

UNDERSTANDING THE EFFECTS OF FOOD WASTE REDUCTION
METHODS AND THE IMPLEMENTATION OF
A FOOD WASTE PROGRAM

by

Alicia Rae Leitch

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DEDICATION

To the ones I love: East, West, and everywhere in between.

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To my phenomenal advisors Dr. Carmen Byker Shanks and Dr. Selena Ahmed and to my always informative graduate committee member Thomas Bass: I am honored to have been a member of your incredibly passionate and ambitious team!

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ABSTRACT

Approximately 1.3 billion tons of food is wasted each year totaling nearly a third of all food produced in the world.¹ Food service operations are one of the leading contributors to food waste.² Decreasing the amount of food waste is an emerging priority of the United States Department of Agriculture. Large-scale food service operations such as university dining facilities may be prime location to implement food waste reduction strategies in order to reduce overall food waste and increase sustainability. Despite the notable contribution of large-scale food service operations to food waste, there is a lack of research on the effectiveness food waste reduction strategies in such operations. The research presented here seeks to address this research need of identifying food waste reduction strategies and their effectiveness within large food service operations through a systematic review of literature using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement guidelines. Findings from this systematic review were synthesized to design and implement a cross-sectional pre and post study evaluating the effectiveness of two food waste reduction strategies including dining facility changes as well as a large service style renovation. Findings of the systematic review indicate that implementing food waste reduction strategies are effective in reducing overall food waste. Analysis of the cross-sectional pre and post study indicated a positive effect of dining hall renovation on reducing food waste. Findings from this study provide valuable information to inform food waste research and evidence on designing policies and practices to reduce food waste in large-scale food service operations.

CHAPTER ONE

INTRODUCTION

Consumers and food service operations are the largest contributors of food waste within the entire food system.² Food waste refers to the loss of food in all stages of the food supply chain that is meant for human consumption.³ Food waste is a pressing problem globally for achieving sustainability with negative implications for the environment, socio-economic factors, nutrition and, food security. Numerous stakeholders and processes in the food system contribute to the generation of food waste including over production, premature harvesting methods and high appearance quality standards.⁴ Recently, reducing food waste has emerged as a priority area for addressing sustainability and food security by federal and international organizations including the USDA, EPA, and FAO. The USDA and EPA recently partnered to set the nation's first food waste reduction goal to reduce the amount of food wasted in America by 50 percent by 2030 which they seek to achieve through a series of programs and policies).

⁵Universities play a notable role in producing food waste and are also part of the solution in meeting national goals for reducing food waste. As higher educational institutions, universities have the responsibility to be on the forefront of implementing sustainable practices and using available resources to enrich curriculum and quality of life.⁶ Solutions for addressing food waste can be positively integrated into universities through a series of educational and outreach initiatives in a way that meets both larger sustainability as well as learning outcomes.

Food Waste Defined

Food waste refers to the loss of food in all stages of the food supply chain that is meant for human consumption.³

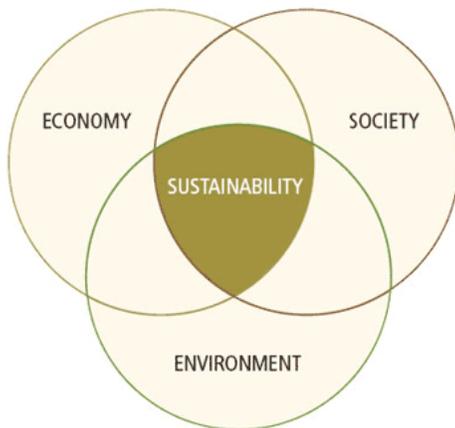
Implications of Food Waste for Sustainability

Food waste has numerous implications for sustainability including impacts on the environment, economics, and social factors nutrition, and food security

³Environmentally, wasting food also wastes the water, soil, and nutrient resources used to grow that food. Economically, food is expensive and throwing away food is directly wasting financial resources. Socially hunger is a large issue both in the United States and all around the world. From a nutrition and food security perspective, food that is being wasted could go toward feeding someone suffering from malnutrition and hunger. ³

⁷Directing food that is wasted in a positive direction such as to those in need or to be recycled aids in food security as well as overall sustainability.

Figure 1. Factors influencing sustainability within a food waste system.



Theoretical Foundations of Reducing Food Waste

Behavioral economics can be applied to food environment interventions and food waste reduction strategies. Behavioral economics study the social, emotional, and cognitive contributors to economic decisions of individuals and institutions.⁸ Applying a behavioral economic framework to food waste reduction methods draws on the physiological that motivate individual behavior. Knowing which environmental changes influence individuals food waste habits allows for a better comprehension of food waste reduction strategies.⁸ Environmental changes include smaller plate sizes, smaller portion sizes, and using smaller serving utensils. Understanding consumers' behavior in conjunction to these changes is crucial in understanding how to reduce food waste.

Goals in Measuring Food Waste

An estimated one-third of all food that is produced worldwide is waste.¹ Determining how much food waste is produced is essential to understanding how to reduce it and how to redirect it in a positive way. The goal of measuring food waste is to accurately measure the amount of waste produced. Food waste measurement may also focus on the types of foods wasted in order to identify specific food items that contribute to waste. Once the amount and type of food is determined, how to reduce and redirect that food waste can be established.

Food Waste, Composting, and Sustainability

Improving campus sustainability is becoming increasingly important to institutions nationwide. Universities may evaluate their sustainability performance against others by using tools such as the Association of the Advancement of Sustainability in Higher Education's Sustainability Tracking Assessment and Rating System™ (STARS).^{9,10} These programs allow universities to display their sustainability efforts and show that they are progressively improving their campus. The United States Department of Agriculture and Environmental Protection Agency, along with other private organizations, recently announced the first national food waste reduction goal to reduce food waste by 50% by 2030.⁵ This push for reduced food waste as a metric of sustainability allows for more support for the implementation of university food waste reduction and composting programs.

Research Questions

The overall research questions of this study are:

1. Will the implementing food environment changes focused on behavioral food waste reduction strategies within a university dining hall reduce post-consumer food waste?
2. Will a large service style renovation of a university dining hall focused on made to order food options, greater appeal of food offerings and increased diversity of options reduce post-consumer food waste?

Overall Objectives and Specific Aims

This thesis focuses on food waste reduction and management in a university setting by evaluating the effects of renovation, behavioral intervention, and waste segregation and composting. Literature was reviewed to assess current food waste reduction methods in large foodservice venues. Food waste data was collected to measure the amount of Pre-Consumer and Post-Consumer food waste available for composting. Once baseline data was collected, Pre-Consumer food waste was collected and implemented into an Aerated Windrow Composting system. The food waste composting system produced a rich soil which is used as a 20% soil amendment for university landscaping. The goals of this thesis are to assess the success of food waste reduction methods in a university dining facility, provide an accurate measure of pre-consumer and post-consumer food waste available for future composting systems, and improve campus sustainability by positively directing that food waste into a newly implemented composting system.

Hypotheses

This research has two overall hypotheses:

1. Implementing food environment interventions focused on behavioral food waste reduction strategies at a university dining facility (Intervention #1) will reduce post-consumer food waste.

2. Renovation of a university dining facility focused on made to order food offerings, greater appeal of food offerings, and increased diversity of options (intervention #2) will reduce post-consumer food waste.

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CHAPTER TWO

FOOD WASTE REDUCTION STRATEGIES IN LARGE FOODSERVICE

OPERATIONS: A SYSTEMATIC REVIEW OF LITERATURE

Contribution of Authors and Co-Authors

Manuscript in Chapter 2

Author: Alicia Rae Leitch

Contributions: Responsible for preparation of review including research design, review analysis, and manuscript writing.

Co-Author: Dr. Carmen Byker Shanks

Contributions: Facilitated study design, provided assistance and constant guidance in research and manuscript preparation, review analysis, and edits to manuscript tables.

Co-Author: Dr. Selena Ahmed

Contributions: Provided input on study design and critical revision to manuscript.

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ABSTRACT

Addressing food waste in large food service operations is a pressing need towards creating more sustainable food systems. The objective of this review was to examine food waste reduction strategies utilized at large food service operations. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement guided the systematic review of literature. The systematic literature review was conducted at [blinded institution] and included peer-reviewed articles published in the United States that collected primary data regarding food waste reduction strategies at large on-site food service organizations (e.g., universities, hospitals, hotels) that have a secondary aim to their business beyond proving food through a restaurant setting. Eleven articles met inclusion criteria. Nine were conducted in university dining facilities, one in a hospital, and one in a chain of hotels. The food waste reduction strategies examined included removing trays, reducing portion sizes, cues to diners, service style changes, reducing plate sizes, observational audits, and employee focus groups. These strategies were found to have a positive influence on reducing food waste. The small body of relevant literature highlights the need for future research to measure effectiveness of food waste reduction strategies within large food service operations using comparable systematic methods.

Key words: Food Waste; Food Waste Reduction; Foodservice; University; Sustainability

INTRODUCTION

Food waste is a pressing problem globally for sustainability with negative implications for the environment, socio-economic factors, nutrition, and food security. In the United States, approximately 70 billion pounds of food is wasted per year¹ with over 97 percent of this food waste being directed to landfills.² Globally, approximately one third of all food that is produced for human consumption is lost or wasted.³ Food waste refers to the loss of food in all stages of the food supply chain that is meant for human consumption.⁴ According to the USDA, households and food service operations including restaurants, cafeterias, fast food chains, and caterers collectively lost 86 billion pounds of food in 2008.⁵ Excessive food waste is a pressing nutrition issue as food wasted has the potential to be redirected to address dietary needs of the food insecure.

Implementing food waste reduction strategies in food service operations may positively influence several aspects of sustainability including environmental, economic, and nutrition benefits.⁵ The environmental benefits of reducing food waste include conserving resources, lowering greenhouse gas emissions, producing rich soil, and improving facility sanitation.⁶ Rotting food waste that ends up in landfills causes a release of the powerful greenhouse gas methane.⁷ Composting provides an alternative to food waste ending up in landfills. Composting improves sanitation by directing food waste into durable closed bins reducing rodent and insect problems.⁶ Composting food waste also produces rich soil which can be used for landscaping and food production.⁸

The disposal of food requires numerous resources including the human resources of disposing of that food, and monetary inputs. Economically, reducing food waste in a

food service setting can decrease the cost associated with disposal, acquiring additional food, and the labor to prepare new food.⁹

Food waste impacts food security as the loss of food leads to less food available to everyone.⁴ Reducing food waste allows more calories to be available for consumption.¹⁰ This aids in bridging the gap between the amount of food available now and the amount needed to sustainably feed the world. There is currently a 70% difference in calories from food produced daily and the total needed to feed the estimated 9.5 billion in 2050. Reducing food waste will help bridge this gap while simultaneously improving livelihood of food insecure populations.¹⁰

Although food waste at the consumer levels are highest from 31 to 39 percent, food service operations notably contribute to the amount of food waste through processing, distribution, and consumption.³ Approximately 4 to 10 percent of food purchased by restaurants and food service operations becomes kitchen waste before that food even reaches the consumer.⁴ Another significant portion of food is served, but never eaten. Plate waste is a significant contributor to losses in the food service industry as well. Plate waste in food service results primarily from large portions and undesired garnishes. On average, diners leave 17 percent of meals uneaten.⁵ Given their size, large food service operations can greatly reduce food waste by implementing more sustainable food practices.

Food waste reduction strategies can be used to reduce overall food waste and increase sustainability.¹¹ Food waste reduction strategies focus on changes within a food environment that can reduce food waste. Examples of food waste strategies include

reducing portion sizes served, reducing plate sizes, as well as changes in service styles in order to produce less waste.¹¹ A better understanding of food waste reduction strategies and their effectiveness is needed to better understand how to reduce food waste within large food service institutions. The aim of this systematic review is to examine food waste reduction strategies at large on-site food services, internal to larger institutions or businesses (e.g., universities, hospitals, hotels), in order to identify research priorities regarding food waste towards designing evidence-based interventions to reduce food waste.

METHODS

A systematic review of peer-reviewed literature was conducted using the following search engines: Google Scholar, Science Direct, ProQuest, and Taylor and Francis. The systematic review was conducted according to PRISMA guidelines.¹² This review was conducted by searching for articles involving food waste at large on-site food service institutions including universities, hospitals, and hotels that have a secondary aim to their business beyond providing food through a restaurant setting and have the potential to produce a large amount of food waste. Key words included combinations of the following terms and words using Boolean search terms: institutional, food waste, reduction methods, university, hotel, hospital, college, restaurant, campus dining halls, foodservice, service style, and sustainability. Search criteria involved primary, secondary, and review peer-reviewed articles that have been published in research journals. We limited articles to within the last ten years to capture current practices, including all articles since January 2005. Articles were excluded if they did not focus on food waste reduction strategies at

large on-site food service institutions including universities, hospitals, and hotels that have a secondary aim to their business beyond providing food through a restaurant setting. Additionally, articles that did not test the effectiveness of food waste strategies were excluded.

Articles were first evaluated by their titles and abstracts. If food waste was in the title or abstract the full article was reviewed to determine relevance. Articles that did not mention food waste in the title or abstract were excluded. Titles and abstracts that met the inclusion criteria were recorded for full text review. Data collection was performed by one author then reviewed by additional two authors. Authors reviewed each article individually and agreed on inclusion or exclusion. The references were utilized to determine if any additional studies were relevant to this review.

Data was collected from finalized articles and organized (See Table 1) to highlight: Purpose, Population, Type of Foodservice, Waste Reduction Method, Duration of Study, and Food Waste Results.

RESULTS

A total of 20,800 articles were retrieved using the database search. After eliminating articles that did not meet inclusion criteria based on title and abstract screening, 56 articles remained for content review. After reviewing the full article studies were excluded because they did not take place at a large foodservice operation or did not focus on food waste reduction strategies. The final sample for this review included 11 studies that utilized food waste reduction strategies within large institutions. See Figure 2 for PRISMA flow diagram resulting in the final set of studies reviewed. Of the reviewed

studies, a total of nine were carried out at University, one was carried out at a hospital, and one was carried out in a chain of hotels.

Food Waste at Universities

Out of the nine articles that were conducted, 5 evaluated the effect of removing trays within a university dining hall on reducing food waste.¹³⁻¹⁷ Two studies focused on reducing food waste by decreasing the portion sizes of specific foods served in a university dining hall.^{18,19} One article implemented a prompting system which included cues to assess the possibility of reducing food waste within a university dining hall.²⁰ Another study evaluated the effects that service style has on food waste within a university dining facility²¹. All food waste reduction strategies were successful in reducing overall food waste by % to %. Removing trays from dining facilities was the most common food waste reduction method One study found that when trays were available consumers wasted 32% more food than when they were not available.¹⁴ Reducing portion sizes also reduced food waste while decreasing the total amount of french fries consumed.^{16,20} Smaller portion sizes minimized the amount of french fries needing to be produced, thus leading to less waste.¹⁸ Visual prompts encouraging returning for additional food and service style reduced food waste as well, the prompts alone decreased food waste by 15%.

Food Waste at a Hospital

One study was conducted in a hospital and focused on food waste reduction strategies using both an observational audit as well as an employee focus group.²² The

aim of this study was to gain insight on pre and post-consumer waste and how the hospital can address this waste towards improving sustainability. Results of this study showed that most food waste was generated from overproduction.²² Staff attitudes were also considered a defining factor in food waste production. Food preparation staff members were more concerned about customer perspective where managerial staff was more interested in financial implications. Overall, improving organization and using further prepared food options reduced food waste, however, assessing staffs perspectives was the most influential factor.²²

Food Waste at Multiple Hotels

One study examined the effects of reducing food waste throughout a chain of hotels by reducing plate size as well as incorporating cues into their dining experience.²³ Diners were exposed to signs that encouraged returning to the buffet multiple times for more food rather than taking too much at once and throwing food away. Smaller plate sizes lead to a 19.5% reduction in food waste. Additional signage reduced waste even further by 20.5%.²³

DISCUSSION

Understanding the effectiveness of food waste strategies is crucial to understanding how to reduce food waste within large food service institutions. Within all 11 articles food waste was reduced. The most common food waste reduction method was removing trays at universities. In addition, for studies that compared tray removal with other food reduction strategies, the former was found to be more effective. Reducing

portion sizes and incorporating cues into the dining experience were also common but less successful than removing trays. Other less common food waste reduction strategies included changes in service style and reducing plate size. Although food waste reduction strategies differed, they all were successful in reducing food waste. Strategic stacking food waste reduction strategies may be a promising avenue to reduce food waste.

Introducing food waste reduction strategies can benefit food service operations in institutions and businesses, such as universities, hospitals, and hotels, by positively influencing the environment, offering economic savings and increase food security by reducing overall food waste. Sustainable practices that can encourage food waste reduction across large foodservices include smaller portion sizes, removing trays, improved signage, and using compostable to-go containers.²⁴ Food service operations can further their sustainability initiatives by creating a composting system where food waste is composted to create rich soil for use in landscaping or further food production.

This systematic review summarizes the current evidence for food waste reduction involving food waste at large on-site food service institutions including universities, hospitals, and hotels that have a secondary aim to their business beyond providing food through a restaurant setting and have the potential to produce a large amount of food waste. Results of this systematic review provide evidence on the effectiveness of food waste interventions at universities including removing trays in dining halls, reducing portion sizes of the food being served, and relating cues to decrease the overall amount of food waste. In a hospital setting, results show that being aware of not only the amount of food wasted but where that waste is coming from is extremely beneficial in order to

reduce food waste as overproduction was found to be the biggest contributor to food waste. This review also shows that a study in a chain of hotels making small changes such as reducing plate size and adding social cues to return to the buffet rather than take too much at once can successfully reduce food waste.

Evidence on the effectiveness of several food waste strategies are highlighted in this review including removing trays and reducing portion sizes. These strategies should be implemented by both large and small food service operations towards reducing food waste.

This review also highlights the limited number of articles evaluating food waste reduction strategies in large food service institutions. Future research is needed to assess food waste at other large food service institutions including schools and restaurants. Research is further needed to measure the effectiveness of additional food waste reduction strategies as well as systematically comparing these. For example, comparing the impact of various service styles within food service settings on food waste would be valuable in designing more sustainable operations.

CONCLUSION

Food waste is a pressing sustainability issue with negative externalities for the environment, socio-economics, and food security. Due to their size, large food service operations can greatly reduce food waste by implementing more sustainable food practices including food waste reduction strategies to reduce the amount food waste they produce. Implementing food waste reduction strategies such as smaller portion sizes, tray-less dining, and using compostable to-go containers can reduce food waste as well as

increase overall sustainability at universities, colleges, and other large food service institutions.

Figure 2. PRISMA flow diagram of systematic review of all relevant articles with an experimental design that focused on food waste at large on-site food service institutions including universities, hospitals, and hotels that have a secondary aim to their business beyond the restaurant.

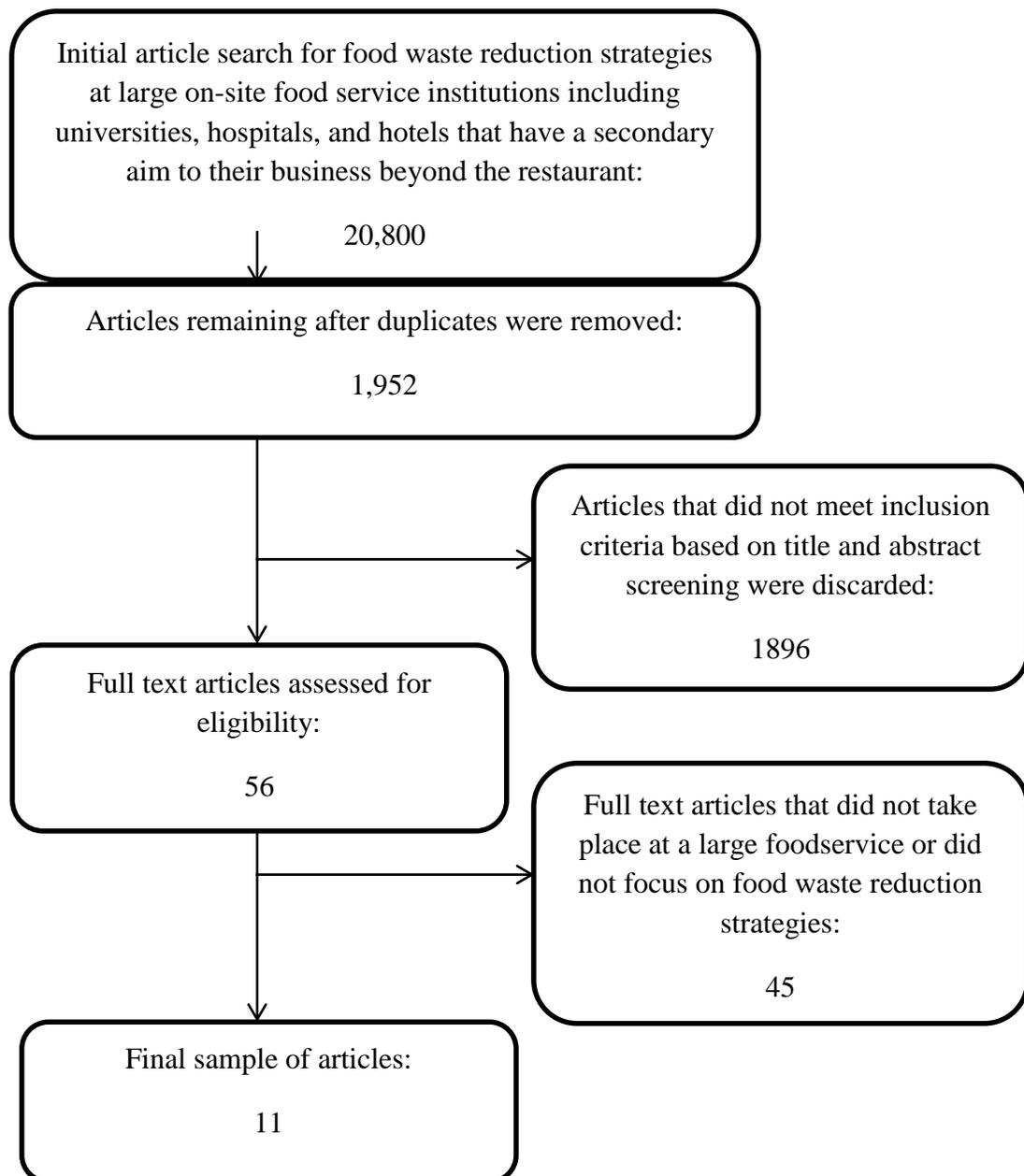


Table 1. Evaluation of Food Waste Reduction Strategies at Large On-Site Food Service Institutions.							
Reference (First Author, year)	Type of Food Service	Institution Type	Study Design	Samples Size, Population, and Location	Waste Reduction Method	Duration of Study	Results Related to Food Waste
Babich, 2010	Understand the process of food service sustainability through a limited “cradle-to-grave” analysis of Southern Illinois University’s (SIU) campus dining facilities.	University	Pre-post	N/A College Students Southern Illinois University	Remove trays	Two days of collecting food waste over three breakfast, lunch, and dinner, in two dining halls.	The average food waste per student was 1.04 ounces a day. Removing trays reduces overall food waste and should be continued in the future.
Brochado, 2010	The effect of decreasing portion size on food intake and plate waste in an all-you-care-to-eat dining facility	University	quasi-experimental	N/A College students San Jose State University	Decreasing portion sizes of French fries in dining hall.	4 weeks at lunch time	Results indicated that portion size was negatively correlated with the number of french fry bags, and positively correlated with the plate waste. Smaller portion sizes made students take more bags but resulted in less food waste. Smaller portions decreased total french fry production. Portion

							size can be reduced to up to 33% before consumers notice a difference. Overall reducing portion sizes reduced plate and food waste as well as excess production costs.
Freedmon, 2011	Determine whether provision of POSNI would affect students' food choice behavior.	University	quasi-experimental, observational study	1,675 Students College Students 18-21 years of age San Jose State University	Decreased portion size of French fries and salad dressing.	Five weeks	Point-of-selection nutrition information significantly decreased the amount of french fries consumed in the largest portions of french fries.
Kim, 2012`	Evaluated the effect of tray removal on food waste production and number of dishes used.	University		360 College students Washington, DC	Remove trays	Over 6 day period	When trays were available to diners they produced 32% more food waste. Results showed that meal time of day was not an important factor in food waste production.
Merrow, 2012	Exploring waste reduction in	University		1,994 meals	Service style comparison of cook to	Waste audit of dining hall	Of the total 466.25 pounds of waste generated, 65.75

	campus dining halls			College students Western Michigan University	order/cook to serve and traditional buffet style dining service.	on March 20, 2012	pounds was organic material including fruits, vegetables. 91.00 pounds were animal products. 309.50 pounds were carbohydrates and other leftovers.
Sarjahani, 2009	Analyze differences in food and compostable waste with and without the use of trays.	University	Pre-post	N/A College students Virginia Tech	Remove trays	A waste analysis was performed Monday through Friday for 2 separate weeks in spring 2008	The use of trays resulted in significantly more waste than when consumers did not have access to trays. With trays available 5829 pounds of edible waste and 1111 pounds of inedible waste was generated over the time period of one week.
Thiagarajah, 2012	Determine whether switching from using trays for meals at a buffet style university dining hall to using a trayless system results	University	Pre-post	1,000 meals per day College Students University dining hall	Remove trays	1 week with trays and 1 week after becoming trayless	A significant decrease in food waste per consumer was observed when trays were removed from access. Results showed a insignificant reduction in liquid waste of 49.77±

	in a reduction of plate waste.						2.62 mL versus 46.36±4.51 mL.
Wansink, 2013	Removing trays from their dining facilities in hope of reducing waste.	University	Field study	417 College students A dining hall of a large north-eastern university, USA.	Remove trays	One evening with trays and one evening without trays.	Trayless dining decreased the percentage of diners who took salad by 65%. Trayless dining did not affect the percentage of consumers who took dessert.
Whitehair, 2013	Determine how to introduce food waste behavior change into a dining facility using a simple message-type intervention that requires little sustained administrative support and can provide optimum effect.	University	operational study	540 University students university in the Midwest	simple prompt-type message interventions	Lunch and dinner over a 6 week period.	On average, more than 57 g of edible food was disposed of per tray. Food waste totaled 1.5 tons during the 6-week study. The simple to-the-point prompt-type message caused a 15% reduction in food waste.
Goonan, 2014	Gain insight into how and why food is wasted before hospital patient consumption to	Hospital	mixed ethnographic methodology	1,752, 680, and 2,420 average meals at each hospital	document analyses, observations, focus groups with kitchen staff, and one-on-	Over a 2 month period in 2012	Most food waste occurred during service as a result of overproduction. Attitudes and habits of foodservice employees were

	facilitate recommendations to minimize the volume of preconsumption food waste to achieve more sustainable hospital foodservice systems.			Hospital Patients Three New Zealand hospitals	one interviews with managers. Thematic analysis was conducted to generate common themes.		considered to be influential factors of generating food waste. When considering employee attitudes managers focused on financial perspectives where kitchen staff focused on social perspectives. Improving organization and using pre-prepared foods reduced food waste. Assessing staff perspectives allows for better understanding of future food waste reduction.
Kallbekken, 2013	Effectiveness of two treatments in reducing the amount of food waste generated. Both treatments rely on influencing consumption norms through external cues.	Chain of Hotels		N/A Hotel Guests 52 hotels	reducing plate size and providing social cues	Between June 1st and August 15th 2012.	Reducing plate size reduces food waste by 19.5%. Implementing signs to tell diners they can come back for seconds reduced food waste by 20.5%.

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CHAPTER THREE

UNDERSTANDING THE EFFECTS OF FOOD WASTE REDUCTION

METHODS AND THE IMPLEMENTATION OF A FOOD WASTE PROGRAM

Contribution of Authors and Co-Authors

Manuscript in Chapter 3

Author: Alicia Rae Leitch

Contributions: Responsible for data collection, data analysis, and writing.

Co-Author: Dr. Carmen Byker Shanks

Contributions: Responsible for study conception and design, leading data analysis, extensive guidance throughout study, continuous review and editing of manuscript.

Co-Author: Dr. Selena Ahmed

Contributions: Responsible for study conception and design, extensive guidance throughout study, critical review of manuscript.

Co-Author: Thomas Bass

Contributions: Guidance throughout study, critical review of manuscript.

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Abstract

Fifty to 70% of food service garbage is compostable waste. Due to their size university dining facilities are prime locations to evaluate food waste reduction and improve sustainability. The objective of this study was to compare pre- and post-consumer food waste after implementing two food interventions. Methods included direct weighing of all post-consumer waste as well as a modified quarter method for pre-intervention and post-intervention #1. Intervention #1 included the following food environment modifications: smaller utensil and portion sizes and messaging through an outreach campaign. Intervention #2 included a renovation consisting of: a change from a buffet service style to a cook to serve service style; improving visual appeal of food display, environment, and offerings for greater desirability and diversity of foods. Pre-consumer waste was measured for the pre-intervention and post-intervention #1 to evaluate kitchen waste. Mann Whitney tests were utilized to compare total amount of post-consumer food waste between pre-intervention, post-intervention #1, and post-intervention #2 for significant differences ($p < .05$) Descriptive statistics were utilized to describe pre-consumer food waste, post-consumer food waste, total waste in pounds per diner, the type and amount of each food that was wasted for pre-intervention and post-intervention #1. In total, 669.2, 470.3, 622.4 pounds of post-consumer food waste were measured during the pre-intervention, post-intervention #1, and post-intervention #2 periods with an average 1.24, 0.18, and 0.13 pounds of post-consumer food waste per diner each day. There was a significant difference in food waste from pre-intervention and intervention #2 with $p = 0.049$. Post-intervention #1 reduced food waste by 0.161 pounds per student ($p = 0.049$).

A total of 122 types wasted foods were observed. Most common foods wasted were salad, rice, chicken, pizza, and stir fry. Recommendations for further food waste reduction strategies include stacking multiple reduction methods and continued education.

INTRODUCTION

Excessive food waste is one of the most prevalent problems universities face when striving to become a more sustainable institution.¹ Introducing sustainable food practices can benefit a university by positively influencing the environment, providing financial savings, and as a marketing strategy to attracting students valuing sustainability.² Reducing food waste also aids in improving food security by directing that waste in a productive way such as feeding those in need or recycling it back into the soil as compost.³ Food waste can also serve as an educational tool to make people more aware how much they waste. Incorporating the food that is wasted into a sustainable composting system also offers educational resources that can be used to enrich curriculum in multiple disciplinarians including agriculture and nutrition.⁴ Sustainable practices that universities can implement to reduce food waste include smaller portion sizes, tray-less dining, smaller utensil sizes, smaller plate sizes, incorporating social cues, food waste signage, and service style.⁵⁻⁸ Universities can further their campus sustainability initiatives by using their composted food waste to create rich soil for use in landscaping or food production, which saves money, and helps the environment.

The environmental benefits of reducing food waste include conserving resources, lowering greenhouse gas emissions, producing rich soil, and improving facility

sanitation.⁹ Food waste results in misdirected resources including the space to produce that food as well as water, energy, and rich soil used to grow that food. Furthermore, food waste rotting in landfills causes a release of the powerful greenhouse gas methane.¹⁰ Economically, reducing food waste at a university may reduce disposal costs, additional food costs, and excess labor costs to prepare that food.^{9,11} Measuring food can provide a university with a more accurate idea of what foods are being eaten and what foods are being wasted. A more accurate understanding of foods being consumed allows for more efficient purchasing and eliminates unnecessary food costs. Reducing the amount of excess food will decrease the costs of disposal, and reduce the amount of labor time spent preparing that food.^{9,11}

Composting provides an alternative to food waste ending up in landfills and improves university sanitation by directing food waste into durable closed bins reducing rodent and insect problems.⁹ Composting food waste also produces a soil amendment which can be used for university landscaping and food production.⁹ Food waste also has value as organic matter, and universities are losing this value if they do not take advantage of their food waste as compost.

Given their size, universities can make a large impact on food waste while also increasing their campus sustainability and improve food security.^{6,9} There are many benefits to reducing food waste, but little research has been conducted to evaluate the impact a dining halls serving style has on food waste. The purpose of this study was to compare the differences in amount of post-consumer food waste in a university dining facility before and after implementing two food waste reduction strategies. Food waste

was also measured to gain information regarding the reuse of the food that is wasted for composting in a movement towards greater campus sustainability.

METHODS

Design

This cross-sectional pre post study collected food waste in a university dining facility located in the Northwestern United States. The dining facility chosen is one of three dining facilities on a university campus. Data was collected on three separate occasions. Pre-intervention data was collected on October 2014; post-intervention #1 data was collected on November 2014; and post-intervention #2 data was collected on October 2015. Intervention #1 included the following food environment modifications: reduction of utensil sizes and portion sizes as well as messaging through an outreach campaign. Intervention #2 included a large renovation consisting of: a change from a buffet service style to a cook-to serve-service style; improving visual appeal of food display, environment, and increasing diversity of foods offered. Food waste data was collected by a team of researchers in order to evaluate the differences in post-consumer food waste. The number of meal swipes each day was recorded to determine the amount of total post-consumer food waste and total waste in pounds per diner.

This study intended to measure the amounts of different types of waste produced in the dining facility setting, including (1) pre-consumer edible, (2) pre-consumer non-edible, (3) pre-consumer liquid, (4) pre-consumer waste, (5) post-consumer compostable, (6) post-consumer waste, and (7) post-consumer liquid. See Table 1.

Inclusion criteria include all pre and post-consumer waste. Exclusion criteria included any food not prepared for consumption or food saved to reuse in another dish in the following days.

Participants

This study is exempt from the Institutional Review Board as no human subjects were participants in data collection. To avoid contamination of food waste measures, diners were not informed of the study before the implementation date. Diners who asked were informed that food waste was being measured to assess the potential for composting on campus.

Food Waste Measurements

Food waste data was collected by researchers at the waste return area in the dining facility. All researchers were trained to collect food waste prior to data collection. Menu items offered each day and approximate portion sizes of each item were recorded four times each day after each meal change. Plates were collected from each consumer by a researcher as they were brought to the waste return area. Food waste collections were carried out in October 2014 and November 2014 by blocking off the dish return area in the dining hall in order for consumers to directly give their plates to the researchers to sort. After the dining hall had been renovated for intervention #2, consumers placed their plates on a plate return conveyer system. Researchers sorted each plate from within the dish room. All other trashcans were removed from the dining facility. Food waste was assessed in two ways by a modified quarter method and direct weighing.^{12,13}

Modified Quarter Method During pre-intervention and post-intervention #1 a researcher recorded the amount of food waste on each plate using the modified quarter method, where each food item left on a plate was estimated using a scale of 1 through 4. Food items left on a plate would score a 1 if there was less than $\frac{1}{4}$ cup left of that item, a 2 if there was $\frac{1}{4}$ to $\frac{1}{2}$ cup wasted, 3 if there was $\frac{1}{2}$ to $\frac{3}{4}$ cup wasted, and a 4 if there was more than 1 cup wasted.¹² Researchers recorded the amount of food waste on the modified quarter method food waste spreadsheet which allotted place a row for each plate and multiple columns to record the type of food and the amount left on the plate. See Appendix A. Clipboards, pens, gloves, and aprons were also used by researchers to make the recording of the food as well as the forting of food more convenient. Due to the dining hall being a buffet service style researchers were unable to determine the amount of food taken by each consumer but instead measured the amount of food waste left on each plate.

Direct Weighing After examining plates, researchers separated waste into three bins labeled compost, waste, and liquid. The compost bin was for all compostable post-consumer food waste, the waste bin was for all non-compostable waste, and the liquid bin was for all liquid waste. Liquids were sorted into a bin with a strainer placed on top to separate food from liquid such as cereal in milk. When the compost, waste, or liquid bin was half full a researcher weighed in pounds and recorded the bin on the direct weighing of food waste spreadsheet. All bins were weighed prior to collection and subtracted from total waste collected to assure accurate weights. The weight and the type of waste within each bag was recorded on the direct weighing of food waste spreadsheet specifying the

type of waste, time weighed, and weight in pounds. See Appendix B. The weighed compost and waste was then placed in the dining facility waste area and the empty bin was placed back at the waste return area. The liquid bin was dumped into the dishwashing sink and returned to the waste return area. Liquid waste was collected separately to avoid an excess amount of moisture in a composting system set up at the university to divert food waste. Plates, dishes, and silverware were cleaned by the dining facility.

In October and November 2014, pre-consumer compostable food waste and pre-consumer non-compostable waste data were also collected in the kitchen area periodically when cans became half full and at the end of the night. Pre-consumer compostable waste and pre-consumer non-compostable waste bins were checked periodically for capacity. When bins were half full a researcher weighed the bin, recorded the type of waste, and documented the weight in pounds on the weight spreadsheet. The pre-consumer compostable waste and pre-consumer non-compostable waste were placed in the dining facility waste area and the empty bin was returned to the kitchen.

Analysis

All food waste weights were recorded in pounds using a ZIEIS Z200 digital scale. Amount and type of plate waste data was recorded in an Excel spread sheet. Analysis included descriptive statistics of all food waste data. Descriptive statistics were used to analyze most commonly wasted individual foods and amount wasted in each food categories observed using the modified quarter method for all individual foods pre-

intervention and post-intervention #1. A Mann-Whitney tests was used to compare the amount of waste in post-consumer food waste, post-consumer waste, and post-consumer liquid of October 2014, November 2014, and October 2015 for statistical significance.

RESULTS

The initial food waste collection on October 2014 measured 3,205 pounds of waste, and counted 13,346 diners, resulting in 0.24 pounds of post-consumer food waste per diner. The first food waste reduction strategy of environmental changes in November 2014 included smaller portions, smaller serving utensils, and signage displaying food waste. A significant ($p = 0.049$) and trending reduction in food waste was observed and totaled 2,418.7 pounds of post-consumer waste, 13,749 diners, and 0.18 pounds of post-consumer food waste per student. The second food waste reduction strategy was the large dining hall also made a significant ($p = 0.049$) and totaled 2,345.5 pounds of post-consumer food waste, 18,088 diners, and .13 pounds post-consumer food waste per student. See Table 2.

Pre-intervention and post-intervention food waste recorded using the modified quarter method compared 122 different food items wasted. The most commonly observed foods wasted during pre-intervention included salad, rice, and chicken. The most commonly observed foods wasted after post-intervention #1 included pizza, salad, and stir fry. See Table 4. The modified quarter method was also used to visually estimate the amount of food wasted. In all food categories less than $\frac{1}{4}$ cup was wasted the most. See Table 5.

Pre-consumer waste in October 2014 totaled 3084.4 pounds of pre-consumer edible waste, pre-consumer non-edible waste, pre-consumer liquid, and pre-consumer waste. In November 2014 pre-consumer food waste was reduced to 1845 pounds of pre-consumer edible waste, pre-consumer non-edible waste, pre-consumer liquid, and pre-consumer waste. See table 2.

DISCUSSION

Food waste reduction strategies implemented during the interventions in this study resulted in reducing post-consumer food waste within a university dining hall. Post-consumer food waste was reduced by 1.06 pounds per student from small environmental changes and by 1.11 pounds per diner from a dining hall renovation. Other university food waste studies show 0.065 pounds of waste per student.¹⁴ Although the newly renovated dining hall attracted more diners, there was still a reduction in overall food waste.

The reduction in pounds of food waste was similar from intervention #1 and intervention #2 however carrying out those interventions had very large cost differences. Intervention #1 is ideal for dining facilities that want to implement small inexpensive environmental changes. Intervention #2 was a much larger financial investment. The total renovation incorporated food reduction strategies but did so while benefiting the overall appeal of new dining experience. The renovation attracted new diners however making small changes to the previous facility was comparably effective in reducing food waste.

Food waste reduction is an important sustainability practice to consider in the university setting because it positively effects the environment, students and university personnel, and can potentially reduce food purchasing and disposal costs. Directing university food waste into a composting system recovers the resources used for that food by putting those nutrients back into the soil. Socially, reducing and directing food waste may increase a universities appeal to current and future students, staff, and administrators. Food waste that is directed into a composting system can result in valuable soil amendment that can be used on campus to reduce costs or sold to increase revenue.

Recently other opportunities, such as development of student food pantries, to beneficially redirect potential food waste have been studied. Thirty percent (30%) of students state that they have problems consistently ensuring access to food.¹⁵ Incorporating the food already on campus into student food pantry programs is an effective way to use food that would otherwise be thrown away. Using leftover food also provides resources that otherwise would need to be purchased through funding or donations.¹⁶

Food waste can also be used in other productive ways including turning the rotting organic matter into a biogas that can be used as an alternative energy source.¹⁷ The University of Wisconsin Oshkosh uses the biogas produced from university food waste to power up to 10 percent of their institution.¹⁷

Further research needs to be done to measure the difference in consumer food waste per meal and how changes in service style affects the amount of food each consumer wastes. Consumer attitudes towards food waste are crucial in an all you can eat dining hall setting. More research needs to be done to evaluate consumer's knowledge, perception, and overall opinion on food waste. Future research also needs to be done to compare the effectiveness of different food waste reduction strategies.

LIMITATIONS

The limitations in this study include the inability to generalize results due to the setting being in a university located in the Northwestern United States it does not represent all university populations within the United States. Future research should focus on pre-consumer waste in addition to post-consumer waste. Lastly, the dining hall meal swipe system resulted in the inability to determine how many meals each student ate but rather the total number of consumers entering the dining hall each day.

CONCLUSION

Implementing food waste reduction strategies within a university dining hall can positively reduce post-consumer food waste. Small interventions such as smaller utensils and reduced portion sizes are an affordable environmental change that can decrease the amount of overall food waste. A large renovation of dining hall service style is also an effective intervention in reducing food waste. Composting, or other resource recovery practices, can be feasible for diverting food waste to beneficial use. Food waste

reduction strategies, both small and large, are beneficial to university dining halls aiming to reduce the amount of food waste they produce.

Table 2: Type of Food Waste Collected	
Type of Food Waste	Definition
(1) Pre-consumer edible food	All compostable food waste produced in food preparation as well as excess food that was never served.
(2) Pre-consumer non-edible food waste	All non-compostable waste produced in food preparation.
(3) Pre-consumer liquid	All liquid food waste produced in food preparation.
(4) Pre-consumer waste	All non-food waste produced in food preparation.
(5) Post-consumer compostable	All food waste left on consumer's plates that they did not eat.
(6) Post-consumer waste	All waste left on consumers plates.
(7) Post-consumer liquid	All liquid waste left by consumers.

Table 3: Difference in Food Waste by Type Collected in a University Dining Facility*+			
Type of Waste	Total Weight (lbs) in October 2014	Total Weight in (lbs) in November 2014	Total Weight in (lbs) in October 2015
Pre-Consumer Edible	363.4±24.3	351.7±41.1	Not collected
Pre-consumer nonedible	102.2±9.9	104.8±16.4	
Pre-consumer liquid	43.2±8.2	27.7±10.2	
Pre-consumer waste	130±4.2	119.2±7.5	
Post-consumer compost	556.6±14.1	403.7±11.2	535.1±18.2
Post-consumer waste	112.6±4.5	66.5±3.5	87.3±7.6
Post-consumer liquid	306.3±4.8	335.7±5.3	159.5±4.1
Number of diners	13346	13749	18008
Food waste per diner	1.24 pounds ^a	0.18 pounds ^b	0.13 pounds ^b
TOTAL	1597.4±756	1403.6±168	781.8±240

*All data reported as mean ± SD

+Means with different superscripts across rows are significantly different (p<0.05) based on paired t-tests, denoting changes in empathy scores.

Table 4: Type And Number of Observations for Pre-intervention and Post-intervention #1 Food Waste Collected In a University Dining Hall*+		
Food Item	Time Period	Number of Observations
Fruits		
Apple	1	102
	2	134
Banana	1	54
	2	23
Berry	1	18
	2	8
Fruit	1	110
	2	156
Grape	1	51
	2	6
Kiwi	1	32
	2	12
Orange	1	3
	2	1
Mango	1	12
	2	0
Melon	1	6
	2	1
Pear	1	45
	2	23
Peach	1	4
	2	2
Lemon	1	2
	2	0
Pineapple	1	36
	2	0
Watermelon	1	19
	2	0

Vegetables		
Artichoke	1	1
	2	0
Carrot	1	43
	2	33
Broccoli	1	5
	2	7
Corn	1	4
	2	0
Beets	1	0
	2	15
Cauliflower	1	6
	2	2
Lettuce	1	27
	2	16
Veggies	1	234
	2	220
Pea	1	13
	2	17
Pepper	1	28
	2	9
Spinach	1	24
	2	6
Olive	1	3
	2	2
Green bean	1	23
	2	2
Cucumber	1	7
	2	0
Tomato	1	9
	2	8
Zucchini	1	9
	2	1
Pickle	1	3
	2	2
Celery	1	1
	2	0
Onion	1	0
	2	5
Snow Pea	1	7
	2	0

Jalapeno	1	0
	2	1
Squash	1	0
	2	3
Salad Bar		
Salad	1	539
	2	473
Grains & Starch		
Bagel	1	96
	2	78
Biscuit	1	24
	2	15
Bread	1	406
	2	285
Bean	1	24
	2	12
Cereal	1	124
	2	131
Chips	1	59
	2	77
Cream of Wheat	1	0
	2	20
Corn Bread	1	13
	2	0
Crust	1	7
	2	24
English Muffin	1	5
	2	0
Flat Bread	1	29
	2	0
Fries	1	260
	2	365
French Toast	1	73
	2	44
Granola	1	15
	2	11
Potato	1	479
	2	348

Oatmeal	1	67
	2	36
Pasta	1	221
	2	216
Pancake	1	50
	0	0
	2	84
Rice	1	510
	2	330
Tater Tot	1	0
	2	65
Desserts & Pastries		
Banana Bread	1	15
	2	0
Brownie	1	11
	2	20
Angel Food Cake	1	15
	2	0
Cake	1	136
	2	120
Cinnamon Roll	1	35
	2	0
Cookie	1	62
	2	30
Dessert	1	166
	2	135
Donut	1	85
	2	83
Ice Cream	1	83
	2	17
Jello	1	38
	2	15
Muffin	0	0
	1	8
Pudding	0	0
	2	12

Proteins		
Bacon	1	2
	2	2
BBQ	1	13
	2	4
Beef	1	5
	2	14
Burger	1	168
	2	269
Chicken	1	489
	2	140
Chicken Fried Steak	1	0
	2	19
Egg	1	205
	2	179
Fish	1	49
	2	54
Ham	1	56
	2	5
Hot Dog	1	14
	2	77
Meat	1	85
	2	49
Wings	1	35
	2	0
Sausage	1	48
	2	37
Rib	1	82
	2	3
Pork	1	6
	2	73
Steak	1	3
	2	40
Shrimp	1	0
	2	2
Turkey	1	0
	2	45

Condiments		
BBQ Sauce	1	9
	2	0
Butter	1	11
	2	1
Cream Cheese	1	9
	2	0
Curry	1	11
	2	1
Dressing	1	2
	2	2
Ketchup	1	66
	2	64
Nutella	1	1
	2	3
Peanut Butter	1	14
	2	23
Ranch	1	60
	2	43
Sauce	1	55
	2	4
Mustard	1	17
	2	5
Salsa	1	51
	2	19
Frosting	1	3
	2	0
Gravy	1	4
	2	1
Syrup	1	4
	2	13
Sour Cream	1	2
	2	5
Mixed Dishes		
Burrito	1	103
	2	14

Cheese Bread	1	0
	2	2
Enchilada	1	12
	2	0
Omelet	1	108
	2	38
Sandwich	1	5
	2	203
Pizza	1	463
	2	518
Taco	1	223
	2	96
Stir Fry	1	294
	2	429
Soup	1	63
	2	80
Miscellaneous	1	11
	2	39
Pasta Combination	1	290
	2	3
Potato Salad	1	10
	2	0
Corn Dog	1	50
	2	0
Egg Roll	1	0
	2	89
Cole Slaw	1	0
	2	31
Stuffed Tomatoes	1	0
	2	32
Onion Rings	1	0
	2	71
Tamale	1	177
	2	0

Dairy		
Cheese	1	61
	2	20
Cottage Cheese	1	19
	2	13
Yogurt	1	61
	2	71
Cream Cheese	1	31
	2	0

Food Category	Modified Quarter Method Visual Observation*	Total Number of Observations		Total Number of Observations per Modified Quarter Method Category
		Time Period 1	Time Period 2	
Fruit	1	259	176	435
	2	178	125	303
	3	62	49	111
	4	21	17	38
Vegetables	1	336	244	580
	2	91	70	161
	3	40	36	76
	4	31	13	44
Salad Bar	1	354	243	597
	2	93	127	220
	3	57	50	107
	4	35	53	88
Grains & Starches	1	1268	1038	2306
	2	614	590	1204
	3	311	317	628
	4	269	196	465
Protein	1	378	222	600
	2	173	128	301
	3	69	54	123
	4	46	41	87
Condiments	1	730	544	1274
	2	345	311	656
	3	126	120	246
	4	70	96	166
Mixed Dishes	1	267	148	415
	2	46	26	72
	3	10	6	16
	4	1	2	3

Dairy	1	830	651	1481
	2	577	513	1090
	3	398	337	735
	4	390	469	859

* Modified Quarter Method Visual Observation records amount of food wasted on a scale (1 = less than $\frac{1}{4}$ cup waste, 2 = $\frac{1}{4}$ to $\frac{1}{2}$ cup waste, 3 = $\frac{1}{2}$ to $\frac{3}{4}$ cup wasted, and 4 = more than 1 cup wasted).

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CHAPTER 4

CONCLUSION

The enormous amount of food waste produced in the United States is a serious national and global issue. In September 2014 the USDA and EPA teamed up with other private sector charitable organizations to lead an innovation in reducing national food waste.⁵ The USDA and EPA fabricated the first national food waste reduction goal to reduce food waste by 50% by 2030. This food waste reduction effort aims to improve food security and conserve national resources lost in the production of that food within the United States.⁵

Universities all across the United States produce a large amount of food. Due to the large amount of food waste created at universities, they are an obvious avenue to research reduce food waste reduction strategies. Universities have an obligation as leading educational facilities to be leaders in reducing the amount of food waste produced and improving campus sustainability. Universities can use programs such as STAR to promote, track, and compare these sustainable efforts.¹⁰

The research presented here aimed to measure two food waste reduction strategies in a university setting by evaluating the effects of renovation, behavioral intervention, and waste segregation and composting. First a review of literature was done to evaluate current food waste reduction strategies such as smaller portion sizes and removing trays from dining halls. Second this research measured the difference in food waste before and after the implementation of two food environment interventions to reduce food waste. Specifically, Intervention #1 included following food environment modifications:

reduced portion sizes, reduced utensil sizes and messaging through an outreach campaign. Intervention #2 included a major service renovation consisting of: changing from a buffet service style to a cook to serve service style; improving visual appeal of food display, environment, and an increased diversity of foods offered.

The number of articles reviewed was limited and many focused on the same food waste reduction strategy. This current lack in food waste reduction strategies within large food service operations displays the need for future research. Future research needs to be done to specifically compare the effectiveness of multiple food waste reduction methods in various contexts.

Food waste reduction should be part of improving comprehensive sustainability at universities This researched focused on providing evidence to design food waste reduction initiatives to improve campus sustainability.

A secondary objective of this study was to measure the amount of compostable pre-consumer food waste towards designing and implementing a pilot campus compost program. As highlighted in Chapter 3, this study found an average of 2,464.7 of pre-consumer food waste is compostable, representing 47% of total food waste that can be redirected from the landfill for usable compost. Implementation of the compost program at MSU resulted in composting 53,605 of food waste during the periods of January 2015 to October 2015. Analysis of this compost for quality through mineral and pathogen testing found this compost to be safe and of relatively high quality compared to commercial compost.

A university composting system has the potential to enrich curriculum and produce a quality product that can be used again on campus landscaping. Implementing a food waste composting system at a university is challenging. There are many aspects that need to be considered including type of composting system, amount of funding available, and overall attitudes and support regarding the project. For example, universities need to determine the type of composting system, which is optimal for their context including space, time, and monetary resources as well as overall goals. Choosing a system that can handle a large amount of compost such as an Aerated Windrow Composting, Aerated Static Pile Composting, or an In-Vessel Composting is important to insure the success of the food waste composting operation.⁴²

Reducing food waste is vital to conserving resources and improving environmental, socio-economic, nutrition and food security aspects of sustainability. Measuring the effectiveness of food waste reduction strategies such as environmental changes as well as complete service style renovations creates a better understanding of where food can be reduced within large food service operations. Channeling the food that is wasted into a productive system such as composting allows for the nutrients in that food to be returned as a rich soil amendment.¹⁶ Universities present an ideal environment where large amounts of food waste are produced and there is great potential to use that food waste to improve campus sustainability in more ways than one.

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APPENDICES

APPENDIX A

MODIFIED QUARTER METHOD SPREADSHEET

SHIFT DATE AND TIME:

AMOUNT WASTED

1 = Less than 1/4 cup waste; 2 = 1/4 to 1/2 cup wasted; 3 = 1/2 cup to 3/4 cup waste; 4 = more than 1 cup wasted

Tray Number	Menu Item & Amount Wasted					
Example	Peaches 1	Lasagna 4	Cookie 1			

APPENDIX B

DIRECT WEIGHING OF FOOD WASTE SPREADSHEET

Bag Number	Pre-Consumer Edible	Pre-consumer nonedible	Pre-consumer liquid	Pre-consumer waste	Post-consumer compost	Post-consumer waste	Post-consumer liquid	Time	Weight
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									