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Investigating Contextual and Personal Drivers of Food Waste Behavior at University Dining Commons

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Investigating Contextual and Personal Drivers of Food Waste Behavior at University Dining Commons

By

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THESIS

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Acknowledgements

Though first in my thesis, I saved this bit for last. There’s excitement that comes with finishing but also the sadness comes with the realization that this windy journey called grad school is coming to an end. I never thought that I would even go to grad school, let alone finish with a degree, but I guess I have done enough. That being said, I have so many people so thank so without further ado, let’s just jump into it.

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Table of Contents

Investigating Contextual and Personal Drivers of Food Waste Behavior at University Dining Commons

Abstract

Background: Food loss and waste is a huge problem worldwide when it comes to the environment, economy, and society. In the United States, food waste – food that is wasted at the retail and consumer level – is more of an issue than food losses that occur upstream in the food value chain. There are strategies to valorize waste, but the most impactful strategy would be preventing waste in the first place. In order to create more effective interventions to curb food waste, drivers for this behavior must be understood. There have been many papers that have examined household food waste, but there has been a lack of studies that specifically investigate university dining commons, which have large food waste reduction potential.

Objectives: The goal of this research was to understand how dining common factors (e.g., serving style, food types served) and personal factors (e.g., frequency of eating at the dining commons, meal satisfaction) were related to amount of food waste diners produced.

Methods: The main study took place at five different university dining commons during Spring and Fall 2019. After intercepting 736 diners near or inside the dining commons 296 produced complete, useable data. Participants scanned a QR code which led them to a Qualtrics survey that walked them through the process. Diners were asked to get their meal, take a photo of it, and then answer questions of what they selected, how it was portioned, and how confident they were going to like the dish before taking it. After eating their meal, they were asked to take another photo of what remained and answer questions of how satisfied they were with the meal, their role at the university, and their frequency of going to the dining commons. The photos were coded to provide estimates as to how much food was taken and wasted (taken – what was leftover). Free responses for what diners took were also coded into food type categories. All the variables were first analyzed using Multiple Correspondence Analysis, then multiple linear regression models were made to further investigate different factors' effects on how much food was taken and wasted.

Results: Certain food types (animal protein and mixed dishes), pre-plated dishes, dishes with more hedonic appeal, and consumer confidence in liking an item before taking it were all factors that were correlated to more food being taken. Different factors – increased meal satisfaction and frequency of visiting the dining commons – were correlated to less food being wasted. The amount of food that was taken was also a significant predictor for estimating food waste.

Conclusions: This study highlighted some significant factors that were related to diners' food choice and waste at five different universities. Finding relationships could help inform future studies design better interventions to reduce food waste at university dining common

1. Introduction

One third of all food that is made worldwide is lost or wasted (FAO 2011). This issue affects the three pillars of sustainability – social, environmental, and economic (Hansmann et al., 2012). The FAO estimates that 8.9% of the world population was undernourished in 2019 (FAO 2020). Food security is a complex issue so it could not simply be fixed by redistributing excess food. Getting food from the farm to the table is an intensive process, requiring water, fertilizer, land, and labor on the growers' side, transportation along the supply chain, and energy for processing. Food can be lost or wasted at any point of the food supply chain, but the environmental impacts tend to increase the further down the chain as additional inputs and effluents accumulate at each stage.

It is troubling to then realize that 63 million tons of food loss and waste (83% of total by weight) in the United States is wasted at the consumer-facing business or household level (ReFed 2016) and continues to increase (Hall et al., 2009). The United States is part of a larger trend where more developed countries tend to have higher levels of food waste – reduced food at the retail and consumer level – and developing countries have higher levels of food loss – reduced food from post-harvest up to, but not including retail (Parfitt et al., 2010). In addition to having social and environmental ramifications, food loss and waste is also estimated to have an economic cost of approximately $936 billion (FAO 2014 accounting). In response to this challenge, the United Nations (UN) established Sustainable Development Goal 12.3 to halve per capita food waste by 2030 (UN SDG).

There are different ways of dealing with food loss and waste at each stage of the food system, however there are some strategies that are more effective than others. Food loss at the manufacturing level accounts for 2% of food loss and waste in the United States (ReFed, 2016), which is likely the result of successful valorization of processing byproducts and waste streams. Valorization – enhancing the price or value – is specific to different processing streams and has been reviewed for different food items (Galankis, 2020). When it is not possible to have direct edible use for food products, it is possible to use food waste to make biofuels and biomaterials (Girotto et al., 2015). Having a more consistent and homogeneous waste stream allows for a more optimized process when it comes to extraction or anaerobic digestion.

The food waste hierarchy shows prevention, avoiding loss and waste in the first place, having the greatest impact whereas disposal options are not as favorable (Papargyropoulou et al. 2014). Prevention across the whole food supply chain has been studied (Canali et al., 2017), but with limited resources, focusing on consumer food waste prevention approaches have the most impact due to the potential for high volumetric reduction and the high levels of embedded resources in the food at the end of the supply chain.

Food loss and waste studies and reviews have increased in recent years (Spang et al., 2019; Xue et al., 2017) but more work needs to be done (Hodgins and Parizeau, 2020). This literature review includes the challenges that will need to be overcome to achieve this goal, strategies that have been used, and ideas for future work.

1.1 Defining and Measuring Food Waste

Being able to define and measure food waste is crucial when trying to assess the current state of food wastage as well as quantify effects of food waste reduction strategies. However, measurement and characterization of food waste is not so simple. The FAO has defined food loss as losses in edible food mass that take place at the production, post-harvest, and processing levels in the food system, whereas food waste is defined as the losses that take place at the retail and final consumption levels (FAO 2011).

Though the FAO definition is a good starting point, there is subjectivity in what is considered "edible" at the farm and consumer levels which makes quantification difficult (Gillman et al., 2019). Underestimates have been seen on farms as a result of a disconnect in what farmers and researchers consider as edible food waste (Baker et al., 2019; Gillman et al., 2019; Johnson et al., 2018). Underestimates are also common with household food waste. Using diaries to write down weekly food waste has been found to be more accurate than questionnaires (Giordano et al., 2019), but diaries still tend to underestimate household food waste by 7-40% compared to compositional analysis (Quested et al., 2020).

At the University of California – Davis (UC Davis), the dining services group conducts quarterly waste audits where interns intercept all the waste during a two-hour period and sort it based on edible waste, inedible waste, liquid waste, and napkins. This type of direct measurement is a good way for schools to know how much and roughly what kind of food is being wasted. Further, by putting the wasted food on display, students are reminded of their individual plate waste contribution to the larger waste stream. However, this type of approach but can be logistically tricky since the dining hall needs to have sufficient staff available to direct students and weigh the plate waste (Burton et al., 2016).

Even after collecting measurements, it is important to remember that food waste amounts vary across location and time, so most studies just offer a snapshot of what is taking place (Griffin et al., 2009). Further, there are often large discrepancies that can come from using different measurement methods, so standardizing methodologies would allow for higher quality data and greater opportunity for larger data aggregation and cross-cutting comparisons (Delley and Brunner, 2018; Elimelech et al., 2019).

Previous studies have also tended to focus on food waste in terms of overall reduction and overlook the economic, environmental, and social impacts (Goossens et al., 2019) which could lead to a different interpretation of the data (Costello et al., 2015). There is more food waste work that is needed to be done globally, so it is crucial to learn how to better measure food waste to get a more accurate idea of the problem (Xue et al., 2017). Luckily, there are new methods being developed, including hybrid approaches (Elimelech et al., 2019) that can leverage indirect measurement (van Herpen et al., 2019a; van Herpen et al., 2019b; van Herpen and van der Lans, 2019; Yu and Jaenicke, 2020), generate more granular data (Elimelech et al., 2018), and aggregated and compare data across studies (Corrado et al. 2019; Withanage et al., 2020).

1.2 Modeling Food Waste Behavior

Household Food Waste

Most studies about food waste behavior in the literature examine households. Household food waste behavior has been found to vary depending on age (Ilakovac et al., 2020), income level (Ilakovac et al., 2020), number of children under 18 (Ilakovac et al., 2020), household size (Elimelech et al., 2019; van der Werf et al., 2020), shopping behaviors (Aschemann-Witzel et al., 2015; Farr-Wharton et al., 2014), routines (Stanccu et al., 2016), and food type (Visschers et al., 2016). Given this inherent variation due to differences among people and locations, it is even more important to have consistent and accurate measurements.

Building off existing literature and behavioral frameworks can help make studies more comparable. The Theory of Planned Behavior (TPB) (Azjen, 1991) has been used by many studies to try to explain food waste behavior. The model posits that subjective norm, attitude, and perceived behavioral control lead to intention which leads to behavior. Some studies have added additional predictors like routine (Russell et al., 2017; Stanccu et al., 2016), environmental concern (Tsai et al., 2020), socio-demographic factors (Qi and Roe, 2016; Visschers et al., 2016), and emotions (Russell et al., 2017) to increase model fit. One study criticized the use of TPB for modeling food waste behavior since the act of throwing away food is not intentional (Janssens et al., 2019). People do not intend to waste food (Bolton and Alba, 2011), but rather is the byproduct of good intentions of consumers wanting to provide for their household (Graham-Rowe et al., 2014). Household production theory (Becker, 1965; Deaton and Muellbauer, 1980) was the basis of some econometric models trying to explain food waste behavior (Min et al., 2020; Smith and Landry, 2020).

Though there is much variation among consumers, clustering models have been used to identify groups of behaviors (Gaiani et al., 2018; Smith and Landry, 2020; Di Talia et al., 2019) to better inform policies addressing food waste. Qualitative methods such as interviews have also been used to understand the barriers of minimizing household food waste (Farr-Wharton et al., 2014; Graham-Rowe et al., 2014).

Food waste behavior, and studying behavior in general, is complex and requires proper analysis methods (Quested et al., 2013). Even after identifying potential influencing factors, the analytical method applied can change the factors that are significant in the resultant model (Grainger et al., 2018b; Secondi et al., 2015). Regression analysis offers a powerful tool and it is the backbone of many common statistical tests like t-tests and analysis of variance (ANOVA). When used correctly, it allows for the explanation of current data as well as the prediction of what has not yet been measured. In regression, there is usually an equation of best fit and an additional error term. Taking more precise measurements and limiting external variation can help reduce this error term. Including more terms in a model needs to be balanced with overfitting, collinearity, and increased alpha. Newer studies have used techniques such as hierarchical models (Bravi et al., 2020; Graham-Rowe et al., 2015; Secondi et al., 2015; Visschers et al., 2016), Structural Equation Modeling (SEM) (Abdelradi, 2018; Fami et al., 2018; Ponis et al., 2017; Russell et al., 2017; Stancu et al., 2016; Tsai et al., 2020), machine learning algorithms (Grainger et al., 2018a), and Bayesian Networks (Grainger et al., 2018b) to combat issues that arise with normal regression.

Institutional Food Waste

Institutional and foodservice consumer-facing businesses, which includes university dining commons, were found to have 5 million tons of wasted food annually (Refed 2016). In 1998, it was estimated that a moderately-sized university could waste one ton of food per day (Creighton, 1998, pg. 180). At Rhodes University in South Africa, it was found that $80,000/year could be saved by a 10% reduction in food waste (Painter et al., 2016). In addition to the food waste and cost reduction potentials, habits have been found to be important for food waste behaviors (Russell et al., 2017; Stanccu et al., 2016), so setting good attitudes for young adults while in the university setting can be beneficial in reducing food waste as adults (Tsai et al., 2020).

University settings can also be more controlled, which makes collecting data on food waste behavior and implementing interventions easier. The ability of the university to modulate the dining environment to directly influence on-campus diners (Nikolaus et al., 2018). A comparative study found dining systems with more incentive not to waste (tied to price) and more autonomy (tied to free selection) resulted in less food waste than a system with less incentive and less autonomy (Matzembacher et al., 2020).

At the University of California, Davis (UC Davis), the university dining commons operate on an all-you-care-to-eat (AYCE) system where the diner will pay a flat rate using an ID card swipe and is able to eat as much as they care to. This represents a significantly different dining and payment system compared to cooking at home or dining out, which leads to substantial differences in food waste drivers and behaviors. The current UC Davis dining commons has some free choice in portioning at certain stations but with the AYCE swipe, there is no incentive to not waste. A qualitative study at UC Davis proposed suggestions for reducing food waste – changing the payment system, having a variety of plate sizes – which echoes findings from the comparative study (Yui and Biltekoff, 2020).

Offering food that diners enjoy can also reduce food waste (Lam, 2010), though people have different preferences so satisfying everyone is always difficult. Personal factors like age (Steen et al., 2018), gender (Long et al., 2021; Painter et al., 2016), disposable income (Wu et al., 2019), and education level (Wu et al., 2019) have also been correlated with food waste. These factors are not modifiable but are useful for knowing who to target for interventions.

1.3 Food Waste Interventions

Though food waste research studies are increasing, there is still a lack of research that provides evidence-based evaluation of food waste interventions (Hebrok and Boks, 2014; Reynolds et al., 2019; Stöckli et al., 2018). Given the complexities of defining food waste, choosing the right data collection and analysis methods and designing an effective experiment is inherently challenging. Cost can also be a barrier to implementing interventions, so choosing the right method for the right population, and taking accurate measurements to properly evaluate the intervention effect are essential for success (Muth et al., 2019). For this literature review, university dining common interventions is the focus, however, as previous reviews have pointed out, curbing food waste will require action at every level of the food system by multiple parties (Halloran et al., 2014).

Informational messaging campaigns that have been implemented have achieved food waste reductions ranging from 3.9% to 15% (Ellison et al., 2019; Dölekoğlu and Var, 2019; Pinto et al., 2018; Whitehair et al., 2013). Messaging prompts can influence intentions but those might not lead to actual behavioral change (Kurzer et al., 2020). More involved interventions that appealed to diners' social responsibility through cooperation (Chen and Jai, 2018; Warren, 2017) and encouraged sharing (Lazell, 2016) also resulted in food waste reduction.

Building interventions that build off of motivations and theories in the literature can lead to more effective results (van der Werf et al., 2020). For example, nudging or changing choice architecture to affect behavior (Thaler and Sunstein, 2008), has been implemented through changing dish shape and size (Richardson et al., 2020), reducing portion sizes (Freedman and Brochado, 2012), and removing trays (Kim and Morawski, 2012) to reduce food waste in dining commons. Food waste reduction was also found by using smaller plates in a simulated dining model (Ravandi and Jovanovic, 2019). These types of interventions should also be monitored over time, since human behavior is known to have a temporal element (Kasza et al., 2020; Pelt et al., 2020).

Even with better measurements and interventions, there still needs to be buy-in from universities which does not seem to be the current trend (Filho et al., 2020). There are tradeoffs when it comes to implementing interventions – cost, logistical challenges – but hopefully the reduction in embedded GHG emissions and overall costs, as well as exciting new research from forward-thinking schools including UC Davis, will encourage other universities to follow suit.

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2. Main Study

Note: This chapter has been published in *Foods*

Abstract: The purpose of this multi-campus research was to investigate the relationships of food type and personal factors with food choice, consumption, and waste behaviors of college students at all-you-care-to-eat dining facilities. The amount of food taken and wasted was indirectly measured in units relative to the plate size using before and after photos taken by the diners themselves. Animal protein and mixed dishes (e.g., stir fry, sandwich) took up more of diners' plate space and these items were correlated to both greater hedonic appeal as well as a higher likelihood of the item being pre-plated. Greater confidence in liking an item before choosing it was correlated to a larger portion being taken. Finally, increased satisfaction with the meal and frequency of visiting the dining commons was correlated to less food waste. Understanding these potential food choice drivers can help dining facilities better target healthier meals to diners while reducing food waste.

Key words: food choice, food waste, university dining commons, multiple correspondence analysis

2.1 Introduction

Food waste, as well as the prevalence of overweight and obese individuals, has been increasing in the United States (Hall et al., 2009; Singh et al., 2011). Food waste is problematic, given that the negative environmental impacts of investing significant resources in cultivating and processing food items are exacerbated when those items are never eaten. Meanwhile, food waste prevention has been identified as the highest value food waste solution relative to recovery, recycling, and disposal (Papargyropoulou et al., 2014). Consumer food choice and food waste behaviors are complex but must be understood to inform preventative solutions (Furst et al., 1996; Quested et al., 2013). Studies have been conducted to investigate and understand what drives and inhibits healthier eating (Brug et al., 2008; Kearney and McElhone, 1999), while other studies have been conducted to understand the motivations behind consumer food waste in order to encourage people to waste less food (Gaini et al., 2018; Graham-Rowe et al., 2014).

University dining commons are great settings to investigate the drivers of food choice and waste because students in this developmental stage are beginning to form their longer-term food habits, including their potential to engage in food waste reduction (ReFED, 2016; Sogari et al., 2018). Many universities have buffet-style/all-you-care-to-eat facilities (AYCE) where diners can take as much food as they desire for a fixed price. This has the advantage of allowing schools to offer more food options and faster service but can result in higher food waste (Yui and Biltekoff, 2020). Interventions using informational prompts, taking away trays, changing plate shape, and reducing portion amounts have been implemented with some success in reducing food waste (Freedman and Brochado, 2010; Kim and Morawski, 2012; Richardson, 2019; Whitehair et al., 2013). Further, it is important to note that not all food waste carries the same economic and environmental impact. Animal product waste is generally the best target for reduction since it usually costs more and requires the most resources to produce (Nijdam et al., 2012).

Reducing food waste needs to be balanced with encouraging university diners to eat healthier foods, specifically vegetables, which provide a protective factor for obesity (Crovetto et al., 2018). Personal factors like cognitive restraint, susceptibility to stress, and gender, as well as environmental factors like time constraints and dining commons design, have been linked to differing food choice behavior (Lacaille et al., 2011; Moreira et al., 2005; Unusan, 2006). Nudging interventions, such as changing the presentation of healthy items or adjusting the serving style in university dining commons, have had varying levels of success getting diners to eat more nutritious foods (Bevet et al., 2018; Friis et al., 2017; Rajbhandari-Thapa et al., 2018).

Most of the existing studies that explore food choice and food waste behaviors at universities focus only on a single school. Given the complexity of these issues, studies that utilize multi-campus data have the potential for greater analytical robustness given the increased sample size and captured variance. The intervention's effects and potential reproducibility can also be seen across a greater population (Turnwald et al., 2019). Though useful, these studies can be logistically challenging in collecting and comparing sample data. One technique used in previous studies to streamline data collection involves taking photos of food as a proxy for other measures of the amount of food taken and wasted (Roe et al., 2018; van Herpen and van der Lans, 2019). This method was utilized in this multi-campus study to identify amounts of quantities of food taken and wasted. These values were then used to investigate the correlations among the food type, the reasons for choosing foods and portions, and the personal factors with the amount of food taken and wasted at university dining commons.

2.2 Materials and Methods

2.2.1 Study Design and Protocol

Five colleges and universities from the Menus of Change University Research Collaborative (MCURC) participated in this study in Spring 2019 or Fall 2019. The participating schools included Stanford University, University of California – Berkeley, University of California –Davis, University of California – Santa Barbara, and Lebanon Valley College. Stanford University (School B) participated in both the Spring and Fall cohorts. Characteristics of these schools are shown in Table 1. Each school had an AYCE dining hall that could be accessed with a card swipe as part of a meal plan, though the different schools demonstrated variation in the average percentage of pre-portioned dishes.

An online survey was designed in Qualtrics and used at all the schools. The lead researcher was from Rice University so the Rice University's Institutional Review Board granted exempt status for the study protocol for research activities at all of the campuses, though they did not collect any data at their dining commons. Diners were intercepted at their dining halls and asked if they wanted to participate in a study about food choices and satisfaction, but the objective of investigating food waste behavior was not disclosed. Each participating school determined which incentives would best encourage participation (e.g. raffles for gift cards or spinning a wheel for a small prize) and how best to approach students. Both QR codes and tinyurls were used to distribute the survey link. While all studies took place over the same general time periods (Spring or Fall semesters of 2019), the number of data collection days varied among schools. The goal derived from previous MCURC studies was to collect data from at least 50 people per school which was met at most schools. However, after removing incomplete responses, two schools were unable to reach this quota.

The survey's general sequence involved the subject taking a photo of their plate before and after eating, answering a few questions about each item they took (up to six), and responding to some additional questions about themselves. The flow of questions is shown in Figure 1 and specific questions are provided in Table S1. The survey was started after participants had already selected their items so as not to influence their food selection. Similarly, the subjects were not asked why they did not finish their food until after they finished to avoid influencing how much they consumed.

2.2.2 Data Organization

Responses that were incomplete or incomprehensible were not used. Further, responses relating to food items outside the study's scope (e.g. beverages) were also re-moved. The food items entered by participants were read and then coded according to seven main categories: Fruits and Vegetables, Grains/Starches, Plant Protein, Pre-pared/Mixed, Animal Protein, Dessert, and Other. If an item was thought to have two separate components, it was put into the Prepared/Mixed category. Plant Protein was separate from Fruits and Vegetables and included items such as beans, tofu, and plant-based meat. Not many items were in the Dessert and Other categories, so they were not included in the analysis. The total number of item responses was 818 which came from a total of 296 people. The breakdown of how many subjects and items were discarded at each step is shown in Figures 2 and 3.

For the choice and portion questions that were "check-all-that-apply", each category was turned into its own response and then each item was coded with a binary value of either zero for "unselected" or a value of one for "selected". "Pre-plated" and "Someone else served" were combined for a "Pre-plated_combined" category to indicate the instances where a server, rather than the diner, chose the portion quantity.

After their meal, diners were asked if they finished each item they selected. If the item was not finished, they were asked to select a reason why. This provided an overview of how many items were finished and the self-reported reasons why diners did not finish the other items. To determine the quantity of food wasted, the "before" and "after" photos were examined and coded separately by two staff researchers at Rice University, then checked for agreement. Photos that were either unclear or did not match the survey responses were excluded. The "before" photos were coded for the approximate amount of food in relation to a plate per item mentioned by the diner: 1 tablespoon (1/16 plate), few bites (1/8 plate), ¼ plate, ½ plate, 1 plate. The "after" photos were then coded by the approximate amount of food eaten in relation to the "before" photo, and percentages were assumed for each calculation: fully eaten (100%), mostly eaten (75%), half-eaten (50%), mostly uneaten (25%), uneaten (0%). Food eaten was approximated by multiplying the percentage eaten in the "after" photo by the amount taken in the "before" photo. Food waste was then approximated in units of "percentage of plate" by subtracting how much was eaten from how much was taken. The amounts of food taken and wasted were standardized into z-scores by school/semester combination to minimize school variation and to normalize the residuals.

2.3 Data Analysis

RStudio (Version 1.1.463) using R Version 4.0.0 was used to analyze the data. The type I error rate (α) was set at 0.05 when reporting significance.

2.3.1 Multiple Correspondence Analysis (MCA)

An MCA was created using the FactoMineR and factoextra packages in R. For the analysis, the amounts of food taken and wasted were not scaled but rather converted into factors to run the analysis. Personal and situational factors were measured per subject or item to assess correlations with the amount of food taken and wasted. Factors of food type (Type), how confidently a diner thought they would like the item before choosing it (Confidence), frequency of eating at the dining commons (Frequency), satisfaction with meal (Satisfaction), school (School), and disposal category (Disposal) were analyzed with amount taken (Taken), and amount wasted (Wasted) with an MCA.

Food waste was measured in two ways: self-reporting categorization and photo-graphic numerical estimation. The MCA was used to assess how these measurements aligned. The "Finished" category was found near the numerical "Waste_0%" factor while reasons for not finishing ended up near the numerical "Waste_100%" and "Waste_75%" factors.

2.3.2 Multiple Linear Regression

Multiple linear regressions using the lme4 package were run to investigate the relationship of question responses to the standardized amounts of food taken and wasted, which were treated as continuous factors. Disposal categories were not included in the model since the standardized quantities were of greater interest here. Confidence and satisfaction scores were assumed to be continuous and normal. Food type and frequency of eating at the dining commons were treated as categorical factors. Models that included food type:confidence and food type:satisfaction interactions were also created but were not significantly different from the models without the interaction terms, so they were not used. ANOVA and adjusted R-squared values were used for model comparison.

2.3.3 Analysis of Variance and Post-hoc Tests

ANOVAs were created and run to determine if there were significant differences among food types on the amount of food taken and wasted. Fisher's LSD from the agricolae package was used as a post-hoc test.

2.3.4 Correspondence Analyses

After chi-square tests showed significant differences of distributions in responses among food types and confidence levels, correspondence analyses from the FactoMineR and factoextra packages could be run on the check-all-that-apply data. Correspondence analyses were used to relate amount of food taken and food types with the reasons for selecting the portion size. Another correspondence analysis was run to relate confidence of taking items to reasons for selecting the items.

2.4 Results

2.4.1 Factors Affecting the Amount of Food Taken and Wasted

The MCA results (Figure 4) that explain 10.8% of the variation after the first two dimensions, show that not wasting food ("Waste_0%" factor in the MCA) is in the same domain as the factors for going to the dining commons for multiple meals a day, being extremely certain they were going to like the dish before they chose it, and extreme satisfaction with their dish. Associations around wasting more food ("Waste_100%" and "Waste_75%" factors in the MCA) are less clustered but include going to the dining commons less than once a week, being less certain they were going to like the dish before they chose it, and extreme dissatisfaction with the dish. Overall, the MCA suggests that having more confidence in choosing the dish before eating it, being satisfied with the dish after eating it, and going to the dining commons more frequently were all positively correlated with the diner finishing the dish.

2.4.2 Factors Affecting the Amount of Food Taken

A linear model was created relating food types, confidence, and satisfaction to the amount of food taken. The coefficients are shown in Table 2. Prepared/mixed items ($p<0.01$) and animal protein ($p<0.05$) food types demonstrated a significant positive correlation with the amount of food taken. And perhaps not surprisingly, the diners' confidence in liking the food before choosing it also had a positive correlation with the amount of food taken ($p<0.05$). Figure 5 shows the results of the correspondence analysis that relates the reasons why people selected their dish and the confidence they had in liking it before selecting it. After two dimensions, 95.3% of the total inertia (0.025) is explained.

2.4.2.1 Food Type Differences

The amount of food taken by the diner, measured in percentage of the plate, was significantly different among the food categories ($p<0.05$), as shown in Table 3 and Figure 6. Prepared/mixed items took up a greater percentage of the plate over animal protein and grains/starches, which took up a greater percentage than fruits and vegetables and plant protein. Meanwhile, the amount of food wasted was not significantly different among the various food categories ($p=0.058$).

Figure 7 shows the results of the correspondence analysis that relates the reasons why people selected the quantity they did to the different food types. After two dimensions, 98.2% of the total inertia (0.032) is explained. Fruits and vegetables and grains and starches are closer together and share the same space of liking the food as the main reason why a particular portion was selected. Animal protein and prepared/mixed dishes are closer to pre-plated and suggested amounts as influencing reasons for selecting the portion size for these food types.

Figure 8 is a correspondence analysis that relates the reasons why people selected the portion they did and the amount of food they took. After two dimensions, 98.2% of the total inertia (0.032) is explained. The greater amounts of food taken (Took_1_Plate and Took_1/2_Plate) are closer to the reason of the item being pre-plated. Food being pre-plated or served by someone else is related to a higher amount of food on a diner's plate.

2.4.3 Factors Affecting Amount of Food Wasted

A linear model was created to relate standardized amount of food wasted to food type, confidence, satisfaction, and frequency. The coefficients are shown in Table 4. Amount of food taken, satisfaction with the meal, and frequencies of going to the dining commons – 2-3 times a week, multiple times a day – were significant predictors of the standardized amount of food wasted ($p<0.05$). None of the food types were significant predictors which aligns with the previous result that food waste did not significantly differ among food types ($p>0.05$).

The standardized amount of food wasted was significantly affected by the standardized amount of food taken so there was an indirect impact from factors affecting food taken – food type, confidence. Other direct factors that impacted food waste included satisfaction with the meal and frequency of going to the dining commons. Diners who were more satisfied with their meal wasted less. There was a trend with frequency of going to the dining commons where the more frequent the visit, the less the diner wasted. The 2-3 times a week category was an exception where subjects in that group wasted less on average than subjects in other groups.

2.5 Discussion

2.5.1 Food Waste Drivers

Drivers of food waste have been studied in households but not as frequently in institutional settings such as university dining commons. Drivers in these settings differ since AYCE facilities offer the diner the possibility of getting more food with no financial penalty if it is not finished. Informing households that they could save money by wasting less has been shown to reduce food waste (van der Werf et al., 2019), but that does not apply to AYCE dining commons. The significant factors that affected food waste in the model (Table 4) were satisfaction with the dish, frequency of visiting the dining commons, and amount of food taken.

Higher ratings of satisfaction were related to less food being wasted. However, increasing the appeal of food to reduce food waste is not straightforward. Consumers have different preferences so changing a dish to fit one person's taste might reduce satisfaction for others. Offering a wider variety of dishes can be a way to appeal to the diverse group of diners, but this could lead to diners taking more than they need if they exhibit variety-seeking behavior. Diners who visited the dining commons more often tended to waste less, which could be due to them knowing what dishes they like since dining commons often have rotating menus. Data were collected a few weeks into Fall or Spring semesters so it is possible that diners would have already had an idea of which dishes they liked. Since the diners and institutions tested differed between Spring and Fall, it was not possible to compare how food waste behavior might have changed over time, an interesting question to investigate in the future. The one institution that tested in both Spring and Fall collected data at different dining commons for each semester, so their data was also not suitable for an analysis of how behavior changed over time.

A higher amount of food being taken was also related to more food being wasted, most likely due to more waste potential. Animal protein and mixed dishes were found to be taken in significantly higher proportions of the plate ($p<0.05$). Pre-plated items were in the same space as animal protein and prepared/mixed dishes in Figure 5, and in the same space as taking 100% and 50% of the plate in Figure 7. Due to the lack of controls in this observational study, it is not possible to conclude if food type, method of portioning, or another unidentified reason led to animal protein and mixed dishes taking up a greater portion of diners' plates on average. Portioning should be considered since less portion control has led to more food waste in previous studies (Matzembacher et al., 2020; Roe et al., 2018).

In household food waste studies, foods considered less valuable are wasted more (Gaiani et al., 2018; Roe et al., 2018). In this study, there was no significant difference in the amount of food wasted among the food types ($p>0.05$). Since most people reported that they finished their food, the lack of variance in plate waste may have prevented the detection of any significant difference. This could be due to underreported food waste values, which can occur when participants are asked to self-report (Visschers et al., 2016). Food waste behavior also differs in an AYCE setting since financial incentives to finish higher valued products are not present like in households (Matzembacher et al., 2020). Context could also help explain this difference with previous studies since unlike in a household, there are no financial penalties for not finishing food in an AYCE setting. Prompts and signs could be used to remind diners not to waste food, even though there is no financial incentive to do so.

Increased confidence in liking a dish before choosing it also led to a higher amount of it being taken, but less being wasted. In the correspondence analysis relating confidence and reasons for taking items (Figure 5), higher confidence levels were in the same area as having the item before, as well as looking and smelling good. Looking and smelling good are subjective judgments and are difficult to standardize for all diners; however, allowing diners to sample the dish could be a strategy to increase confidence and encourage healthier options. Offering small samples of dishes could help diners decide what they want to choose and thus reduce disappointment after taking a full dish. If this option is pursued, staffing and sample placement must be considered since it can be difficult during busy hours for staff to prepare samples and for diners to obtain these samples (Yui and Biltekoff, 2020).

2.5.2 Data Limitations

2.5.2.1 Sampling

Asking about food waste could cause subjects to feel embarrassed or ashamed if they did waste food and thus might impact their behavior. The study was designed to try to minimize the effects of the survey on food consumption and waste behavior through its pacing, the order of the questions, and by disguising the main purpose of the study; yet there is a possibility that the goal of the study could still have had an effect. There could have also been selection bias where potential participants who tend to waste more might not have volunteered for this food choice study.

2.5.2.2 Data Analysis

Running an MCA allowed multiple correlations to be examined at the same time. This type of multivariate analysis is necessary for exploring multifaceted issues such as food behavior. MCA also works well with a range of different data types (e.g. categorical, continuous), which aligned well with our data seta. However, the downside of multivariate statistics is that they generally lead to a low percentage of the variance being explained.

This study had a mix of self-reported as well as photographic data which was coded by the researchers. Previous food waste studies have quantified food portions and waste using photographs (Roe et al., 2018; Williamson et al., 2003) or measured food waste directly (Kurzer et al., 2020; Painter et al., 2016; Vermote et al., 2018). Having both self-reported and photographic data would have allowed comparisons to see how well the two methods aligned. However, due to most items being finished, it was not possible to carry out a meaningful comparison.

Subjects reported the items and their amounts, so they were not standardized to servings and thus made comparisons difficult. For instance, a participant's "4 slices of pizza" would have been counted the same as another participant's entry of "salt." The condiments/other category was excluded in this analysis for that reason, as well as the lack of items reported in that category.

Photos were used to estimate the proportion of the plate taken up by items. While this allowed the quantification of food taken relative to the plate, there was not enough information to convert items to servings, which might have been be a more meaningful metric. Estimates were also based on photos so there could be variations depending on how items were placed on the plate by the participant. Future studies with options to self-report food items could benefit from asking participants to report servings of items along with specifications of typical serving sizes for popular foods.

In the data organization process, incomplete items had to be removed which eliminated data on certain items from subjects or all the data from a subject entirely. This reduced the number of observations from 1406 to 818, as seen in Figure 3. The greater number of items would have strengthened the analyses and could have helped increase model fit. Since different numbers of items were deleted for different diners, conclusions could not be drawn regarding how many items each person selected.

Linear models were created to explore a range of factors that might explain the amount of food that was taken and wasted. When it comes to decision making, there are a multitude of factors to consider, each with a lot of variation, so modeling people usually results in low model fit (Roe et al., 2018; Wang et al., 2017). There was an especially low R-squared value for the amount of food wasted model. This could be due to the skewed distribution observed in the amount of food wasted, likely a result of most people finishing their food. Standardizing the data was an attempt to correct this skew by normalizing the residuals. Since food waste amounts were converted to z-scores per school, school to school variation could not be studied. This was acceptable for this study since the data were analyzed together, and the individual school was not used as a factor aside from preliminary analysis in the MCA.

Due to the data structure, the check-all-that-apply responses for why items and their portion sizes were chosen were analyzed using correspondence analyses which can only compare two variables at a time. The check-all-that-apply responses were related to food type and the amount of food taken. These analyses elucidated why certain food types were taken as well as why they were taken in larger amounts. However, with these analyses, it is not possible to differentiate the effects of the variables. For instance, it is not possible to know if a greater amount of food being taken was due to it being a mixed/prepared dish or pre-plated dish since the analysis only enables two variables to be examined at one time.

In contrast to most university food waste studies focusing on a single institution (Painter et al., 2016; Vermote et al., 2018; Whitehair et al., 2013), this study included multiple campuses and various times of data collection. Though this increased the sample size and relevance to multiple schools, this also in-creased the amount of variation due to factors such as student population and menus. All the participating schools had an AYCE system, which allowed for some comparisons. The same researchers coded all the photos to also reduce noise. The plate amounts were standardized to z-scores by school and those values were used as the dependent variable to further reduce the variation due to differences in school/dining hall/etc. Future experiments that investigate the drivers of food choice and waste or that conduct interventions to reduce food waste should consider multi-campus studies to ensure findings can be generalized outside that institution. There also needs to be a way to properly deal with the variation that could appear as noise when analyzing the data. This could be reduced by collecting additional situational information (participant interest in the menu, number of people they were with, how busy was the dining commons) and of the dining environment (proximity of seats to dining stations, method of dish return), which has also been found to affect behavior (Yui and Biltekoff, 2020).

2.6 Conclusion

University all-you-care-to-eat dining commons are a well-suited environment to study and understand free-choice food choice and waste behavior. For food choice, prepared/mixed and animal protein items took up a greater percentage of the plate compared to other food types. These items were correlated to the more hedonic-driven reasons for selection and to pre-plated servings. Healthier items such as fruit and vegetables and plant protein dishes took up a smaller percentage of the plate comparatively. These items were correlated to the reasons of meeting goals and being self-served.

Food waste did not significantly differ among the food types but was related to the amount of food diners took, how satisfied they were with their meal, and how often they went to the dining commons. An increase in the amount of food taken was correlated with an increase in waste. The more satisfied diners were with their meal, the less they wasted. Increased frequency in visiting the dining commons tended to decrease the amount of food wasted.

Future studies could investigate other recruitment methods that reduce selection bias for a more representative sample of food waste behaviors. Researchers should also be mindful of survey design to prevent missing data whenever possible. Questions should be designed with data analysis methods in mind to avoid having to convert continuous data to categories. Building questions off key factors from existing behavior literature could help capture more variation and increase model fit. Different modeling techniques such as using Bayesian, generalized linear models, or structural equation modeling could be used to deal with non-normal data, set subjects as random variables, and examine multiple variables' relationships with each other and to latent variables, respectively.

This multi-campus study provided insight into drivers of university dining common food choice and food waste as well as ideas for the conduct of future studies. By understanding drivers, universities can work with their dining commons and students to get diners to eat healthier and waste less.

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2.9 Figures and Tables

Table 1. Characteristics of the schools that participated in this study.

Characteristic	School A	School B	School C	School D	School E
Undergraduate population (%)	90	45	76	90	60
Female (%)	54.3	54.7	51.7	57.9	55.7
Private/Public	Private	Private	Public	Public	Public
Population density	Suburban	Suburban	Urban	Suburban	Suburban
Quarter/Semester observed	Fall	Spring, Fall	Spring	Spring	Fall
Plate size (in.)	10	9.5	9.5 x 6.75	9	9
All you care to eat	Yes	Yes	50%	25%	Yes
Operator served - plated	25-30%	Action stations	50%	75%	Most are operator served

Table 2. Model predicting standardized amount of food taken regression results.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.71427	0.18284	-3.906	0.000101 ***
Grains/Starches	0.09782	0.10999	0.889	0.374060
Plant Protein	-0.03517	0.14730	-0.239	0.811329
Prepared/Mixed	0.70146	0.08641	8.118	1.75e-15 ***
Animal Protein	0.28342	0.09686	2.926	0.003527 **
Confidence	0.09183	0.03415	2.689	0.007314 **
Satisfaction	0.01543	0.03954	0.390	0.696356

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.9475 on 811 degrees of freedom

Multiple R-squared: 0.1034, Adjusted R-squared: 0.09675

F-statistic: 15.58 on 6 and 811 DF, p-value: < 2.2e-16

Table 3. Means and standard deviations were calculated for each food category for amount taken and wasted in percentage of plate. The number of responses for each category is also listed. Fisher's LSD lettering is given for amount taken.

Food Category	N	Amount Taken (% Plate)			Amount Wasted (% Plate)	
		Mean	LSD	Std Dev	Mean	Std Dev
Fruits & Vegetables	224	0.260	c	0.153	0.041	0.085
Grains/Starches	113	0.288	bc	0.144	0.041	0.071
Plant Protein	51	0.252	c	0.136	0.016	0.047
Animal Protein	168	0.326	b	0.178	0.054	0.113
Prepared/Mixed	262	0.432	a	0.266	0.055	0.090

Table 4. Model predicting standardized amount of food wasted regression results.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.14197	0.32328	3.532	0.000435 ***
Std_Taken	0.32810	0.03491	9.399	< 2e-16 ***
Grains/Starches	-0.10930	0.10976	-0.996	0.319620
Plant Protein	-0.26305	0.14613	-1.800	0.072221 .
Prepared/Mixed	-0.16809	0.08937	-1.881	0.060362 .
Animal Protein	0.01615	0.09671	0.167	0.867459
Confidence	-0.02684	0.03418	-0.785	0.432509
Satisfaction	-0.10252	0.03945	-2.599	0.009532 **
Once a week	-0.38276	0.30338	-1.262	0.207438
2-3 times a week	-0.60250	0.29668	-2.031	0.042601 *
4-6 times a week	-0.46817	0.28856	-1.622	0.105103
Daily	-0.49057	0.28057	-1.748	0.080762 .
Multiple meals a day	-0.58855	0.27661	-2.128	0.033664 *

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.9393 on 805 degrees of freedom

Multiple R-squared: 0.1252, Adjusted R-squared: 0.1122

F-statistic: 9.605 on 12 and 805 DF, p-value: < 2.2e-16

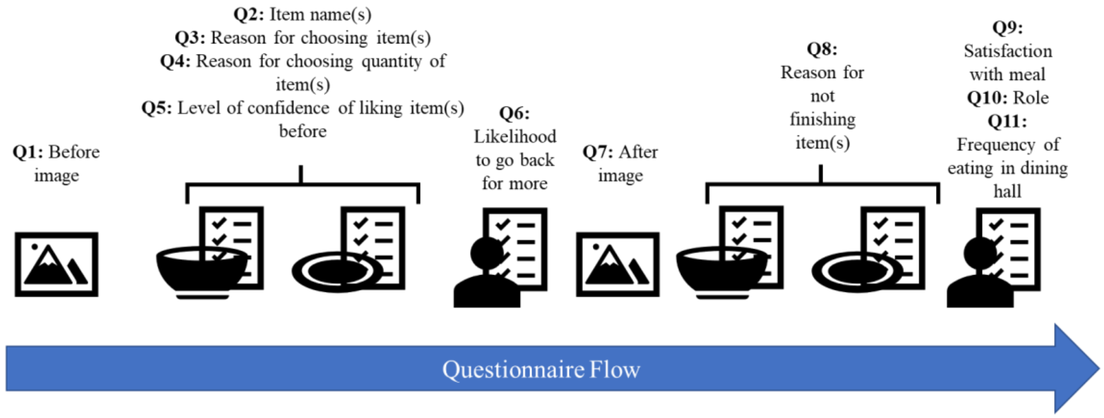

Figure 1. Questions and question type – photo, per dish, per individual – that were asked in this survey.

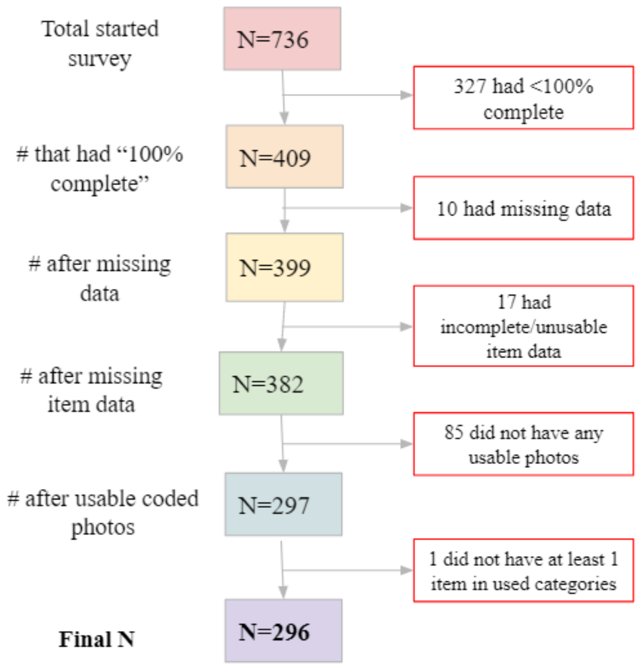

Figure 2. Flow chart with the number of people that started the survey and the final number analyzed after excluding missing and incomplete data.

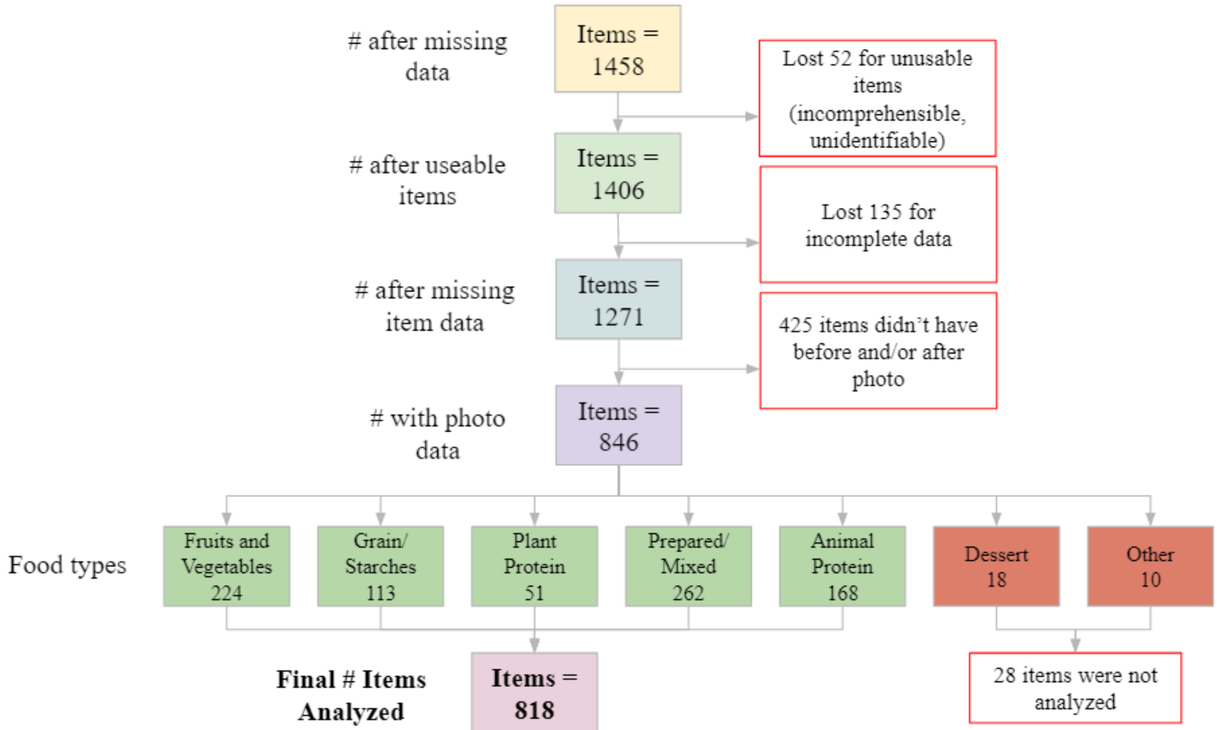

Figure 3. Flow chart with the starting and final number of items analyzed after excluding items with missing and incomplete data.

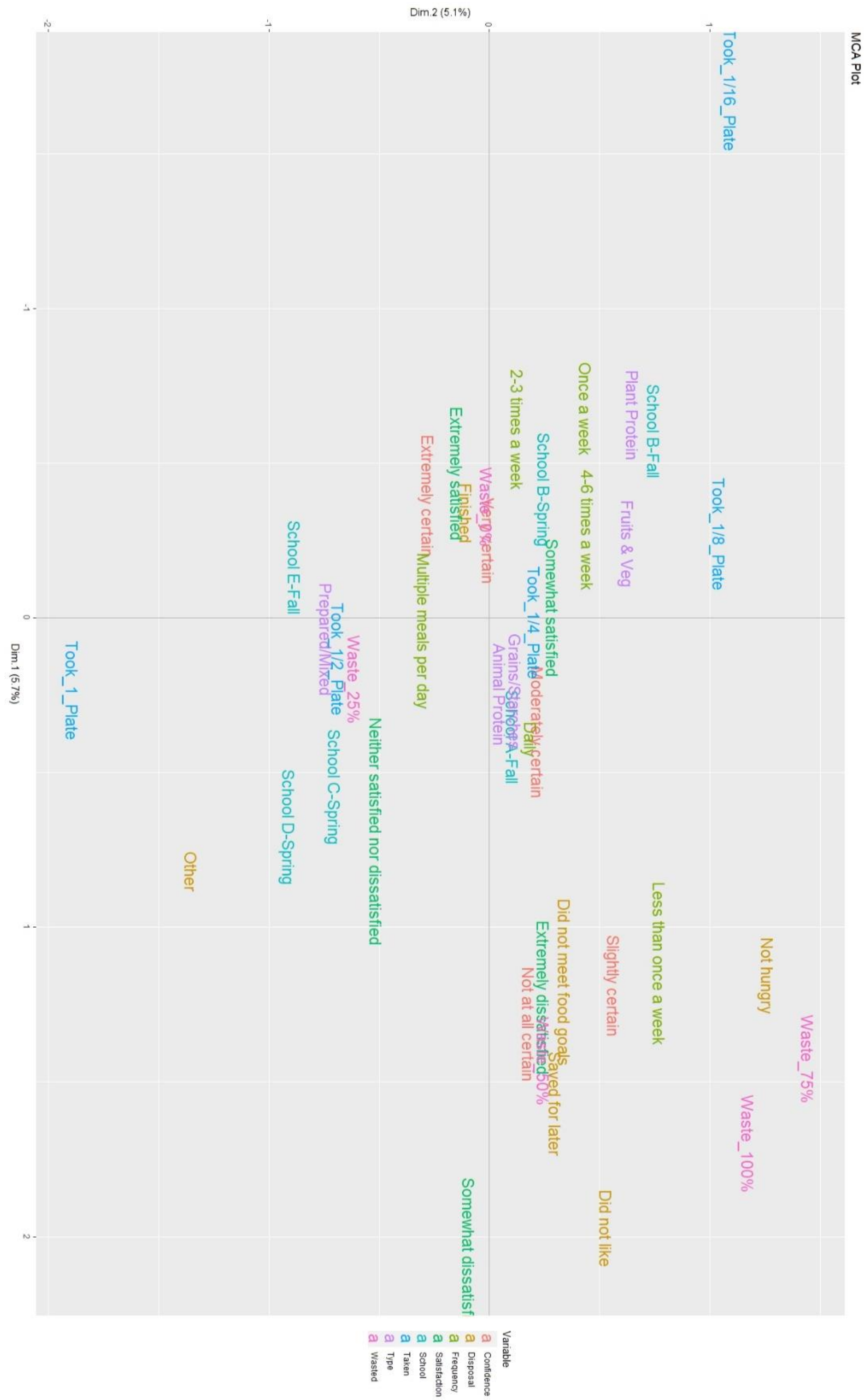

Figure 4. MCA of personal and situational factors related to the amount of food taken and wasted.

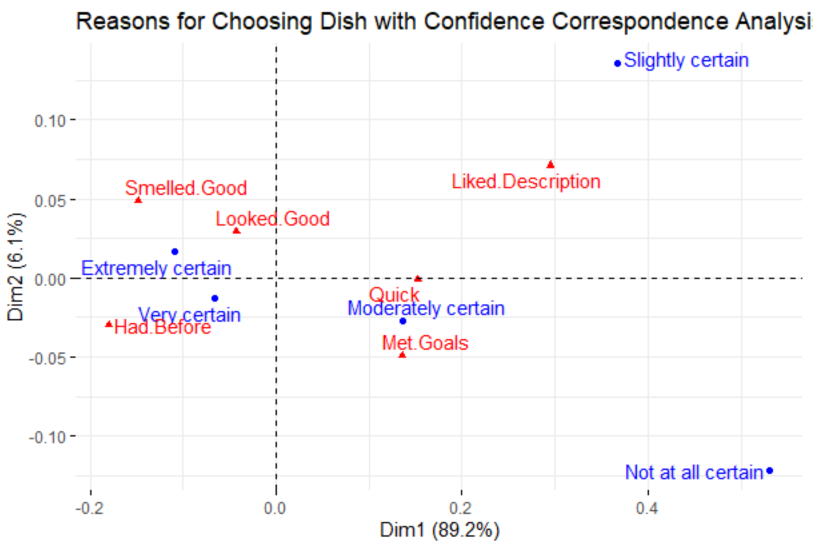

Figure 5. Correspondence analysis relating reasons why participants selected food and the level of confidence they had before taking the item.

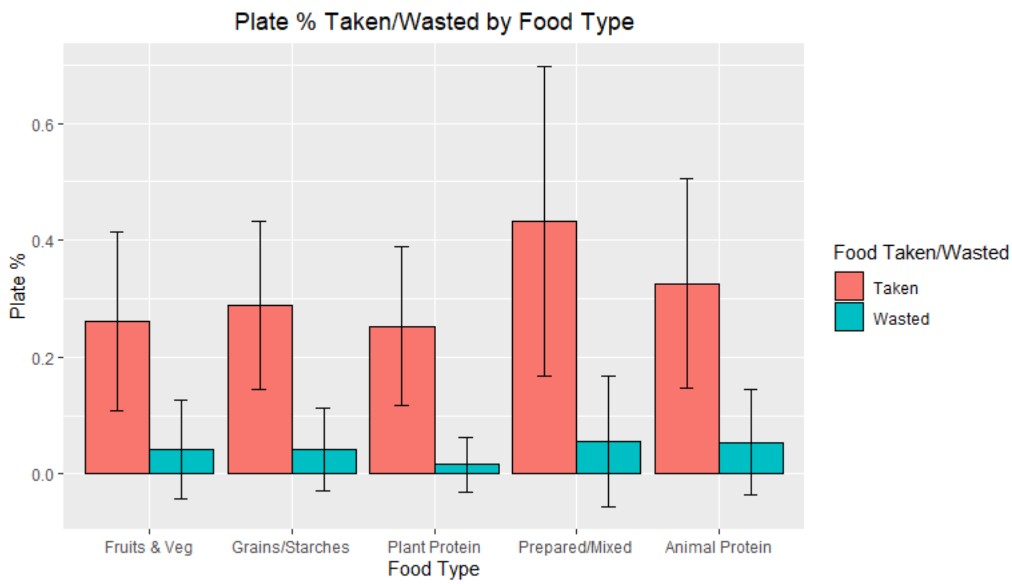

Figure 6. Percent of the plate that was taken and wasted by food type.

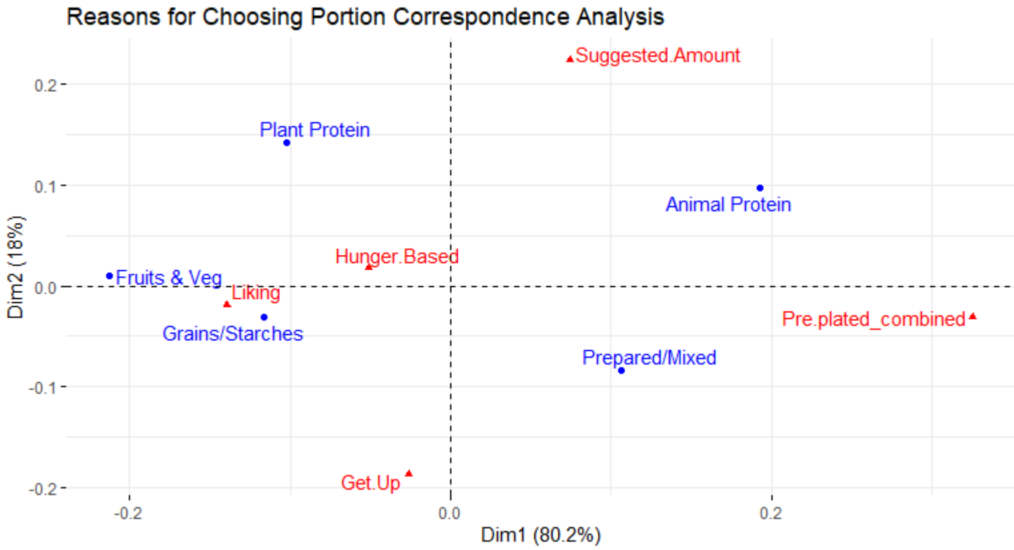

Figure 7. Correspondence analysis relating reasons why participants selected the portion size of the food and the different food types.

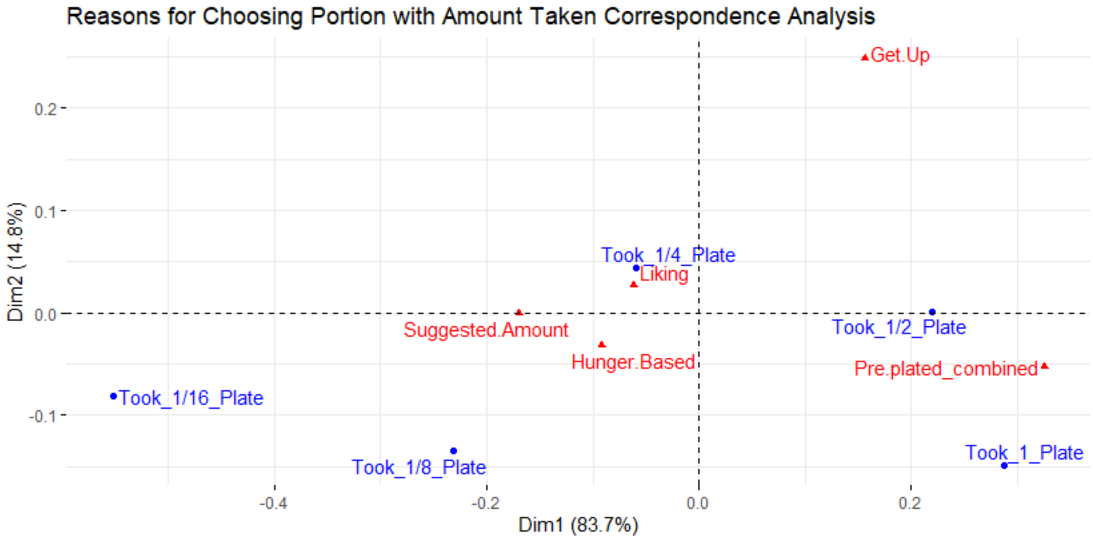

Figure 8. Correspondence analysis relating reasons why participants selected the amount of food and the amount of food taken.

Table S1. The questions that were asked in the order they were presented in the survey.

Info	Question	Asked Per	Question Type	Options
Before Photo	Please take a picture of your plate (before you start eating), and upload it using the button below. If you have more than one plate, please try to take a picture of all of your food together. Don't worry about taking a picture if you go back for more, we will ask you about that in the questions that follow.	Person	Photo	N/A
Items	Please tell us what you chose to eat today (in your words, so we can use it for subsequent questions). If you have more items than spaces for them, please just write the most significant ones in the spaces provided. Please focus on main dishes and sides (rather than drinks or desserts). Please write down at least one item, and up to six different items.	Person	Open-Ended	N/A
Reason	Please tell us why you chose the items on your plate today. Select all that apply:	Item	Check-all-that-apply categorical	Looked good Smelled good Liked Description I've had before It was quick Met my nutritional goals Other
Choice	Please tell us how you chose the quantities of food you took today. Select all that apply:	Item	Check-all-that-apply categorical	Pre-plated Someone else served Suggested amount Based on my hunger Liking of food I didn't want to get up again Other
Confidence	How confident were you that you would like this item before you took it?	Item	Ordered categorical	Not at all certain Slightly certain Moderately certain Very certain Extremely certain
Go Back	How likely are you to go back for more (of any item) if you like it?	Person	Ordered categorical	Extremely unlikely Somewhat unlikely Niether likely nor unlikely Somewhat likely Extremely likely
After Photo	Please take a picture of your plate when you are finished eating, and upload it using the button below. Please try to show us whatever food is left on the plate.	Person	Photo	N/A
Disposal	Why did you choose not to finish (if you did not) each of the following items?	Item	Categorical	Did not like Not hungry Did not meet food goals Saved for later Other Finished
Satisfaction	How satisfied were you with your meal today?	Person	Ordered categorical	Extremely dissatisfied Somewhat dissatisfied Neither satisfied nor dissatisfied Somewhat satisfied Extremely satisfied
Role	Are you:	Person	Categorical	Student Staff Faculty Visitor Other
Frequency	How often do you eat in the dining hall?	Person	Ordered categorical	Less than once a week Once a week 2-3 times a week 4-6 times a week Daily Multiple meals per day

3. Conclusions and Future Considerations

This research spanned five universities in the United States which is a first when it comes to studying university diners' food waste behavior. Though there was large variation and mostly categorical data collected, significant findings relating contextual and personal factors to the amount of food diners took and wasted were still found. Food amounts were able to be estimated from photos, which is easier logistically and requires less labor at the times of data collection. Certain aspects like collecting data at multiple sites and indirectly measuring food amounts may be of interest for new methodologies interested in measuring food waste behavior. There were also many lessons learned which can be helpful for future studies.

Multi-campus studies are beneficial for more confidently extrapolating out findings to the reference population. However, with it comes more variation. Creating a protocol with school-to-school variation in mind can help limit the variation from the experimenter's end. Running a small trial at one school before expanding to other universities would also help experimenters anticipate problems like adequate participation and survey responses.

Determining factors to study can be daunting due to the complexity of human behavior but building off existing models and theories could help. Survey questions should be informed by this as well as the type of anticipated analyses. New modeling techniques like SEM as well as incorporating Bayesian statistics could aid with reducing false positives and should be considered when appropriate.

University dining commons are a place with a lot of food waste reduction potential due to the volume of food being consumed, but it is just an environment for a few years in some peoples' lives. Food waste continues in other spaces such as the home, restaurants, retail, and on the farm. The current food system has food waste built into it. Consumers can try to do their part, this graduate student is trying their part, but ultimately, the system needs to change in order to stop seeing the figure of 1/3 of the world's food being lost and wasted.