IMPACT OF PLATE SHAPE AND SIZE ON INDIVIDUAL FOOD WASTE IN A UNIVERSITY DINING HALL SETTING

BY

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THESIS

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ABSTRACT

With an estimated 50% increase in global food demand by the year 2050 (Campanhola & Pandey, 2019), countries are trying to find ways to increase production and decrease waste to help meet these needs. Young adults (18-24 years of age) have been identified as a high-wasting segment of the population (Thyberg & Tonjes, 2016). In the United States, young adulthood often coincides with the pursuit of postsecondary education. Many students receive housing and meals through the university. Because of this, university dining facilities make an excellent target for food waste reduction strategies. The purpose of this study is to evaluate one food waste reduction strategy: changing the plate size and shape in university dining facilities. Specifically, this study compares individual food selection, consumption, and waste between round plates (9" x 9") and smaller oval platters (9.75" x 7.75") in a self-serve, all-you-care-to-eat dining environment. Data was collected at an individual level where diners' plates were weighed directly after selection and again before disposal. Results suggest using plates with a smaller surface area reduces food selection, consumption, and waste. However, the intervention does increase the odds of a diner selecting seconds, but the amount of waste produced from a second helping could not be measured. Implementing an intervention such as this in many university dining halls may contribute to reducing global food waste among a highly wasteful population.

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CHAPTER 1: INTRODUCTION

Since the first report to the United States Congress on food waste in 1977 by the United States Department of Agriculture (USDA), there has been interest in identifying ways to reduce food loss and waste across the food system (Buzby, Wells, & Hyman, 2014). A recent assessment on agriculture systems sustainability by The Food and Agriculture Organization (FAO) of the United Nations (UN) estimates a 50% increase in global food demand by 2050 (Campanhola & Pandey, 2019). FAO notes that global production already meets this demand, however challenges with distribution among increasingly urbanized populations, change in dietary preferences, and decline in health outcomes due to an increase in obesity and micronutrient deficiencies will cause new strains on our current agricultural systems (Campanhola & Pandey, 2019). Already, agricultural production uses 80% of available consumptive water in addition to about 50% of land use (Birney, Franklin, Davidson, & Webber, 2017; Gunders, 2012). Overall, food processing and agricultural production is estimated to consume 10% – 16% of total US energy (Canning, Charles, Huang, Polenske, & Waters, 2010; United States Energy Information Administration, 2018). In developed countries, a majority of food loss occurs at the retail and consumer-levels (Gunders, 2012). Buzby et al. (2014) estimates a combined food loss of 31% of total available food at the retail and consumer-levels. These groups squander a remarkable amount of consumable water, energy, and intangible resources input earlier in the supply chain (Birney et al., 2017). The USDA and United States Environmental Protection Agency (EPA), in alignment with goals set by the UN, have already set a national goal to reduce food loss and waste 50% by the year 2030 (United States 2030 Food Loss and Waste Reduction Goal, 2015). However, the mechanisms to reduce waste are broad. Specific policies and programs aimed at reducing food loss and waste are continuing to develop to achieve this goal.

This study focused on retail and consumer level food waste rather than the all-encompassing problem of food loss. While the definitions of food loss and waste vary (for an overview, see (Bellemare, Cakir, Peterson, Novak, & Rudi, 2017; Ellison, Muth, & Golan, 2019), we adopt the definition used by the USDA Economic Research Service (Buzby et al., 2014). Under this definition, food loss includes any edible food consumable by humans lost postharvest due to

shrinkage, mold, pests, improper storage, among other loss mechanisms, while food waste is a subset of food loss that includes any edible food portion left uneaten at the retail and consumer levels (Buzby et al., 2014). From data reported in 2010, after recycling for paper waste, food waste alone made up 21% of municipal solid waste (Buzby et al., 2014). With such a high percentage of food waste occurring at the retail and consumer levels, waste reduction programs targeting consumers may have a wide-reaching impact. Young adults between the ages of 18 and 24 are seen to waste more food than any other age group (Thyberg & Tonjes, 2016). In the United States, this age group frequently attends post-secondary education where they are often provided housing and meals through the university. University dining halls have been estimated to expend 124.5 g of CO_2e per diner (Costello, Birisci, & McGarvey, 2015). As of the 2015-2016 academic year, about 16.98 million students were enrolled in public and private four year universities (National Center for Education Statistics, 2018), the majority of which will have dining facilities available to (or even required for) students to obtain meals.[1] Thus, targeting university dining halls could curb waste from a relatively inattentive population at a large scale.

This purpose of this study is to investigate the impact of replacing round plates with smaller oval platters on individual selection, consumption, and waste (SCW) in a university dining hall. This study also examines characteristics that may lead to an increase in individual plate waste, including demographics and characteristics of the dining environment. Overall, this research aims to fill gaps in the literature concerning the lack of interventions aimed at reducing food waste (Reynolds et al., 2019).

[1] Many four-year universities require students who are living on campus, which is often a requirement for first-year students, to purchase a meal plan. Thus, a conservative estimate would be that approximately 25% of students eat in university dining facilities, though it is certainly possible that older students (sophomores, juniors, seniors, or graduate students) may also opt in to purchasing a meal plan.

CHAPTER 2: REVIEW OF SCIENTIFIC LITERATURE

2.1 Overview

There have been a variety of studies measuring ways to alter university dining halls in order to observe changes in food SCW. Many of these studies focus on improving food choices by emphasizing healthier options or implementing nutrition (e.g., calorie) labeling in dining facilities (e.g., Christoph, Ellison, & Meador, 2016; Cioffi, Levitsky, Pacanowski, & Bertz, 2015; Scourboutakos et al., 2017). However, there are fewer studies dedicated to reducing food waste in this setting. Of the existing research, food waste interventions within university dining halls tend to fall within three categories: education campaigns, alternative pricing strategies, and environmental nudges. Research on plate shape/size within a university dining hall has not yet been conducted.

2.2 Education Campaigns

Educational campaign strategies tend to present educational materials in the form of informational signs, table tents or napkin inserts, and customized posters with food waste data specific to the dining hall or university (Ellison, Savchenko, Nikolaus, & Duff, 2019; Soares Pinto, Machado dos Santos Pinto, Fochat Silva Melo, Santos Campos, & Marques-dos-santos Cordovil, 2020; Whitehair, Shanklin, & Brannon, 2013). These methods tend to be low-cost and require minimal maintenance by dining staff (Ellison, Savchenko, et al., 2019). Both the Ellison et al. (2019) and Whitehair et al. (2013) studies used signage with either informational food waste statistics or a "call to action" message intended to encourage mindful selection and emphasize personal responsibility. Similarly, Soares Pinto et al. (2020) created signage aimed at involving students in waste reduction by having them voluntarily request smaller potions sizes at service lines. Thus far, the results on educational campaigns are mixed. The campaign to have students request smaller serving sizes led to a decrease in food wasted, but it was unclear if this was due to the promoted behavioral change or an increase in consumption due to food waste awareness (Soares Pinto et al., 2020). Additionally, prompting students to act on their pre-existing beliefs about food waste through signage has been seen to lead to a decrease in food wasted (Whitehair

et al., 2013). However, Ellison et al. (2019) observed a minimal reduction of food waste after an 8-week intervention and noted students admitted they still selected more food than they could eat despite awareness of food waste as a problem.

Many food waste studies suggest education campaigns as an effective method of food waste reduction without reproducible results (Reynolds et al., 2019). Overall, educational campaigns alone may not be the most effective way of reducing food waste as it wholly relies on independent action of the dining patron. Moreover, any long-term effects of education campaigns are unknown. As this student population ages, their attitudes and beliefs about food waste may change (Thyberg & Tonjes, 2016). Educational campaigns implemented while students receive their meals at university dining facilities may leave an impression reducing their food waste in the future. At present, more direct methods targeting behavior may lead to larger reductions in food waste.

2.3 Altering Pricing Strategy

There are no known studies directly comparing food waste between all-you-care-to-eat and a la carte style university dining halls. However, several studies have identified price and cost as motivating factors for consumers to reduce or avoid waste (e.g., Graham-Rowe, Jessop, & Sparks, 2013; Jovanovic, Katare, & Wetzstein, 2018; Thyberg & Tonjes, 2016). A la carte dining prices items individually where as an all-you-care-to-eat system charges students a one-time entry fee and allows them to select as much food as they desire while in the confines of the dining hall (Ellison et al., 2019; Heikkilä, Reinikainen, Katajajuuri, Silvennoinen, & Hartikainen, 2016). Students identify price as being the chief motivator for food purchase (Kim, Ng, & Kim, 2009), often making all-you-care-to-eat options more financially advantageous than a la carte. In an all-you-can-eat fixed price dining hall, Jovanovic and colleagues (2018) found a 15% discount conditional on finishing all food selected effective in reducing food waste. However, they did not find a reduction in selection, suggesting students consumed more food than they otherwise would to receive the discount (Jovanovic et al., 2018). This may raise other concerns related to overeating or obesity. Kim et al. (2009) concluded that the optimal pricing strategy is one that gives diners a high level of satisfaction. While changing the pricing structure is likely to generate

results in terms of waste reduction, long-term effects of a change in price strategy is unclear and financial incentives may lead to an increase in negative health outcomes if they are designed to reduce waste via greater consumption. Further, the all-you-care-to-eat structure is often used as a marketing tool for many university dining operations when recruiting students, so dining administrators may be reluctant to make a pricing change.

2.4 Environmental Nudges

Nudges have become an increasingly popular tactic to change food choice behaviors. In general, nudges are adjustments to the choice environment that can alter behavior without removing choices or changing economic incentives (Thaler & Sunstein, 2008). In the university dining hall setting, decreasing standard serving sizes and implementing trayless dining are two nudges designed to reduce food waste by preventing over-selection of foods. Two studies have examined the impact of decreasing the standard serving size of French fries in a university setting (Freedman & Brochado, 2009; Vermote et al., 2018). Freedman and Brochado (2009) reduced standard serving sizes from 88 grams to 44g over four weeks in 15g increments. Diner SCW and dining hall pre-consumer food production all decreased over time, with individual consumption and plate waste significantly decreasing (Freedman & Brochado, 2009). Vermote et al. (2018) found similar results; most notably, the proportion of French fries eaten by each individual increased from 88.1% to 95.2% after a decrease in the standard size served. Standard serving size reduction seems to be a viable and effective strategy in reducing food waste. However, this may not be a feasible waste reduction solution in all-you-care-to-eat or self-serve dining environments where pre-portioned servings are generally not provided.

Trayless dining is a similar type of nudge that has been widely adopted on college campuses in recent years (Foderaro, 2009). Trayless dining removes the ability to carry multiple dishes at once but does not restrict one's choices. It can be easily implemented in a variety of dining environments, generally at low-cost. Several studies found trayless dining decreased food waste (Kim & Morawki, 2012; Rajbhandari-Thapa, Ingerson, & Lewis, 2018; Sarjahani, Serrano, & Johnson, 2009; Thiagarajah & Getty, 2012). Over a 6-day period, Kim and Morawski (2012) saw a 32% reduction in food waste after tray removal. Rajbhandari-Thapa and colleagues (2018) found

a significant decrease in lunches and drinks served as well as fewer plates with uneaten food once trayless dining was adopted.[2] However, they did not directly measure SCW and instead used plate types as a proxy for meal items selected (Rajbhandari-Thapa et al., 2018). In a 2012 study, individual edible food waste significantly decreased by 18.4% after trayless dining was implemented (Thiagarajah & Getty, 2012). Participants in both the Rajbhandari-Thapa et al. (2018) and Thiagarajah and Getty (2012) studies selected less food in the first place, suggesting trayless dining decreases selection which leads to an increase in consumption and decrease in waste. While most studies concluded trayless dining reduced food waste, one study found the impact of trayless dining to be more nuanced. Wansink and Just (2013) observed a decrease in selection of salad, an increase in returning for seconds, and a marginal increase in disposal of entrée and dessert items when trays were removed.

In addition to trayless dining and reducing standard serving sizes, changing the dishware available to diners is another nudge that could reduce food waste in the dining hall environment. In the general population, research has shown that consumers often respond to environmental ques, such as plate and serving utensil size, when determining how much food is appropriate to select and consume (e.g., DiSantis et al., 2013; Rolls, Roe, Halverson, & Meengs, 2007; Van Ittersum & Wansink, 2011; Wansink & van Ittersum, 2013; Wansink, van Ittersum, & Painter, 2006). Both lab and field studies have explored the impact of plate and utensil size on food SCW. Diners at a buffet style restaurant who were provided larger plates (26.5 cm) selected, consumed, and wasted more than diners who were given smaller plates (21.0 cm) (Wansink & van Ittersum, 2013). Similarly, Wansink et al. (2006) found participants who received a larger bowl at a self-serve ice cream bar served and consumed 31% more than those with a smaller bowl. DiSantis et al. (2013) found a significant increase in lunch quantity self-served and consumed among first-grade students when participants switch from child sized to adult sized dishware. In a lab setting, Van Ittersum & Wansink (2011) observed bowl size to have a significant effect on soup portion

[2] The type of dining environment this study was conducted in was not specified. In a fixed-entry-price all-you-care-to-eat environment, a decrease in number lunches and drinks served may be beneficial as this would reduce dining hall production costs. However, if the number of lunches served decreased due to a decline in the number of students eating at the dining hall this could negatively impact the dining facility's revenue. Additionally, in an a la carte environment where customers are charged by item, a reduction in lunches and drinks served would not be beneficial to dining hall revenue.

served. Those with bowls smaller than the control underserved themselves, while participants with larger bowls overserved themselves (Van Ittersum & Wansink, 2011). Further, Rolls et al. (2007) saw no difference in food intake between plate sizes in a controlled lab setting. However, this study did not measure difference in selection or waste and was not in a natural dining environment. Overall, these results are promising, but evidence of this intervention working in a dining hall setting has yet to be tested. This research aims to fill this gap in the literature by testing the influence of plate size and shape on food SCW in a university dining hall setting.

CHAPTER 3: METHODOLOGY & ANALYSIS

3.1 Measurement Strategy

There are four standard food waste measurement strategies within dining halls and food service: direct weight, visual observation, self-reported dietary recall, and digital recording (Buzby & Guthrie, 2002; Christoph & Ellison, 2017; LizMartins, Cunha, Rodrigues, & Rocha, 2014).[3] The direct weight method involves physically weighing a participant's plate after selection and before disposal. This strategy was identified as the optimal method for data collection as it provides the ability to look at food SCW on an individual level and is easily implemented into an all-you-care-to-eat dining environment. Additionally, direct weight is regarded as the most accurate means of waste measurement and has the ability to capture individual behavioral factors (LizMartins et al., 2014).

3.2 Study Design and Data Collection Strategy

Data was collected at two dining halls at a large midwestern university in the Fall of 2018. Both facilities were all-you-care-to-eat and trayless. Diners were charged a single-entry fee and were able to select as much food as desired while in the dining area. Both locations used self-serve stations with each station specializing in a type of cuisine (e.g. American, Italian, Asian, etc.). Additionally, each facility had a salad and deli bar with options for specialized diets (e.g. vegetarian, gluten free, vegan, etc.). The researchers and dining hall staff monitored and limited the dishware available for patron use. The only intervention this study focused on was change in plate size/shape. Traditionally, the university dining facilities used round plates (9"x9"). In this study, the intervention was to replace the round plates with oval platters (9.75"x7.75")

[3] We use the direct weight method in this study but provide a brief description of the other methods here. Visual observation method requires researchers to estimate the proportion of food leftover on participant's trays. Proportions are often categorized into quarters (e.g. all, ¾, ½, ¼, or none) based on a standard portion served (Wansink & Just, 2013). Self-reported dietary recall utilizes participant memory to estimate their own SCW (Kubik et al., 2003). Lastly, digital recording is similar to visual observation where researchers take photographs of participants plates then later compare their contents and may estimate SCW (Christoph & Ellison, 2017).

decreasing the plate's surface area by 6.76% (63.62 in^2 to 59.32 in^2).[4] See figure 1 for examples of both plate types. Using a crossover trial design (see table 1), data was collected in each dining hall for two one-week periods in September and October. Both dining hall menus were on a four-week cycle; the research team selected data collection dates where the menu offerings would be the same for both the round plate and oval platter weeks in each dining facility. Lunch service ran from 11:00am to 1:30pm.

Dining hall patrons were free to choose to participate in the study but were exposed to the intervention and control plates regardless of participation. Additionally, those with a meal plan were able to eat at any dining facility on campus, including locations that were not involved in this study. Diners were eligible to participate if they were over the age of 18 and had not already participated that day. Participants were able to take part on multiple days and treated as a new observation each day of data collection.

A group of nine data collectors were trained using a standard protocol (see Appendix A) before data collection began. Each position included a detailed explanation of their duties. Researchers were able to review and clarify data collection procedures prior to the start of data collection in September. Any given day, 3-5 researchers recruited, directly weighed, and digitally recorded pre-consumption plates. One to two researchers were responsible for post-consumption weight and digital record. There was at least one researcher experienced in food waste data collection present each day of data collection to manage all other researchers and assist with any problems.

Patrons were approached by researchers to participate and incentivized with a later drawing for a $50 Amazon gift card. Diners were recruited after their plate(s) had been assembled, but before they sat down at a table. This was to ensure that 1) interacting with a researcher did not influence food selection and 2) diners had not started eating when asked to participate. Researchers invited diners to assist with identifying popular food items and meals as to avoid priming participants on the topic of food waste.[5] Once diners gave verbal consent,

[4] While the research team preferred to have each dish type offered in isolation, certain menu items (e.g., soups, cereal) required non-plate dishes like cups and bowls. In addition, one of the dining facilities had a stir fry station that required a different type of dish that could not be replaced with the round plates or oval platters.

[5] University Dining administration was also interested in this information and wanted to collect feedback from students.

researchers then placed each dish on a 5 kg scale (Taylor TE11FT 11lb. Digital Portion Control Scale) and recorded the pre-consumption weight, a combined weight of the plate and food. A photo of each plate and corresponding weight was taken to allow identification of non-compliance and provide a second reference for data input. Only initial plates selected were measured. We did not record the weight of a second round of plates by participants due to logistical constraints of the dining halls and researcher limitations. Keeping track of a second round of plates would require the researchers to closely observe participants, which is difficult based on the open concept layout of both dining facilities; however, the researchers asked participants whether they went back for seconds on the accompanying survey, which is described below.

After pre-consumption weights and photos were completed, researchers gave participants a survey to take while eating (see figure 2). Participants were asked about their overall satisfaction with their meal, if they went back for seconds, how many other diners they ate with, and general demographics. All factors included were thought to potentially influence individual SCW based on previous studies conducted at the University of Illinois Champaign-Urbana (Christoph & Ellison, 2017; Christoph et al., 2016; Ellison et al., 2019; Nikolaus, Nickols-Richardson, & Ellison, 2018) and anecdotal evidence from dining administration and staff members. To prevent leading or confusing questions, all survey questions were piloted with several undergraduate students prior to the start of the study. Once done eating, participants returned their plates and corresponding questionnaire to the researcher located by the dish return. This researcher removed any inedible items left on the plates (e.g. napkins, straws, bones, peels, etc). Then, the post-consumption weight was recorded along with a photo of each plate.

During data entry, participants with multiple round plates or oval platters had their SCW weights combined. To find the true weight SCW per participant, the average plate weight was subtracted from each observation. The research team weighed five empty round plates (average: 195.6 g) and five empty oval platters (average: 242.2 g) to determine the average plate weight. It should be noted some round plates were not the same weight as the standard round plates. After beginning data collection, dining administration estimated one in five round plates were approximately 100 g heavier than the standard round plate (Etchison & Van Liew, 2018). Due to

researchers' inability to visually differentiate between the standard and heavier round plates, the research team decided to subtract the average plate weight of the standard round plates for all round plate observations when calculating SCW.[6] The research team felt as though this would reflect the most accurate measurements and provide results most closely aligned with the true outcome. Consumption was calculated by subtracting the waste weight from the selection weight and was not directly observed.

3.3 Model & Data Analysis

Stata/MP Version 15.1 was used for data analysis. To assess the impact of change in plate size and shape on individual food SCW, we conducted a t-test with unequal variances between oval platters and round plates by location. To further determine intervention impact and control for potential confounders, we estimate a linear regression model using survey responses and individual plate SCW weights:

$$(1)\ Y_i = B_0 Intercept + B_1\ Oval_i + B_2 Location_i + B_3 Seconds_i + B_4 Feamle_i + B_5 Int'lStudent_i + B_6 Satisfaction_i + B_7 LunchMates2_i + B_8 LunchMates3_i + \varepsilon_i$$

Where *Y* denotes the outcome of interest (food selection, consumption, or waste) for individual *i* in grams. For waste, both the weight in grams as well as the percent waste (calculated as waste weight divided by selection weight) are used as dependent variables. $Oval$ is an indicator variable where 1 equals an oval platter and 0 equals a round plate. $Location$ is an indicator variable that equals 1 if the diner ate at Ikenberry Commons Dining Hall and 0 if the diner ate at Pennsylvania Avenue Dining Hall. The indicator variable $Seconds$ takes on 1 if participants indicated they returned for more food and 0 if they did not. $Female$ is an indicator variable where 1 is female and 0 is male. International Student (*Int'lStudent)* is also an indicator variable with 1 representing

[6]In the future, the research team will go back to the plate photos to identify potential cases where individuals received the heavier round plate. In these cases, post-photos would reveal a clean plate (0 g waste), but the calculated waste value would be greater than zero, generally around 100 g as this was the weight difference between the standard and heavier round plates.

an individual having grown up outside of the United States and 0 having grown up within the U.S. $Satisfaction$ is measured on a Likert scale from 1 being very dissatisfied to 5 being very satisfied with the meal eaten that day. Finally, the $LunchMates2$ and $LunchMates3$ indicator variables denote how many other people the individual ate with during the lunch period. $LunchMates2$ indicates that the person ate with 1-2 additional people whereas $LunchMates3$ indicates that the person ate with 3 or more people. The reference category for both variables is individuals who dined alone. ε is included as a random error term.

Based on equation (1), we have developed several hypotheses. As waste is our primary outcome of interest, we present our hypotheses for how each independent variable will affect waste. First, we hypothesize that $B_1 < 0$, meaning oval platters will result in less waste compared to round plates. This is because the surface area of the oval platter is smaller than that of the round plate, reducing the amount of food participants can fit onto their plate(s). Less selection should ultimately result in less waste. The effect of B_2 is ambiguous. We are unsure of differences in waste at the individual level between locations. We expect $B_3 < 0$, implying that participants who went back for seconds wasted less food from their first helping than those who did not return for more food. Selecting seconds would suggest the individual is still hungry after finishing their first plate(s). Sex is known to impact food SCW as females tend to regulate their food selection and intake more than men (Beardsworth et al., 2002). Therefore, we hypothesize the female coefficient, B_4, to be negative, meaning females waste more food than males. Females are expected to consume less of their selected food compared to males, resulting in higher food waste. It is unclear what sign B_5 will take on as food SCW habits between international and domestic students is unknown. International students may inherently select or consume more or less food than domestic students. These students may be less familiar with dishes offered in the dining halls. In this environment, students have indicated over selection of a variety of food as a way to hedge their satisfaction (Nikolaus et al., 2018); one meal component is bound to be satiable. Additionally, cultural norms, such as cleaning your plate, may dictate how much food is wasted between domestic and international students. We hypothesize that the satisfaction coefficient, B_6, will be negative, implying waste decreases as meal satisfaction rating increases. A higher rating of satisfaction should lead to greater consumption and less leftover edible food.

Lastly, we predict coefficients B_7 and B_8, will be positive, meaning that those who eat with others will waste more food than when dining alone. The behavior of others has been seen to both negatively and positively influence individual consumption and waste (Nikolaus et al., 2018). Nikolaus et al. (2018) noted dining hall goers frequently reported serving more food than they could consume. In the dining hall environment, socializing may take precedent to mindful eating and individuals may reflect waste behaviors of peers.

Additionally, we examine the impact of the intervention on the selection of seconds. Previous studies have found a significant increase in number of diners returning for seconds when using smaller plates (Rolls et al., 2007); while others saw no difference between plate sizes (Wansink & van Ittersum, 2013). In this study, it is important to know if there is a significant difference between plate types. A significant increase in the number of participants taking seconds when exposed to oval platters may change overall individual plate waste. Understanding if oval platters increase the likelihood to select seconds may influence future study designs and areas of focus. Due to our inability to directly measure seconds selected in this study, we estimate a logistic regression to estimate the probability that an individual went back for seconds, based on their survey response. We use the same predictor variables from equation (1), with the exception of *Seconds*.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Participant Characteristics

There were 1,825 total observations collected. A total of 1,408 observations were kept for analysis. Observations were excluded if: the participant did not return their plate (n=55); submitted an incomplete survey (n=100); or only selected food using non-standard dishware (e.g., only eating a bowl of soup; n=263).[7] The most recent enrollment statistics from The University of Illinois at Urbana-Champaign reported that 7,609 new Freshman students enrolled in the Fall of 2018, making up about 22% of the undergraduate population (University of Illinois System, 2018). The vast majority of these new students will live in university housing, which requires them to purchase a meal plan.

Table 2 presents the characteristics of the sample. There were no significant differences in sex or number of international students between the intervention and control groups. Our sample consisted of 40.20% female and 85.16% domestic students. The proportion of female students is slightly lower than the campus estimate of 46%, but the proportion of domestic students is in line with campus estimate of 85% (University of Illinois Urbana-Champaign, 2018). Dining administration estimated an average of 2,186 diners per weekday at Ikenberry Commons Dining Hall (IKE) and 652 diners per weekday at Pennsylvania Avenue Residence Dining Hall (PAR) during lunch hours (Etchison, personal communication, Dec. 11, 2018). Most diners reported being very (38.00%) to somewhat (48.30%) satisfied with their lunch, while only 13.71% reported feeling neutral, somewhat, or very dissatisfied. Approximately 38.35% of participants ate with one or two other people and 10.37% reported eating with 3 or more people. Of the participants exposed to oval platters, 30.92% returned for seconds, while 21.58% of those with round plates returned for seconds.

[7] There were no significant differences between included and excluded observations in terms of sex or country of residence. After excluding observations that included any non-standard dishware, there was no significant difference in selection between those that returned their plates and those that did not. In addition, students who did not return a complete survey were not statistically different from the sample in terms of selection.

4.2 Impact of Change in Plate Size and Shape

Table 3 presents the overall sample averages for food selection, consumption, and waste. The average amount selected per participant was 349.6 g, with consumption equaling 291.1 g for a total average waste of 58.5 g per person. Mean percent of plate waste was 16.0%. Table 4 shows the difference in mean SCW between round and oval platters per person. In this analysis, we see a 15.4% decrease in selection when oval platters were used. Mean selection with round plates was 377.4 g whereas oval platters saw an average of 319.4 g per person ($p < 0.001$). Similarly, there is a significant decline (8.3%) in consumption. Consumption was at 303.1 g per person with round plates, but only 278.0 g with oval platters ($p < 0.001$). On round plate days, the average participant wasted 74.3 g of their selected meal while oval platter days resulted in a mean waste of 41.4 g; a significant decrease in grams of food wasted ($p < 0.001$). Since selection, consumption, and waste were all lower with oval platters, it is important to determine if the rate of waste, or percent waste, is also lower. The percent waste for round plates was 19.1% and 12.7% for oval platters ($p < 0.001$). This suggests a smaller surface area prevents students from selecting more food than they can realistically consume. These results are in line with findings by Van Ittersum & Wansink (2011) and DiSantis et al. (2013). Both studies found that larger plates resulted in greater selection and consumption but did not report on waste. Additionally, a waste level of 12.7% is more in line with acceptable levels of waste in the National School Lunch Program (Buzby & Guthrie, 2002).

Using a two-sample t-test with unequal variances, we found a significant difference in SCW between locations ($p < 0.001$). For an in-depth analysis, we separated mean SCW by location (see table 5). In the IKE location, oval platters resulted in significantly lower selection, waste, and percent waste than round plates (all $p < 0.05$). At PAR, oval platters significantly reduced all outcomes of interest compared to round plates (all $p < 0.01$).

Table 6 presents the linear regression estimates for SCW. For selection, we see that oval platters are estimated to reduce selection by 55.7 g ($p < 0.001$) per participant, all else constant. Additionally, selecting seconds, sex, and satisfaction level all significantly influence selection. The selection of seconds decreased initial selection weight by 26.1 g, on average ($p = 0.001$). Females

selected 48.8 g less than males, on average ($p < 0.001$), while satisfaction increased overall selection ($p = 0.001$).

Similar to selection, consumption also declines with the introduction of oval platters (-18.6 g per student; $p = 0.003$). Going back for seconds, sex, and satisfaction all significantly influence consumption in addition to location. Returning for seconds is estimated to decrease consumption by 19.0 g, on average ($p = 0.010$). Females are estimated to consume an average of 60.0 g ($p < 0.001$) less than males. Individuals are estimated to consume 26.9 g ($p < 0.001$) more with each unit increase in meal satisfaction. Additionally, diners at the IKE location are estimated to consume 35.3 g ($p < 0.001$) more than those who eat at PAR, all else constant.

Lastly, waste and percent waste see a significant decline with the oval platter intervention (-37.1 g and -7.2%, respectively; both $p < 0.001$). Location, sex, satisfaction, and eating with 1-2 others all significantly impact waste and percent waste. Individuals dining in the IKE waste 31.8 g ($p < 0.001$) less than those in PAR; a decline in percent of meal wasted of 6.7% ($p < 0.001$). Females are estimated to waste 11.2 g ($p = 0.003$) more than males; approximately 5.3% ($p < 0.001$) more of their meal, on average. As hypothesized, those with a higher rating of satisfaction are less likely to waste food (-11.9 g and -4.1% per unit increase in satisfaction; both $p < 0.001$). Dining with one or two others is estimated to increase waste by 11.1 g or 2.7% (both $p = 0.004$) relative to eating alone. Unlike selection and consumption, waste and percent waste are not significantly influenced by returning for seconds.

4.3 Selecting Seconds

Using a chi-squared test, we found a significant difference in those returning for seconds between round plate and oval platter groups ($p < 0.001$). To further explore this, we ran a logistic regression to estimate the odds of selecting seconds (see table 7). The odds of going back for seconds for participants using oval platters is 1.48 ($p = 0.002$) times higher than those using round plates. Other significant variables that change the likelihood of selecting seconds are location, sex, international student, satisfaction, and dining with 3 or more people. Diners at IKE were less likely to select seconds than diners at PAR (OR=0.55; $p < 0.001$). Females were less likely to select seconds than males (OR=0.43; $p < 0.001$). Individuals that grew up in the United States were less

likely to select seconds than International students (OR=0.49; $p < 0.001$). Each unit increase in satisfaction increases the probability of going back for seconds (OR=1.20; $p = 0.026$). Lastly, those that dine with three or more people are 1.66 ($p = 0.014$) times more likely to select seconds.

Even though we could not directly observe those selecting and wasting seconds, we may estimate the total amount wasted from the number of participants who indicated they selected seconds and the average amount of food wasted by plate shape. For this calculation, we assumed the average amount of plate waste is the same from the first serving to the second.[8] Those using round plates wasted an average of 74.3 g with their first plate (table 4), and 21.58% (n=158) of round plate participants indicated that they returned for seconds. Those using oval platters wasted an average of 41.4 g with their first plate (table 4), and 30.92% (n=209) of oval platter participants indicated they returned for seconds. Table 4 reveals that individuals with oval platters waste 32.9 g less than those with round plates. Multiplying average waste by the total number of observations ((74.3 g*732 round plate observations) + (41.4 g*675 oval platter observations)) plus the number of participants selecting seconds based on plate shape ((74.3 g*158 round plate seconds) + (41.4 g*209 oval platter seconds)) gives us total participant waste (66,124.4 g for round plates; 36,585.6 g for oval platters). This would increase average plate waste to 90.3 g for round plates and 54.2 g for oval platters, meaning oval platters still result in less waste (36.1 g) than round plates. Thus, the increased proportion of diners selecting seconds with oval platters does not appear to offset the waste reduction gains.

4.4 Limitations

While this study makes several contributions to the food waste literature, there are some limitations that should be acknowledged. First, many participants commented on the difference in plate shape and size between weeks and locations, noting that they could not fit as much food on the oval platters as the round plates (figure 1). The difference in plate shape and date of implementation may have heightened diners' awareness of the intervention and study intentions. Similar participant awareness found by Rolls et al. (2007) did not impact the study's

[8] This is likely a conservative estimate, as one would expect waste to decrease with the second serving, as diners are more aware of their current state of satiation and preferred foods.

results, so there may not be need for concern. However, to mitigate any negative feedback from diners, the phasing in of an oval platter after university breaks or between academic years may produce a more favorable reception with students after not having repeated exposure to other dishware sizes prior to oval platter implementation. Furthermore, dining hall staff felt as though there was more food waste found on the floor and on tables when oval platters were used. Due to the oblong shape, diners may have found it more difficult to carry platters without spillage. This negative externality was beyond the scope and research capacity of this study but should be considered in future work.

Second, there was low participation in the study overall. Based on the number of observations per week and the average number of diners per week in each location, we were able to estimate population coverage. Although PAR had higher coverage rates than IKE, overall coverage was still low (range of 8.5% to 11.5% in PAR; 2.9% to 4.0% in IKE). Clearly, higher coverage rates would have been preferred, but due to participant recruiting protocol and physical limitations in both dining halls, larger participation was unachievable. Alternative methods to increase participation may be more useful for attaining higher coverage rates in future studies.

Additionally, the field nature of this study resulted in some issues that were beyond the researchers' control. As noted in the methods, there were two types of round plates, with one much heavier than the other but visually identical. While the prevalence of these heavier plates was likely low (estimated to be one in five), the research team proceeded with an analysis thought to best represent the data in estimating SCW for round plate observations. This could overstate waste in some cases. Further, this study did not account for SCW of second helpings. Diners returning for seconds may be beneficial in reducing plate waste in dining halls. Students returning for seconds may be more attune to their levels of satiation and enjoyment of the foods served and would only select seconds that would fulfil their needs and preferences. It is also important to note there may be selection bias in the sample as students opted to participate in the study. Diners electing to participate in the study may have inherent waste-related characteristics that this study did not measure, such as anti-waste attitudes and/or various levels

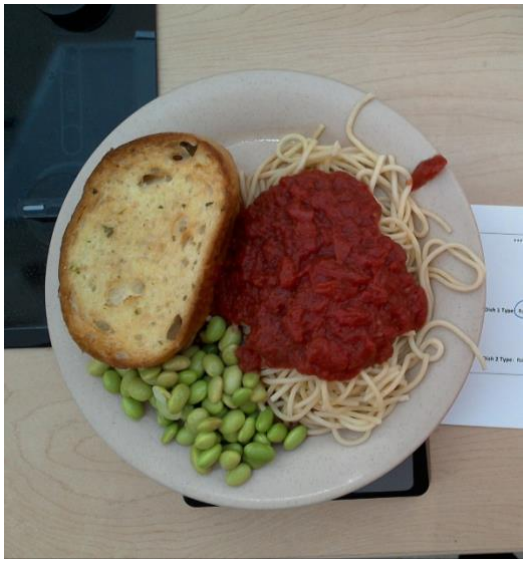
of nutrition education, relative to those who declined to participate. Each issue should be considered in future research.

Lastly, this study did not analyze shifts in meal components selected. Wansink and Just (2013) noted a decrease in salad selection with trayless dining. The change in plate shape/size may lead diners to make trade-offs between different dishes. Plate photos allow us to investigate shifts in food choices and subsequent dietary quality in future research.

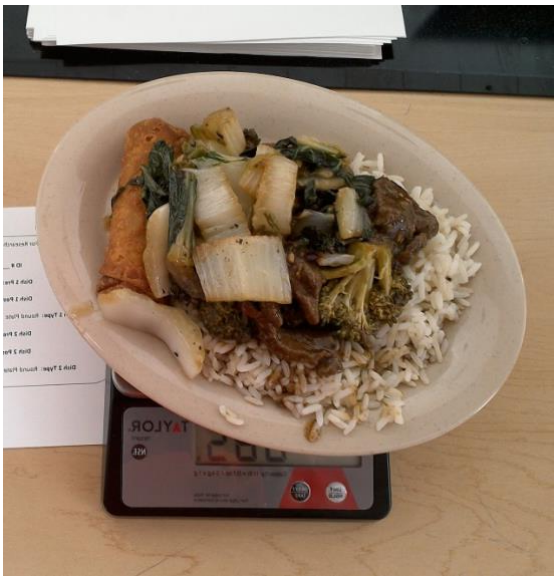
CHAPTER 5: CONCLUSION

Students continue to disregard personal responsibility when it comes to food waste in dining halls (Nikolaus et al., 2018). With inattentive patrons, dining administration should implement strategies that directly reduce food waste. This study shows that introducing smaller oval platters in a university dining setting can significantly reduce plate waste compared to using larger round plates. This study confirms transitioning from round plates to smaller oval platters reduces individual selection, consumption, and waste in all-you-care-to-eat university dining halls. Of the three categories for waste reduction interventions in university dining halls, findings from this study have a large impact at a moderate cost as compared to education campaigns, standard serving size alterations, or pricing strategy adjustments. Future research should study the impacts of smaller size and alternative shaped plates on selection, consumption, and waste of seconds. Changes in dietary choices and unintended intervention consequences, like spilled food, should also be investigated. Likewise, long-term effects of this intervention are unknown. Supplementary research should test this intervention over a long period of time.

FIGURES



Round
9” x 9”
Surface Area: 63.62 in^2



Oval
9.75” x 7.75”
Surface Area: 59.32 in^2

Figure 1. Main Dish Plates

1. **How would you rate your satisfaction with your lunch today?**
   - ◯ Very Satisfied
   - ◯ Somewhat Satisfied
   - ◯ Neither Satisfied nor Dissatisfied
   - ◯ Somewhat Dissatisfied
   - ◯ Very Dissatisfied

2. **How would you describe the length of the lines in IKE to get your lunch today?**
   - ◯ This is my first time eating in IKE
   - ◯ Lines were longer than normal for IKE
   - ◯ Lines were about the same as normal for IKE
   - ◯ Lines were shorter than normal for IKE

3. **Did you feel rushed during your lunch today?**
   - ◯ Yes
   - ◯ No

4. **Did you go back for a second plate of food (non-dessert) today?**
   - ◯ Yes
   - ◯ No

5. **How many people did you eat with today?**
   - ◯ I ate by myself
   - ◯ 1-2 other people
   - ◯ 3-4 other people
   - ◯ 5 or more other people

6. **What is your sex?**
   - ◯ Female
   - ◯ Male

7. **Did you grow up in the U.S.?**
   - ◯ Yes
   - ◯ No

Thank you for participating in our study! To enter to win one of the $50 Amazon cards, enter your email below.

_____

For Research Team Only – Do Not Complete

ID # _____

Dish 1 Pre: _____

Dish 1 Post: _____

Dish 1 Type: Round Plate Oval Platter Other _____

Dish 2 Pre: _____

Dish 2 Post: _____

Dish 2 Type: Round Plate Oval Platter Other _____

Figure 2. Survey and Weight Record

TABLES

Table 1.
Crossover Trial Design.

Week	Dates	Location	Plate Type
Week 1	Sept. 17-21	PAR	Oval
Week 2	Sept. 24-28	IKE	Round
Week 3	Oct. 15-19	PAR	Round
Week 4	Oct. 22-26	IKE	Oval

Table 2.
Descriptive Statistics (*N* = 1,408)

	N	%
Location		
IKE	757	53.76
PAR	651	46.24
Plate Type		
Round	732	51.99
Oval	676	48.01
Week		
1 (PAR, Oval)	374	26.56
2 (IKE, Round)	455	32.32
3 (PAR, Round)	277	19.67
4 (IKE, Oval)	301	21.45
Day		
Mon.	279	19.82
Tues.	339	24.08
Wed.	236	16.76
Thurs.	334	23.72
Fri.	220	15.63
Meal Satisfaction		
Very satisfied	535	38.00
Somewhat satisfied	680	48.30
Neutral	139	9.87
Somewhat dissatisfied	46	3.27
Very dissatisfied	8	0.57
Lunch Mates		
Ate alone	722	51.28
Ate with 1-2 people	540	38.35
Ate with 3 or more people	146	10.37
Seconds [a]		
Yes	367	26.07
No	1,041	73.93
Sex		
Male	842	59.80
Female	566	40.20
Country of Residence		
International	209	14.84
United States	1,199	85.16

[a] Participant indicated they returned for additional food.

Table 3.

Average selection, consumption, and waste per participant; combined round plates and oval platters. (*N* = 1,408)

	Mean	SD	Min	Max
Total Selection (g)	349.6	±134.5	69.8	1186.8
Total Consumption (g)	291.1	±123.5	12.0	1075.0
Total Waste (g)	58.5	±72.4	0	461.8
Pct. Waste (%)	16.0	±0.5	15.1	16.9

Table 4.

Two-sample t-test with unequal variances. Difference in average selection, consumption, and waste between round plates and oval platters.

	Round Plates		*Oval Platters*		
Outcome	Mean	Std. Dev.	Mean	Std. Dev.	p-value
Selection (g)	377.4	±137.9	319.4	±124.1	p<0.001
Consumption (g)	303.1	±127.5	278.0	±117.7	p<0.001
Waste (g)	74.3	±80.1	41.4	±58.4	p<0.001
Pct. Waste (%)	19.1	±18.2	12.7	±16.2	p<0.001

Table 5.

Two-sample T-Test with unequal variances. Difference in average selection, consumption, and waste between round plates and oval platters by location.

	Round Plates		*Oval Platters*		
Outcome	Mean	Std. Dev.	Mean	Std. Dev.	p-value
IKE					
Selection (g)	366.0	±136.6	344.0	±121.9	p=0.022
Consumption (g)	314.4	±135.6	302.7	±118.3	p=0.207
Waste (g)	51.5	±54.6	41.4	±54.0	p=0.012
Pct. Waste (%)	14.7	±15.1	12.0	±14.1	p=0.015
PAR					
Selection (g)	396.3	±138.0	299.6	±122.4	p<0.001
Consumption (g)	284.4	±110.5	258.1	±113.6	p=0.003
Waste (g)	111.9	±99.1	41.4	±61.7	p<0.001
Pct. Waste (%)	26.2	±20.4	13.3	±17.7	p<0.001

Table 6.
OLS Regression estimates for average selection, consumption, and waste per participant (*N* = 1,408)

Variable	Selection (g) *(Std. Error)*	Consumption (g) *(Std. Error)*	Waste (g) *(Std. Error)*	Waste (%) *(Std. Error)*
Intercept	346.6	210.6	136.0	36.8
	(21.8)	(19.7)	(11.5)	(2.8)
Oval [a]	– 55.7***	– 18.6**	– 37.1***	– 7.2***
	(7.0)	(6.3)	(3.7)	(0.9)
Location [b]	3.5	35.3***	– 31.8***	– 6.7***
	(7.1)	(6.4)	(3.7)	(0.9)
Seconds [c]	– 26.1***	– 19.0**	–7.1	– 1.0
	(8.1)	(7.3)	(4.3)	(1.0)
Female [d]	– 48.8***	– 60.0***	11.2**	5.3***
	(7.2)	(6.5)	(3.8)	(0.9)
Int'l Student [e]	– 15.2	–15.6	0.11	0.6
	(9.8)	(8.8)	(5.2)	(1.2)
Satisfaction	15.0***	26.9***	– 11.9***	– 4.1***
	(4.3)	(3.9)	(2.3)	(0.6)
Lunch Mates 2 [f]	10.9	–0.24	11.1**	2.7**
	(7.3)	(6.6)	(3.8)	(0.9)
Lunch Mates 3 [f]	3.5	–0.01	3.5	1.0
	(11.8)	(10.6)	(6.2)	(1.5)

* Significant at 0.05 level
**Significant at 0.01 level
***Significant at 0.001 level
[a] Effect relative to round plate
[b] Effect relative to PAR
[c] Effect relative to not returning for additional food items
[d] Effect relative to male
[e] Effect relative to participants who did not grow up in the United States
[f] Effect relative to eating alone

Table 7.
Odds of participant choosing seconds (*N* = 1,408)

Variables	OR	CI 95%	
	(Std. Error)	*Lower*	*Upper*
Intercept	0.38	0.17	0.87
	(0.16)		
Oval [a]	1.48**	1.15	1.91
	(0.19)		
Location [b]	0.55***	0.43	0.57
	(0.07)		
Female [c]	0.43***	0.33	0.57
	(0.06)		
Int'l Student [d]	0.49***	0.36	0.68
	(0.08)		
Satisfaction	1.21*	1.02	1.42
	(0.10)		
Lunch Mates 2 [e]	1.17	0.89	1.52
	(0.16)		
Lunch Mates 3 [e]	1.66*	1.11	2.49
	(0.34)		

*Significance level at 0.05
** Significant at 0.01 level
***Significant at 0.001 level
[a] Effect relative to round plate
[b] Effect relative to PAR
[c] Effect relative to male
[d] Effect relative to participants who did not grow up in the United States
[e] Effect relative to eating alone

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APPENDIX A: DATA COLLECTION PROTOCOL

"The Impact of Dining Environment Factors on Food Choice Behavior" Protocol
September 17 - 28 & October 15 - 26

Purpose of the study is to test if a change in plate shape and size decreases plate waste at two University of Illinois dining halls. Further research on nudges within dining halls to reduce plate waste. Weighing plates before and after consumption will determine the amount students are wasting. Intervention weeks will be in September and October.

Study Locations: Pennsylvania Avenue Residence Dining Hall 9/17-21 & 10/15-19
Ikenberry Commons Dining Hall 9/24-28 & 10/22-26

PAR 9/17-21 Oval Plates
IKE 9/24-28 Round Plates
PAR 10/15-19 Round Plates
IKE 10/22-26 Oval Plates

Start of lunch **Set Up** (10:45-11:00):

1. Record clock-in time [see time sheet]
2. Set out signs near dining hall entrance, select dining stations, and data collection tables (pre- and post-weight tables)

Pre-Weight Table	*Post-Weight Table*
○ Signage set up ○ Scale out (set to *grams;* only use 5 kg scales) ○ Tablet ready for photographs ○ Blank surveys and study info sheets available ○ Be sure to wear gloves	○ Set up table near dish return; include gloves ○ Trashcan near for napkins & other non-food waste ○ Scale out (set to *grams;* can use 1 kg or 5 kg scales) ○ Tablets ready for photographs ○ Box/folder to store completed surveys; additional study info sheets available ○ Be sure to wear gloves

End of lunch **Break Down** (1:45pm-2:00pm):

1. Stop giving out surveys between 1:30 and 1:45pm to allow final students to complete surveys

2. Make sure there are no remaining students with surveys
3. Wipe down tables and scales
4. Set the tables and signage aside
5. Record clock-out time [see time sheet]

Experiment Procedure:

	Pre-Weight Table	*Post-Weight Table*
Role of Investigators	1. Approach and recruit students waiting in line or who have full plates. Be sure to recruit students before they sit down and start eating 2. Weigh participant's plates and record on survey	1. Identify and assist participants that have filled out the entire survey and direct them to return their plates 2. Weigh participants' plates and record on survey. Once done, place plates on dish conveyer 3. Assist with weighing while busy and compare dining site's stated menu to actual menu on-site documenting any discrepancies
Protocol for Weighing	1. When a student approaches, pick up a survey a. Make sure it has a survey ID 2. Either have student place their plate on scale *or if wearing gloves* place their plate on the scale for them a. Zero scale before weighing by pressing ON/OFF/TARE button 3. Record the weight on the back of the survey and circle the type of dish weighed a. There is no need to capture drinks 4. Capture a picture with all edges of plate within the screen making sure it includes a. Survey ID number b. Weight of the plate c. All items on the plate 5. Return student's plate and give them the survey for them to fill out while eating; explain where to return plate and survey	1. Collect survey from student and take their plate a. Participants are free to leave once we have taken their plate b. Zero scale before weighing by pressing ON/OFF/TARE button 2. Remove any non-edible food waste from their plates (napkins or paper products, bones, peels, etc.) 3. Weigh the plate and record the weight on the back of the survey a. There is no need to capture drinks 4. Capture a picture with all edges of plate within the screen making sure it includes a. Survey ID number b. Weight of the plate c. All items remaining on the plate 5. Take student's plate to dish return 6. Place completed survey in folder

Notes and Reminders:

If a student approaches with multiple dishes, only weigh the "main entree" dishes — these should be the round plates or oval platters. In PAR, they also have stir-fry bowls, so you can circle the "Other" dish type and specify bowl on the back of the survey. Smaller dishes like soup/cereal bowls or dessert plates do not need to be included in the study. If a student has multiple main plates, weigh and photograph both plates individually and record on the back of survey. Indicate there were two plates by writing X2 next to main dish identifier on back of survey (Dish1 and Dish 2 information, respectively). Make sure to circle both dish types.

Please request that students return their dishes to the "Drop-Off Table" (post-weight table) before getting seconds. You can also inform students that dishes from second helpings do not need to be documented.

Do not inform students of what we are measuring. IF they ask, inform them we are helping the dining hall keep track of what items students like eating, or determining menu changes, etc. Keep it broad. If they ask specifically about weighing, you can tell them we are trying to help dining improve their menu forecasting and planning.

It is extremely important to capture participants after consumption. Be sure to monitor students putting their plates away. If they have a survey in-hand they need to give their plate to the *Post-weight table*.

Lead student needs to confirm set up of experiment each day. Make sure the correct plates are out and are replacing the larger bowls.

Silver bus will take you from Mumford to PAR Dining Hall
#22 Illini bus takes you from Mumford to 4th and W Gregory Dr. close to Ike Dining Hall