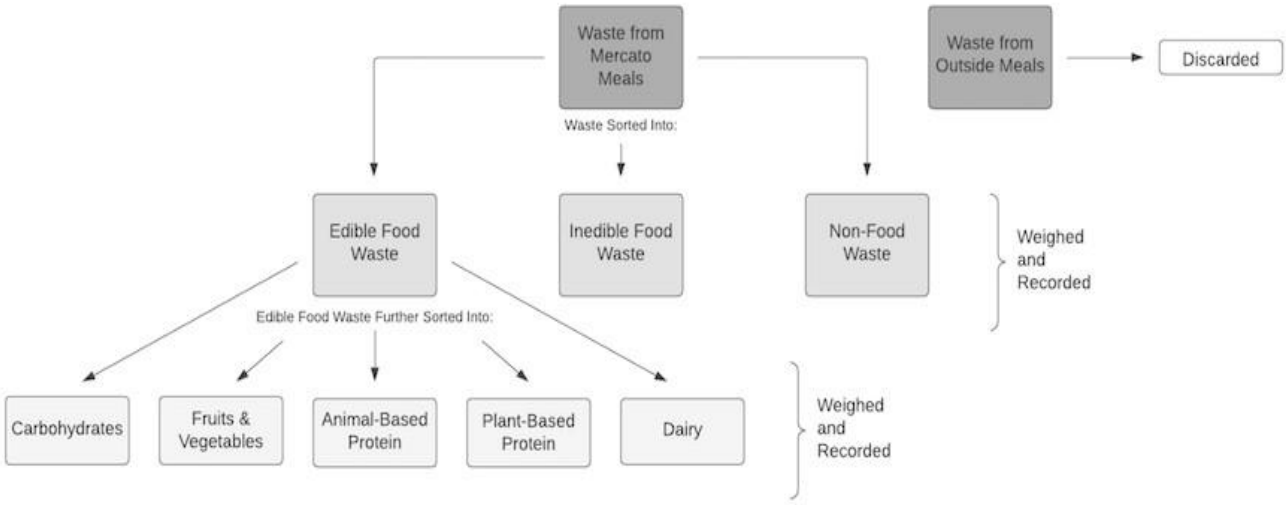
Study design 1: The food waste audit

The first study conducted was a waste audit. Researchers collected all garbage disposed of at the Mercato during major mealtimes. Food waste was collected three times during breakfast between 7:00 am and 9:00 am, three times during lunch between 11:30 am and 1:30 pm, and three times during dinner between 4:30 pm and 6:30 pm. To account for day-to-day changes in consumption and waste volume, collection occurred on nine different days and covered every day of the week. Participants included staff, students, and the public, as all individuals who disposed of waste in the labelled garbage bins were included.

At the beginning of each designated mealtime, researchers labelled half of the garbage bins in the Mercato with the following label: "GARBAGE FROM MERCATO MEALS ONLY. If you are disposing of trash from outside meals, please use labelled garbage bins in the Mercato." The remaining garbage bins were labelled "GARBAGE FROM OUTSIDE MEALS ONLY." The labels were taped on one side over the opening of the garbage bin and required the individual to lift the label to dispose of waste. Consent was not collected as there was no researcher interaction with participants. Following the designated mealtimes, researchers and volunteers collected the trash bags from the bins labelled "GARBAGE FROM MERCATO MEALS ONLY" and sorted the contents into edible, inedible, and non-food waste. In this study, *edible food waste* was defined as any food that humans can consume. *Inedible food waste* was defined as any food not usually consumed by humans, including peels and bones. *Non-food waste* was classified as any waste that was not a food item (e.g., napkins, containers, and straws). The sorted contents of each category were weighed and recorded by the researcher and volunteers. In total, nine samples (three from each mealtime) were collected.

Edible food waste was sorted into fruits and vegetables, animal protein, plant-based protein, carbohydrates, and dairy. These categories were weighed and recorded. A summary of this design is shown in Figure 1. Fruits and vegetables are also included in the carbohydrate category as they are a type of carbohydrate. Similarly, dairy was included in the animal protein category as it is a type of animal protein. Fruits and vegetables and dairy were also weighed separately as this aligned with methods from similar studies. Therefore, they were counted twice, once individually, and once as part of their respective category.

Figure 1: Study design 1: Food waste audit methodology



Study design 2: Measurement of individual plate waste and distribution of questionnaire

The second component of this study was a cross-sectional design with a convenience sample. Data were collected on weekdays during lunch (between 11:30 and 2:30 p.m.) and dinner (between 4:30 and 7:30 p.m.) as these were the busiest times at the Mercato and when recruiting participants would be more likely. A researcher station was set up at the Mercato to weigh students' individual plate waste and have them complete the questionnaire. Recruitment posters advertising the chance to win one of four $25 gift cards were taped on one side of the opening of the garbage bins to encourage students to participate. Posters were placed to recruit students before they discarded leftover, as recruiting before meals could influence behaviour. A recruitment poster was also posted on the bins near the dish pit to recruit students who ate their entire meal.

The poster instructed participants to approach the research station with their leftovers, where they read and signed an information letter and consent form. Researchers sorted students' plate waste and weighed the edible waste. Participants then filled out a five-minute questionnaire that asked demographic questions, their reasons for throwing food away, whether they were on the meal plan, and whether they were studying food and nutrition, as a comparison of waste among different student demographics was of primary interest to this study.

Participants' individual edible waste weight, in grams, were identified on their questionnaire with a number. Consent forms were kept separate from questionnaires to maintain anonymity.

This study design included undergraduate and graduate students who purchased a meal at the Mercato. Staff and outside visitors were excluded. Participants from the food waste audit were excluded from participating again.

Statistical analysis

Data analysis was conducted using SPSS® (Statistical Package for the Social Sciences) software, version 29.0. Based on our literature review, we chose 35 g as the detectable difference based on sample size calculations using an expected standard deviation of 63 g, a power of 0.80, and a significance level of 0.05. At a 35 g difference between means, the required sample size dropped to 51 per group compared to 100 per group for a 25 g difference. This made recruitment more feasible. We recruited 121 participants, of which there were 63 meal plan students, 58 non-meal plan students, 54 students studying food and nutrition, and 67 students not studying food and nutrition. This study determined a probable impact of education on reducing food waste. With over 51 participants in each interest group the sample size calculation results were met and statistical analysis proceeded as planned.

Study design 1: The food waste audit

We ran descriptive statistics to compare average total waste during mealtimes, average edible plate waste during busy mealtimes, and average waste in each food category. Two separate two-way ANOVAs were used to compare the mean weight of each waste type at different mealtimes, classified by meal type (breakfast, lunch, and dinner). Waste type represented edible, inedible, and non-food waste as well as different edible waste types: fruits and vegetables (FV), carbohydrates, plant-based protein (PBP), animal-based protein (ABP), and dairy. The first two-way ANOVA compared mean weight of edible food waste to inedible and non-food waste. The second two-way ANOVA compared types of edible food waste. Parametric statistics were used as there were minor variations between the means and medians in each of the above categories.

Study design 2: Measurement of individual food waste and distribution of questionnaire

Descriptive statistics were used to analyze participant demographics, their reasons for throwing away plate scraps, and how to reduce plate waste. Normality testing indicated that the data did not fit a normal distribution; therefore, median was reported in place of mean and non-parametric statistics were used.

The non-parametric equivalent of the independent samples t-test (independent samples Kruskal–Wallis test) was used to compare weight of edible plate waste with participant demographic data. Separate tests were run to compare weight of edible plate waste to students' year of study, whether students were on the meal plan, number of meals participants consumed per week at the Mercato, whether students were in a food and nutrition program, and their ethnic background.

To identify common themes among participants' responses, qualitative analysis reviewed responses to the open-ended question, "what could the Mercato do to reduce food waste from plates?"

Results

Study design 1: The food waste audit

Descriptives

Out of the overall weight of waste collected, non-food waste contributed the greatest volume during breakfast and lunch and edible food waste was the most significant contributor during dinner. Inedible food waste contributed the least to the overall weight of sorted waste across all three mealtimes. Mean values of sorted waste are in Table 1. Analysis revealed a significant difference in the amount of edible, inedible, and non-food waste across breakfast, lunch, and dinner. The amount of edible waste was significantly lower during breakfast compared to lunch and dinner, where dinner had the greatest ($p<0.001$). Similarly, inedible waste was minimal during breakfast but increased significantly at lunch and dinner, where dinner had generated the greatest amount ($p<0.001$). Breakfast showed significantly lower values of non-food waste than lunch and dinner, which were not significantly different from each other. Several studies that examined food waste patterns across different mealtimes provided valuable comparative insights. Wang et al. (2017) investigated restaurant food waste in Chinese cities and found that dinner services generated significantly more waste than lunch services; this aligned with our finding of higher edible waste at dinner. Silvennoinen et al. (2015) analyzed food waste in Finnish households, reporting that the largest volume of food waste was associated with dinner preparation and consumption. This further supported the observed trend of increased edible waste during dinner. Additionally, Betz et al. (2015) examined food waste in the Swiss food service sector; dinner contributed to the highest levels of both edible and inedible waste compared to other mealtimes. A report by the Natural Resources Defense Council (Hoover, 2017) also highlighted that, per guest, food waste at lunch and dinner was more than double that of breakfast, reinforcing the significant difference in waste generation across meals. Similarly, a study of snack frequency and food waste found that lunch and dinner significantly increased the likelihood of food waste compared to breakfast, with per capita waste measured at 22.39 g at breakfast, 55.28 g at lunch, and 54.24 g at dinner. Collectively, these findings reinforced the significant difference in food waste across meals and emphasized the need for targeted waste reduction strategies, particularly for dinner services where waste was highest.

The similarity between mean values and standard deviation may indicate that reporting the median would be more appropriate. Standard deviation represents how dispersed data points are in relation to the mean. Low standard deviation indicates that data are clustered close to the mean, whereas high standard deviation means data are more spread out. In cases where the standard deviation is low, the median is the most appropriate measure of central tendency. However, we used the mean as the measure of central tendency, as when testing for normality the Shapiro–Wilks test showed an overall non-significant difference between the data and normality. This meant the data fit the normal curve enough to report the mean and to use parametric statistics.

Table 1: Mean weights of edible, inedible, and non-food waste from all mealtimes.

Waste Type	Breakfast	Lunch	Dinner	All Mealtimes
	Mean ± SD (g)			
Edible	199.1 ± 16.1	1982.5 ± 638.9	2620.8 ± 166.5	1600.8 ± 1136.1
Inedible	8.6 ± 7.5	141.4 ± 79.8	193.0 ± 106.2	114.3 ± 105.9
Non-Food Waste	309.7 ± 91.8	2519.8 ± 2635.5	2383.8 ± 713.7	1737.8 ± 1736.8
All Waste Types	172.5 ± 139.9	1547.9 ± 1734.1	1732.6 ± 1216.9	1150.9 ± 1374.8

When comparing the types of edible food waste evaluated in this study, carbohydrates were the most significant contributor across all three mealtimes, contributing an average of 57 percent of edible food waste. Fruits and vegetables were the second largest category at breakfast and dinner, contributing 22 percent and 29 percent of edible food waste. However, the second largest category at lunch was animal protein, contributing 20 percent. The results indicated that more animal protein (14.8 percent) was wasted than dairy (3.3 percent), which was wasted more than plant-based protein (3.1 percent) across all three mealtimes. A breakdown of the mean values of the sorted waste is shown in Figure 2. Again, though the mean values and standard deviation are similar, the mean was reported as the Shapiro–Wilks test for normality indicating an overall non-significant difference. A breakdown of the percentages of the types of edible waste across all mealtimes is shown in Figure 3.

Figure 2: Mean amount of each waste type per mealtime

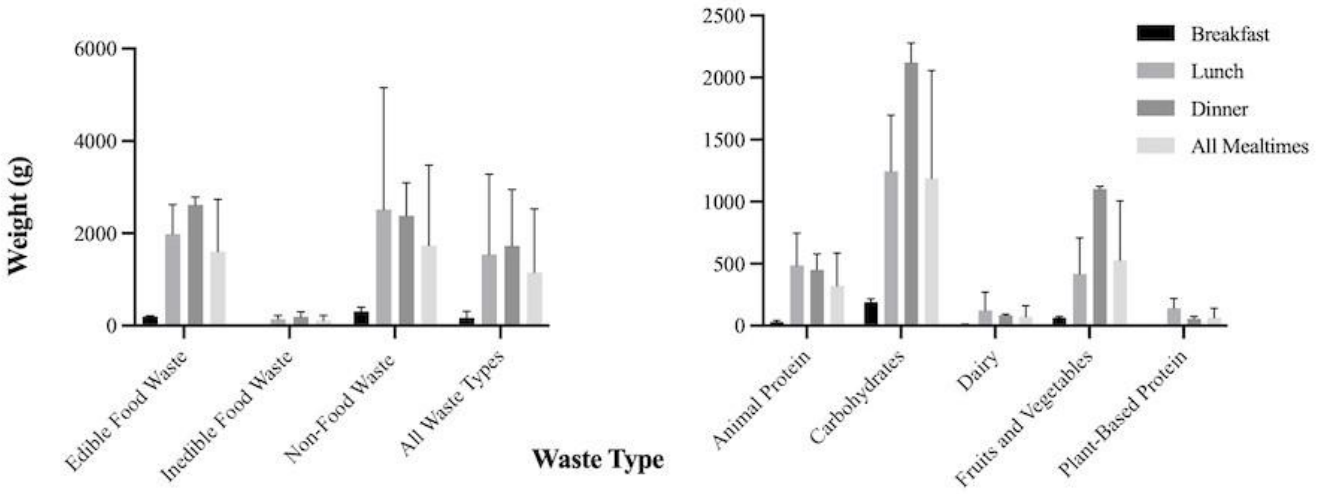
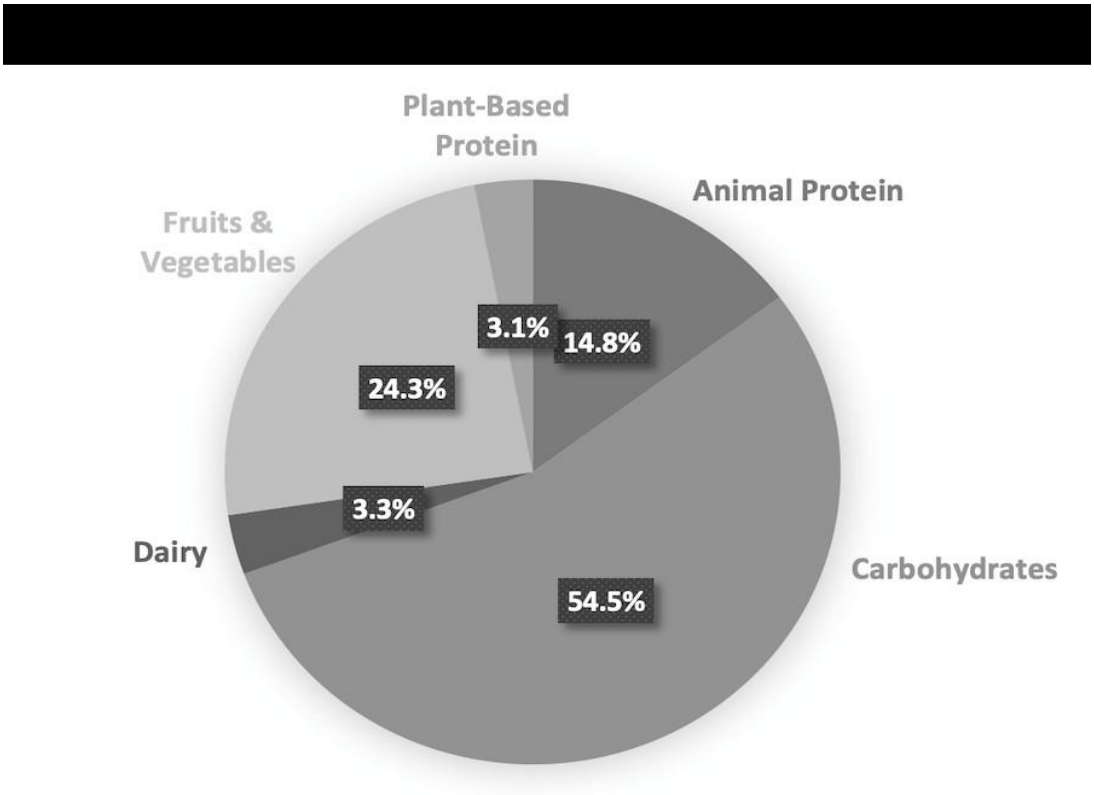


Figure 3: Percentage of edible food waste types at all mealtimes



Weight comparison of edible, inedible, and non-food waste

When comparing the mean weight of edible, inedible, and non-food waste using a two-way ANOVA, there was a significant difference between meal type and weight and waste type and weight ($p = 0.004$ and $p = 0.003$). However, there was a non-significant difference between meal type and waste type. Post hoc analysis found that the amount of edible, inedible, and non-food waste at breakfast significantly differed from lunch and dinner ($p = 0{,}006$, $p = 0.016$). However, lunch and dinner were not statistically different ($p = 0.909$).

Weight comparison between types of edible food waste

A two-way ANOVA was used to compare the mean weight of each type of edible food waste (fruits and vegetables (FV), carbohydrates, animal protein (AP), plant-based protein (PBP), and dairy). Significant results were found between meal type and waste type when compared together and individually ($p<0.001$). A statistically significant difference was found between meal type and weight ($p<0.001$) and between waste type and weight ($p<0.001$). A significant difference was also found when meal type and waste type were compared to weight ($p<0.001$).

Similar to the results when comparing edible, inedible and non-food waste, a significant difference

was found between breakfast and lunch as well as breakfast and dinner ($p<0.001$). Again, a non-significant difference was found between lunch and dinner ($p = 0.078$).

Study design 2: Measurement of individual plate waste and distribution of questionnaire

Demographics

A total of 121 female students from Brescia University College participated in the study. Slightly more participants were on the meal plan than not, and a greater proportion were non-food and nutrition students, which is consistent with Brescia's overall enrollment demographics. Most participants were in their first year of study; graduate students were underrepresented.

In terms of ethnicity, just under half of the participants identified as white, followed by Chinese, Arab, South Asian, and Black. A small number of students identified as Latin American, Southeast Asian, West Asian, Japanese, or multiple ethnicities. These responses were grouped into the "Other" category for analysis along with mixed and written-in responses.

Meal frequency at the Mercato dining hall varied; the largest group consumed only one to five meals per week, even though many participants were on the meal plan. Fewer participants than expected reported a higher meal frequency at the Mercato.

A detailed breakdown of the demographic data is presented in Table 2.

Table 2: Demographic characteristics of study participants (n = 121).

Characteristics	Variable	*N* (%)
Gender	Female	121 (100)
Ethnicity/Race	White	60 (49.6)
	South Asian	8 (6.6)
	Chinese	21 (17.4)
	Black	7 (5.8)
	Arab	10 (8.2)
	European	4 (3.3)
	Korean	3 (2.5)
	Other	8 (6.6)
Meal Plan	Yes	63 (52)
	No	58 (48)
Study Subject	Food & Nutrition	54 (45)
	Non-Food & Nutrition	67 (55)
Current year of study	First year	34 (28.0)
	Second year	21 (17.4)
	Third year	28 (23.1)
	Fourth year	22 (18.2)
	Fifth year or later	14 (11.6)
	Graduate	2 (1.7)
Meals Per Week Consumed in the Mercato*	1-5	50 (41.7)
	6-10	16 (13.3)
	11-15	19 (15.8)
	16-20	14 (11.7)
	21-25	21 (17.5)

*- n=120, one participant did not respond

*It is important to note that data reflecting demographic proportions of the entire Brescia population were not available for comparison.

Perception/opinion of food waste

Ninety percent of participants indicated having left one-quarter or less of their plate of food uneaten. Only 2.5 percent indicated having left three-quarters to a whole plate of food uneaten. The most common reasons participants identified for having wasted food or having plate waste were fullness or lack of hunger, poor taste, too large of a portion size, and inability to store/bring home leftovers. Lack of awareness surrounding food waste was the least cited reason for wasted food. Twelve percent of participants indicated that a poor ratio/balance of carbohydrates to vegetables to meat was a reason for having thrown food away. At the Mercato, carbohydrates are typically provided in a larger portion; therefore, they are thrown away. If meals were better balanced, this may eliminate additional carbohydrate waste. Sixteen participants answered "other." The least common theme from responses was not having an awareness of plate waste. A summary of the responses is found in Figure 4. Approximately half of participants (54.6 percent) indicated that they thought students on the meal plan would have more waste than those not on the meal plan. A summary of participants' perception and opinion of food waste is found in Table 3. Qualitative analysis revealed the most common responses participants gave to the question "what could Mercato do to reduce food waste from plates?" were to reduce portion size, provide storage for leftovers, improve the taste of the food, and offer more self-serve options. A summary of the responses to this question is found in Table 4.

Table 3: Participants' perception and opinion of food waste

Category/Question	Variables	*N* (%)
Average amount of uneaten food remaining on plate (N=120)	None	52 (43.3)
	¼ of plate	56 (46.7)
	½ of plate	9 (7.5)
	¾ of plate to whole plate	3 (2.5)
Reasons for wasting food/having plate waste (N=119)	Portion served by staff too large.	39 (32.8)
	Portion served by me too large.	15 (12.6)
	Full/lack of hunger.	54 (45.4)
	Poor taste of food.	48 (40.3)
	Time restraints.	9 (7.6)
	Not aware of food waste issue.	3 (2.5)
	Cannot take/store leftovers.	38 (31.9)
	Cold food.	5 (4.2)
	Poor ratio/balance of carbohydrates to vegetables to meat.	15 (12.6)
	Wanted full amount regardless of how much I wasted because already paid.	7 (5.9)
	Other	16 (13.4)
Predicted effect of the meal plan on the amount of food wasted by students in the Mercato (N=119)	More waste	65 (54.6)
	Less waste	24 (20.2)
	No effect on waste	30 (25.2)
Willing to purchase imperfect fruits and vegetables (N=119)	No	38 (31.7)
	Yes	82 (68.3)
	Yes without discount	30 (36.6)
	Yes with discount	52 (63.4)
	10% discount	18 (34.6)
	25% discount	20 (38.5)
	50% discount	11 (21.2)
	75% discount	1 (1.9)
	90% discount	1 (1.9)
Willing to purchase a meal that does not meet perfect visual standards	No	23 (19.2)
	Yes	97 (80.8)
	Yes without discount	64 (66)
	Yes with discount	33 (34)
	10% discount	13 (39.4)
	25% discount	14 (42.4)
	50% discount	6 (18.2)
	75% discount	0
	90% discount	0
Willing to purchase product close to the best before date	No	29 (24.2)
	Yes	91 (75.8)
	Yes without discount	54 (59.3)
	Yes with discount	37 (40.7)
	10% discount	12 (32.4)
	25% discount	11 (29.7)
	50% discount	13 (35.1)
	75% discount	0
	90% discount	1 (2.7)

Table 4. What can the Mercato/Brescia do to reduce plate waste? Open-ended question responses

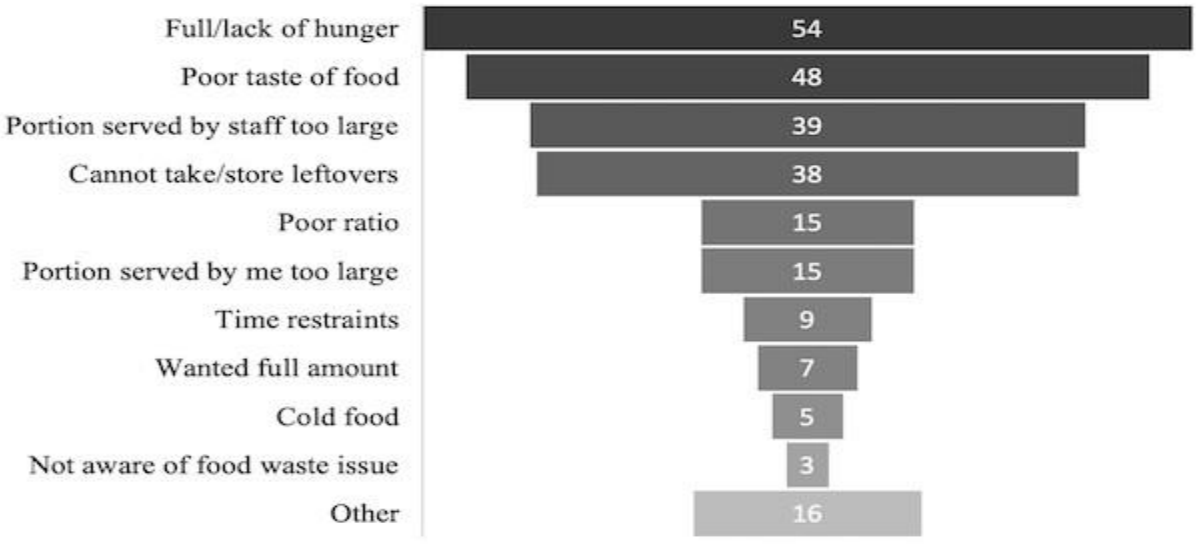
Theme	% of Responses	Participant Response Examples
Portion Sizes	51%	"Have portion size to choose." "Either smaller portions or more weighted options." "Offer various different portion sizes to choose from rather than one serving size." "Sell meals in different portion sizes i.e., small, medium, large." "Reduce the portion, increase the selection of sizes to allow everyone to get the portion size best for them."
Improve Taste	16%	"Improve the taste of food." "Make the food taste good." "Make the meal flavourful." "Make food taste better, add salt and seasonings, meals are sometimes bland."
Self-Serve	8%	"More self-serve stations." "Offer a buffet." "Let students serve themselves."
Storage Solutions	7%	"Provide mini fridges in study spaces so food can be stored when students are in class." "Give students a place to store leftovers when in class."

Comparison of plate waste weight according to participant demographics

The median weight of edible plate waste of participants was 19.0 g, with a minimum of 0 g and a maximum of 298 g.

The independent sample Kruskal–Wallis test indicated a statistically significant difference in the weight of edible plate waste between meal plan and non-meal plan participants ($p<0.001$); participants on the meal plan had more edible plate waste than those not on the meal plan. There was no statistically significant difference in weight of plate waste of food and nutrition students and non-food and nutrition students ($p = 0.844$) nor in participants' ethnic background ($p = 0.870$). A statistically significant difference was found between number of meals consumed at the Mercato per week and amount of edible plate waste ($p<0.001$). The more meals consumed per week at the Mercato, the higher the amount of edible plate waste. Meal plan students typically consumed more meals at the Mercato than non-meal plan students. As meal plan students had high amounts of edible plate waste, this may contribute to the correlation between number of meals eaten at the Mercato per week and a higher amount of plate waste. There was no statistically significant difference between participants' year of study and and amount of edible plate waste ($p = 0.145$). However, there was a significant difference between fourth-year and first-year students, fifth-year and first-year students, and third-year and first-year students ($p = 0.016$, 0.049, 0.047, respectively). Therefore, it is concluded that first-year students had higher levels of plate waste than third-year or later students. Within the sample, there were more first-year students on the meal plan than in other years of study. As meal plan students generated more plate waste than non-meal plan students, this may be a reason why first-year students had higher levels of plate waste than students in their third year or later.

Figure 4: Participants' reasons for plate waste



Discussion

Study design 1: The food waste audit

Our results indicate that the most frequently discarded edible food products were carbohydrates (54.5 percent), FV (24.3 percent), and animal protein (14.8 percent). This aligns with results from Tarczyńska et al.'s (2023) study, conducted at two universities in Poland, in which mainly vegetables, bread, and fruits were thrown away.

Similarly, in a study conducted at six universities in Beijing, China, vegetables were among the most wasted products (Wu et al., 2019). In a report by the Food and Agriculture Organization of the United Nations (FAO, 2019), FV had the highest wastage rate, between 40 and 50 percent of total edible plate waste, which is higher than the results obtained in this study at 24.3 percent (accounting for all meals). This may be related to the customization options offered at the Mercato that allow students to choose which fruits and vegetables they wish to include with their meal.

Our results also indicate that dairy (3.3 percent) and plant-based proteins (3.1 percent) represent a minor proportion of total edible food waste. The higher amount of animal protein waste compared to plant-based protein waste may be due to lower rates of plant-based protein selection; it is unclear whether plant-based protein is wasted less or purchased less.

Similar to our findings, a study comparing edible food waste types at a university in Portugal found that pasta-based meals generated more waste than meat-based meals, which generated more waste than plant-based meals (Martinho et al., 2022).

Study design 2: Measurement of individual plate waste and distribution of questionnaire

Perception/opinion of food waste

The median weight of edible plate waste between all participants was 19.0 g, with a minimum of 0 and a maximum of 298 g. This value was significantly lower than similar, previously conducted studies. Ellison et al. (2019) estimated that students generated approximately 88.23 g of edible plate waste per meal. In another study conducted by Wu et al. (2019) in Beijing, China, the average edible plate waste of students was 73.7 g per meal. A study conducted at a Portuguese university canteen reported an average of 44 g of edible plate waste per meal per student (Martinho et al., 2022).

One reason this study may yield a lower weight of edible plate waste per meal per participant is the customization options available to students allow them to get the items they want, which may decrease the amount of edible plate waste they generate. It is important to note that the median is reported for our results as they did not align with a normal curve. However, comparable studies reported the mean. The mean is impacted by extreme values, whereas the median is not. This may have contributed to our finding a significantly lower level of plate waste among participants.

Poor taste

Participants indicate poor taste as one of their primary reasons for wasting food. This result aligns with Thongplew et al. (2021), whose plate waste study looked at students' opinions from three canteens at Ubon Ratchathani University (UBU) in Thailand.

Their results indicated that students were discouraged from finishing their food when the taste was uninviting (Thongplew et al., 2021). Wiriyaphanich et al. (2021) also found that satisfaction with a dish's taste was a key factor for consumers finishing their meals and having a lower amount of plate waste. Mirosa et al. (2916) highlighted poor taste as the leading cause of plate waste. Visschers et al. (2020) also found that disappointing meal taste was an essential reasonfor students to leave leftovers.

Portion size

In a systematic review of how to fight food waste in university restaurants, researchers found that portion size was the most significant cause of waste (Deliberador et al., 2021a). Thirty-three percent of participants indicated that too large portion size was a contributing factor to their food waste, which aligns with the results found by Wu et al. (2019), who found that 21 percent of students from six universities in Beijing thought that university canteens provided too much food. Reducing portion size may be an effective way for the Mercato to minimize the amount of edible plate waste produced at Brescia University.

Fullness/lack of hunger

Our results indicate that fullness, or lack of hunger, is a key reason why students waste food. A systematic review conducted by Deliberador et al. in 2021a also found that satiety before the end of a meal was a cause of waste in university restaurants. A study conducted at a large Swiss university, reported lack of hunger resulted in plate waste (Betz et al., 2015).

While both large portion size and lack of hunger contribute to plate waste, they are distinct factors. Large portion size leads to waste because the amount served exceeds what an individual can consume, whereas lack of hunger results in waste because the individual is not physiologically inclined to eat in that moment, regardless of portion size.

Comparing participant demographic data to weight of edible food waste

When comparing participants' year of study to weight of edible food waste, we found a significant difference between fourth-year and first-year students, fifth-year or later and first-year students, and third-year and first-year students ($p = 0.016, 0.049, 0.047$, respectively). Based on these results, it appears that first-year students generate a higher level of waste, which aligns with results from similar studies. However, no statistically significant difference was found between first-year and second-year students. One reason for this may be similarity in their level of maturity during these years as well as living in residence. Many students live in residence and, therefore, are on the meal plan in their first and second years; however, few students in higher years of study live in residence or are on the meal plan. No statistically significant difference was found between participants' year of study ($p = 0.145$). This contradicts previous findings of Wu et al. (2019) that edible plate waste decreased with an increase in year of study.

We found a statistically significant difference between meal plan status and weight of edible plate waste ($p<0.001$). Participants on the meal plan generated higher levels of waste compared to participants not on the meal plan. This aligns with results from the questionnaire, where 54.6 percent of respondents believed that the meal plan would lead to more plate waste. Similarly, a significant difference was found between the number of meals consumed per week at the Mercato and edible plate waste, where more

meals eaten at the Mercato led to more waste ($p<0.001$). Meal plan students produce more plate waste since they have prepaid meal; receiving less food does not impact them financially. Finally, no significant difference was found between food and nutrition students and non-food and nutrition students regarding amount of edible plate waste ($p = 0.985$). Previous research has not examined differences between meal plan and non-meal plan students or food and nutrition and non-food and nutrition students.

Suggestions for the Mercato

Our results indicated that carbohydrates were the most wasted edible food item at all three mealtimes. Twelve percent of participants also reported that poor ratio/balance of carbohydrates to vegetables to meat was a reason for having thrown away food. Many participants suggested that better-balanced meals would effectively reduce food/plate at the Mercato. Based on these results, we suggest that the Mercato lessen the amount of carbohydrates provided at each meal (keeping Canada's Food Guide recommendations in mind) to provide a balanced plate. Our results indicate that the Mercato should offer smaller portions, improve food taste, and consider implementing storage spaces for students' leftovers, as these were identified as common reasons for throwing food away.

Finally, based on the significant finding that meal plan students generate more plate waste, we suggest that Brescia University and the Mercato look at the specifics of the meal plan to determine which changes would reduce the high level of plate waste of their students. For example, the remaining balance of the meal plan at the end of the academic year is currently non-refundable. Allowing this balance to roll over into the following academic year may reduce unnecessary purchases in an effort to use up any remaining funds. Reducing purchases may lead to reduced plate waste as students will only purchase meals they want and plan to eat. A future research study should examine how carrying over meal plan funds can impact plate waste.

Limitations and future research suggestions

Although this study contributes to Canadian food waste literature, there are limitations that should be noted. First, the tested population was female; second, the study was conducted at a small university. A larger sample size from a more populous university may provide better insight into university plate waste and the behaviour surrounding it. Another limitation comes from the difficulty of sorting some food items. Some food items were difficult to separate, and there was cross-contamination between categories. For example, melted cheese was often incorporated into a carbohydrate product, making it difficult to separate the components. Social desirability bias creates the potential for participants to report inaccurate information Participants may not have reported their honest reactions, attitudes, or beliefs in the questionnaire, responses which may not align with the weighted waste. However, no significant difference ($p = 0.753$) was found between the amount of waste reported by participants in the questionnaire and the waste weighed by the researcher. Therefore, it is unlikely that this significantly impacted the results. This study looked specifically at plate waste generated by students at the consumption stage; it did not investigate the amount of food service waste that may have occurred during preparation. This will be an essential consideration for future research. One way in which future research may inform which portion sizes to offer students is to determine the percentage of waste from each meal by calculating how much of the meal was initially consumed. Finally, another important area for

future research will consider how education on food waste may decrease plate waste.

Conclusion

This study examined the amount of food wasted by university students, their reasons for throwing food away, which student demographics were associated with plate waste, and which mealtimes and waste types produced the highest levels of waste. The study aimed to determine what the Mercato can do to reduce food/plate waste. The research question was informed by two objectives: (1) quantify and compare an estimate of plate waste during major mealtimes at the Mercato and (2) identify causes and factors related to plate waste at the Mercato. This study consisted of two study designs. The first design was a food waste audit, where food waste was collected, sorted, weighed, and recorded during major mealtimes at the Mercato. The second study design measured individual plate waste and distributed a questionnaire to participants. In this design, we recruited participants, weighed and recorded participants' edible plate waste after eating at the Mercato, and compared the result to demographic data from the questionnaire.

The first study design found that non-food waste was predominant at breakfast (59.8 percent) and lunch (54.3 percent) and edible waste was highest at dinner (51.0 percent). Carbohydrates (54.5 percent) were the major contributor and plant-based protein (3.1 percent) contributed the least.

The second design found a median edible waste of 19.0 g, with fullness, poor taste, large portions, and inability to bring home leftovers as the main reasons for waste. Meal plan students generated significantly higher levels of plate waste than non-meal plan students ($p<0.001$).

Based on our findings, we suggest that the Mercato reduce the amount of carbohydrates in each meal, offer smaller portions, and improve the taste of the food.

Future research should examine a larger sample size from a more populous university to gain better insight into university plate waste and food waste behaviour. The methodology used in our study is applicable to other universities. The first study design can be expanded by collecting plate waste from multiple cafeterias/restaurants, leading to more diverse and larger samples of food waste. The second study design can be scaled up to have research stations in multiple cafeterias/restaurants, also leading to a larger sample size.

Another area for future research is to investigate food waste during preparation as well as the percentage of food wasted at each meal by considering portion size before and after consumption.

The results and methodology of this study contribute to the advancement of scientific knowledge by providing insight into the most significant categories of plate waste, student behaviour, contributing factors of plate waste, and characteristics of students associated with a higher level of plate waste. These findings can be used to create informed and effective plate waste reduction strategies for university dining settings. Investigations of these findings on a larger scale in future research will provide additional insight into plate waste, specifically if conducted with a more diverse sample population, and will lead to further refined and more effective plate waste reduction strategies.

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