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Food Waste in the National School Lunch Program 1978–2015: A Systematic Review

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Abstract

Background—Food waste studies have been used for more than 40 years to assess nutrient intake, dietary quality, menu performance, food acceptability, cost, and effectiveness of nutrition education in the National School Lunch Program (NSLP).

Objective—Describe methods used to measure food waste and respective results in the NSLP across time.

Methods—A systematic review using PubMed, Science Direct, Informaworld, and Institute of Scientific Information Web of Knowledge was conducted using the following search terms: *waste, school lunch, plate waste, food waste, kitchen, half method, quarter method, weight, and photography*. Studies published through June 2015 were included. The systematic review followed preferred reporting items for systematic reviews and meta-analyses recommendations.

Results—The final review included 53 articles. Food waste methodologies included in-person visual estimation (n=11), digital photography (n=11), direct weighing (n=23), and a combination of in-person visual estimation, digital photography, and/or direct weighing (n=8). A majority of studies used a pre–post intervention or cross-sectional design. Fruits and vegetables were the most researched dietary component on the lunch tray and yielded the greatest amount of waste across studies.

Conclusions—Food waste is commonly assessed in the NSLP, but the methods are diverse and reporting metrics are variable. Future research should focus on establishing more uniform metrics to measure and report on food waste in the NSLP. Consistent food waste measurement methods

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

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will allow for better comparisons between studies. Such measures may facilitate better decision making about NSLP practices, programs, and policies that influence student consumption patterns across settings and interventions.

Keywords

Food waste; Plate waste; School lunch; Consumption; Diet

The National School Lunch Program (NSLP) serves more than 31 million children in more than 100,000 schools each school day.[1,2] The NSLP aims to offer balanced meals to schoolchildren, provided at free or reduced costs for low-income populations and subsidized by the federal government.[2] The Healthy Hunger Free Kids Act of 2010 required updated nutrition standards for schools based on the most recent Dietary Guidelines for Americans and Institute of Medicine recommendations.[3] The requirements consist of five meal components: fruits, vegetables, whole grains, low-fat dairy, protein, and sodium content in a specified range. The serving size and caloric limits for each meal for children enrolled in grades kindergarten through 12 are based on age group. A lunch provided to a student must consist of three out of the five components offered to be considered a reimbursable meal, with one of the components being a fruit or vegetable.[3]

The NSLP setting provides an important opportunity for researchers and practitioners to study how much and what types of nutrients children consume and waste. The lunchroom is experimental in nature because menus are designed (and can be changed) by local school food authorities per national nutrition standards, food portions are standardized, and many students dine in the cafeteria every school day. Study results with high external validity have far reaching implications for the NSLP nationwide.

Since the 1970s,[4] researchers have used plate and food waste studies to observe nutrient intake, dietary quality, menu performance, food acceptability, cost, and effectiveness of nutrition education in the NSLP. Plate and food waste are used synonymously throughout most of the school foods research literature and will herein be referred to as food waste. Food waste studies measure the uneaten edible portion of food served to an individual.[5] Food waste methodology can measure several important food and nutrition outcomes,[6] including the amount of a specific nutrient available, consumed, and wasted, the types of food groups most likely being eaten or thrown away, compliance with nutrition practices and policies, the effect of nutrition education on food choice and consumption, acceptability of menu items, and the influence of waste on an institution’s budget and on natural resources. The resulting data can be used to drive important changes in practices, programs, and policies in a school lunch program. In addition, in recent years, global and national food waste campaigns have further amplified the importance of reducing food waste.[7,8]

The purpose of this systematic review was to provide a summary of the literature describing the measurement and results of food waste studies in the NSLP across time.

METHODS

Search Strategy

Articles included in this systematic literature review were extracted from PubMed, Science Direct, Informaworld, and ISI Web of Knowledge using the preferred reporting items for systematic reviews and meta-analyses (PRISMA) format published through June 2015.[9] When testing key words, these databases yielded relevant articles. The authors tested potential key words related to NSLP and food waste through mock searches to ensure that the final list of terms captured relevant articles that met inclusion and exclusion criteria. Keywords entered with Boolean operators included *waste, school lunch, plate waste, food waste, kitchen, half method, quarter method, weight, and photography*. The following are two search strategies used in Science Direct: waste OR “food waste” OR “plate waste” OR “kitchen waste” AND school AND lunch; waste OR “food waste” OR “plate waste” AND school AND lunch AND “quarter method” OR “half method” OR weight OR photography. No limits or filters were used in the search. The search strategy was modified for individual databases.

Study Selection

The main criterion for inclusion was the explicit use and description of a method to measure food waste in the NSLP. Articles included were peer-reviewed, written in the English language, and based on studies conducted in the United States covering the NSLP. Journal articles that collected primary data were considered. Articles were excluded in cases where they did not focus on the NSLP, were conducted outside of the United States, did not measure food waste, or presented a review of literature. Meeting abstracts were excluded due to limited information about methodology conducted. Cross-sectional, intervention, quasiexperimental, randomized controlled trial, and mixed-methods study designs and methods were considered.

Data Extraction

Two reviewers first evaluated articles by titles, abstracts, and key words. In cases where food waste and kindergarten through 12th-grade schools were discussed in the title of an article, abstract, or key words, the full article was reviewed to determine relevance. Titles and abstracts that met the inclusion criteria were recorded for full text review. The references in each article included were reviewed to determine whether any other additional studies were relevant, although no additional articles were found that were not already captured in the search. The authors reviewed each article independently and met to determine inclusion or exclusion; disagreements were resolved via discussion.

For each article included in the review, one coder collected and entered data into an extraction template. Information recorded included: first author and year published, purpose, study design and specific data collection method, school type, number of schools involved, location of school, number of students, free and reduced NSLP eligibility, race/ethnicity, grade level or age, dietary component measures, duration and frequency of the data collected, food waste results, other relevant findings to food waste, and whether conducted before or after implementation of the NSLP standards updated by the Healthy Hunger Free

Kids Act of 2010. The categories for data extraction were determined based on factors that may inform a researcher's decision to select a particular food waste measurement method. For example, it may be useful for researchers to understand the various ways results are reported when using a particular method (ie, waste of nutrients, specific foods, or food groups). The data collected, along with the publication, were reviewed by at least two additional coders to ensure accuracy; all disagreements were resolved by discussing inclusion and exclusion criteria to reach consensus.

Quality Appraisal of Individual Studies

Study quality was assessed using the Effective Public Health Policy Project (EPHPP) Quality Assessment Tool.[10] The EPHPP Quality Assessment Tool provides researchers with criteria to evaluate studies on the basis of selection bias, study design, confounders, blinding, data collection methods, withdraws and dropouts, intervention integrity, and analysis. Each criteria is scored numerically according to provided guidelines by the EPHPP Quality Assessment Tool as strong (score=1), moderate (score=2), or weak (score=3). Subsequently, the entire article is rated as strong (no weak ratings), moderate (one weak rating), or weak (two or more weak ratings).

This study was exempt from institutional review board review because there was no interaction with human subjects.

RESULTS

A total of 10,892 articles were retrieved using the database search. After eliminating duplicates and articles that did not meet inclusion criteria based on title and abstract screening, 66 articles remained for content review. After reviewing the full articles, 13 studies were excluded due to the following reasons: four were conducted outside of the United States; four did not involve the NSLP; three were in preschools; and two were conference abstracts, not full articles (see the Figure).

The 53 studies included in this review used four major types of food waste measurement methodologies: in-person visual estimation (n=11) (Table 1), digital photography (n=11) (Table 2), direct weighing (n=23) (Table 3), and a combination of in-person visual estimation, digital photography, and/or direct weighing (n=8) (Table 4). With regard to study design and methods, most studies identified interventions with a pre–post or pre–post-follow-up design (n=20) or cross-sectional (n=23), two were quasiexperimental, two were mixed methods, one study was longitudinal, and five were randomized controlled trials. Fourteen studies were rated as strong, 20 studies were rated as moderate, and 19 studies were rated as weak according to the EPHPP Quality Assessment Tool. Studies labeled as moderate were likely to have a weak rating for study design, whereas studies labeled as weak were likely to have weak ratings for selection bias or confounders and study design. See Tables 1 through 4 for quality assessment ratings.

In-Person Visual Estimation of Food Waste through Observation

In-person visual estimation through observation of food waste occurred in 11 studies (Table 1).[11–21] Researchers conducted in-person visual estimation through observation by first

viewing several serving sizes of school lunch foods of interest to understand the appearance of the average plated food component. Researchers then weighed several samples of the plated food item of interest to find the average serving weight in grams or ounces. Finally, student trays were collected and assessed for the amount of food wasted in validated increments. Increments included less or more than half wasted,[11,15,20] quarters (eg, none, half, three-quarters, or all),[16–19,21] or a 6-point scale (eg, 0=0% to 10% and 5=91% to 100%),[12,14] or a percent estimation (eg, on a scale of 0% to 100%).[13] In some studies, a computer program was used to estimate the grams or ounces and energy of food consumed from the in-person visual estimation through observation.

One study focused on the total amount of food wasted.[12] Other studies used food waste measurement as a proxy for the amount of foods students consumed. The research had a variety of aims, including to understand the influence of nutrition education[11,13,14,21] or changes in nutrition requirements.[18,19] In addition, studies examined the effects of lunchtime procedures or the food environment or infrastructure[15,16,20] and food acceptability on consumption levels.[17] Studies were concentrated in the West,[15,20] Northeast,[14,16,17,21] and South,[12,18,19] with two studies not reporting geographic location.[11,13] Three studies examined schools with free and reduced lunch eligibility rates of more than 80%.[12–14]

By far, fruits and vegetables were the most frequently studied food groups.[12–21] Nutrition education was minimally effective in decreasing the amount of food waste.[11,13,14,21] Modifying lunchtime procedures or the food itself increased consumption of foods and decreased waste.[15–17,20] New nutrition standards resulted in no significant differences in the percentage of fruits, vegetables, or whole grains consumed or wasted.[19] Sex and age significantly influenced waste in Reger's study.[12]

Visual Estimation of Food Waste through Digital Photography

Visual estimation through digital photography was used in 11 studies (Table 2).[22–32] Researchers conducted visual estimation of food waste through digital photography by photographing either or both reference serving sizes of the food component of interest, or the student's selected food pre-consumption. When taking photographs of the reference serving sizes, researchers generally calculated an average weight for the food component as well. Each student's tray was then photographed at the tray return area (post-consumption). In reviewing the photographs, food consumption was estimated as a percentage of the reference serving size or student's preconsumption selection. Food waste estimates were made as a raw percent[22–24] or in increments of 10%,[25,26,32] 25%,[27–31] or 0% to 10% to 25% to 50% to 100%.[26,27] Computer applications were used to estimate the weight and energy of food consumed from the visual estimation through digital photography in studies using this method.

The purposes of each study varied, with food waste measures aimed at primarily understanding the amount of food waste[22,31] and food consumption,[25,27,28] modification of food environment or lunchtime procedures,[26,29] instrument validity,[23] compliance with nutrition recommendations,[24] and nutrition education.[30,32] Studies were conducted in the West,[25,26] Midwest,[27,28,30,31] Northeast,[29] and South,[22,24,32] although one did not report geographic location.[23] Alaimo and colleagues[30] and Monlezun and colleagues[32] reported

free and reduced rates near 100%, whereas several other studies did not report free and reduced rates.

As in the studies using visual estimation techniques to measure waste, studies using digital photography also focused predominantly on fruits and vegetables. Several distinguished between forms of fruits and vegetables, such as cooked, raw, canned, and fresh.[25,29,31] Two studies reported that waste of fruit and vegetables was the highest when compared with other dietary components.[22,24] Three studies reported a decrease in waste of fruit and vegetables and other dietary components as a result of an intervention.[25,27,29] Several studies expressed food waste in terms of calories rather than as a percentage of food wasted.[26,28,32]

Direct Weighing of Food Waste

Direct weighing of food waste was used as the main research method in 23 studies (Table 3).[5,33–54] The process for direct weighing of food waste generally includes to determine what is being served in the cafeteria on the day of the study, to determine which food(s) will be included in the study, to weigh random samples of the food(s) and calculate an average weight, to collect and weigh food waste from student trays, to calculate percent or grams or ounces consumed by subtracting the food waste collected in Step 4 from the average weight determined in Step 3 and multiplying by 100. Some research measured waste for all foods on the tray,[5,33–36,44,46–49,53,54] whereas others focused on collecting waste data about specific foods or food components.[37,39–43,45,50–52] Three additional studies measured the weight of all food before it was served, collected all food waste from student trays, and subtracted the total amount leftover.[38,50,51] About three-fourths of studies used food waste as a proxy for understanding the amount of food students consumed.

Research aimed to understand the impacts of nutrition education,[40,43,50,51] changes in nutrition requirements,[47] lunchtime procedures or the food environment,[36,38,49,52] or food acceptability on consumption levels.[37,39,41,42,44,45,52,53] Six studies specifically aimed to directly measure the amount of waste produced in the NSLP.[5,33–35,46,48,54] Studies were concentrated in the West,[38,39,49–51] Midwest,[36,42,53] Northeast,[40,43,44,46,48,52] South,[5,34,32,54] and mixed locations,[33,35,41,45] with two studies not reporting geographic location.[37,47] Seven studies reported free and reduced lunch eligibility rates above 80%.[42–44,46,48,49,52]

The most common food components examined in studies involving direct weighing were fruits and vegetables. Sixteen studies reported the quantity of waste from fruits and vegetables. Other dietary components examined included milk, grains, and high-protein items such as soy-based products. Studies examined acceptance of specific foods in the cafeteria, such as whole grains.[38,39,41,42,45] Two studies found a reduction in food waste from changing recess to before lunch.[36,49] Many interventions (eg, nutrition education, changes in nutrition requirements, lunchtime procedures or the food environment, or food acceptability on consumption levels) led to a decrease in waste for some foods.

Combination of Methods

Eight studies used a combination of in-person visual estimation through observation, visual estimation through digital photography, and/or direct weighing methods (Table 4).[55–62] One

study used direct weighing, visual observation, and children's ratings.[55] Three studies used direct weighing and visual observation.[56,58,59] Three studies used direct weighing and digital photography.[57,61,62] One study used direct weighing, two types of visual observation, and visual photography.[60]

Four studies were designed to validate or compare food waste measures,[55,56,60,61] one study validated a questionnaire against a food waste methodology,[58] and three used food waste as a proxy for measuring the amount of food students consumed.[57,59,62] Research aiming to understand food waste and consumption examined responses to changes in food requirements.[57,59,62]

Studies were concentrated in the West,[58,59] Northeast,[62] South,[57] with four studies not reporting the geographic location in the United States.[55,56,60,62] Rates for free or reduced school lunch eligibility ranged from 35.0%[61] to 93.6%[58]; however, more than half did not report this information.

Fruit and vegetables or components were consistently assessed across all studies except one, which was focused on competitive (snack) foods.[57] Researchers used a combination of measures to validate a food waste measurement tool through comparison with a gold standard of direct weighing of waste. For the validity studies, the digital imaging and observation technique was found to be comparable to weighed plate waste with 96%[61] agreement and the quarter-waste method had a reliability measure of 0.9,[60] both showing promise as alternatives to direct weighing. One other study found that the Day in the Life Questionnaire-Colorado dietary assessment had a high level of validity compared with plate waste.[58]

DISCUSSION

This literature review highlights methods and results from four main research methodologies found across 53 food waste studies in the NSLP across time. Studies using in-person visual estimation, digital photography, direct weighing, and a combination of in-person visual estimation, digital photography, and/or direct weighing varied greatly in research goals, protocol, and reporting. The results of this review may be useful for researchers seeking to measure food waste in school meals, influence what is consumed and wasted at schools, implement effective interventions, and develop new methods for measurement of food waste.

Study aims ranged from evaluating the effects of programs on food consumption and/or waste to generally assessing food waste. No discernible trends in food consumption or food waste outcomes were observed based on study design (cross-sectional, intervention, quasiexperimental, mixed methods, or randomized controlled trial), the percentage of students who were eligible for free or reduced school lunch, geographic location of the school, and/or race or ethnicity. Most studies covered elementary schools, followed by middle schools; only five studies were conducted in high schools. Inconsistencies were noted in reporting key study design features (eg, number of schools, location of school, and dietary component measured), and participant characteristics (eg, eligibility for free or reduced school lunch eligibility, race/ethnicity, and specific grade of students).

There was a large degree of variability regarding how food waste was characterized in results. For example, units of measurement were reported in grams, ounces, percentages, or kilocalories. More uniform reporting metrics would lead to pooling food waste data across studies with potential to understand consumption patterns and influence the school lunch field. Across methodologies, most studies reported the percentage of food groups or specific foods wasted. Some studies using in-person visual estimation through observation or digital photography reported food waste in terms of calories or number of servings wasted.[15,20,27,29,32] In one study using direct weighing, findings were presented by cost and the percentage of the total food budget wasted.[46] Researchers also reported findings in terms of nutrients wasted and weight of food wasted. This variability contributes to the difficulty in understanding changes in food waste over time and difference across settings and populations by methodology.

Many studies used observation, photography, and/or weighing of food waste as a proxy for measuring food consumption. Perhaps using “plate consumption” rather than “food waste” or “plate waste,” as Alaimo suggests,[30] would increase the relevance of the measurement method to a study’s purpose. The language around plate waste and food waste should be selected carefully, especially in light of the attention that the NSLP receives from the public, media, and policymakers.[63] In addition, plate waste and food waste are used interchangeably in the school lunch literature and researchers should choose one term to reduce confusion.

Several trends were noted across the methodologies. Nearly all studies were cross-sectional or interventions; only two studies were quasiexperimental, two studies used mixed methods, one study was longitudinal, and five were randomized controlled trials. Few longitudinal food waste studies existed; thus, there is no clear understanding of how much food is wasted or not wasted as a result of an intervention in the long term. For example, studying the long-term influences on waste of Smarter Lunchrooms design[64] is important for knowing how changing the cafeteria food environment changes student consumption and waste throughout kindergarten through grade 12.

Some studies aimed to validate a method, compare methods, or to assess intake or another method to assess waste. The five studies that validated or compared measures found acceptable correlation values or similar results between measures.[55,56,58,60,61]

More studies should incorporate qualitative data in a mixed-methods design. Pairing qualitative with quantitative data allows for study designs that address research questions that are complex and multifaceted.[65] Food waste researchers could address several qualitative questions along with quantitative food waste research, such as: How does student perception of the quality of the particular school’s food influence the amount of waste? And, why do students waste food in general, from their own perspective?

Overall, researchers using the in-person visual estimation through observation methodology collected food waste data for a greater period of time and at a higher frequency than those who used visual estimation through digital photography and direct weighing, likely given the lower burden on the researchers for data collection and analysis. Direct weighing has been used for a longer period of time when compared with visual estimation through both in-

person observation and digital photography. Eighteen articles published before 2014 used weighing compared with eight in-person observation and four digital photography studies. In 2014–2015, 10 studies used direct weighing, seven used in-person observation, and six used digital photography—evidence of the increasing popularity of visual methodologies.

Fruits and vegetables were the most consistent dietary components measured, except for 12 studies. Fruits and vegetables were often reported to be the foods wasted in the largest quantities across the methodologies to assess waste. Adequate and balanced nutrition is of vital importance in assisting children to grow and learn. It is important to understand fruit and vegetable consumption within the context of the entire tray (meal). Examining only a segment of the diet does not account for understanding the other foods that compete with a student's food consumption patterns. Analyses of food preferences toward studied food components, as well as food exposures, would also provide insight into food waste and consumption, especially when research has demonstrated that several exposures may be needed to influence food acceptance.[66,67]

In addition, a few studies noted that older students wasted more than younger students and girls wasted more than boys; therefore, when addressing food waste, it may be important to consider consumption differences between boys and girls as well as in different age groups.

Of note, no studies reported zero food waste. Since the 1970s, most studies reported more than 30% food waste and, furthermore, no studies have reported <5%. With an increasing focus on supporting self-regulation (eg, internal cues for satiety and hunger) instead of a clean plate or responding to visual cues to consume more,[66] some level of waste should be expected. A multitude of other factors also influence food waste, including balancing caloric requirements with energy expenditure, metabolic and physical factors, food preferences, serving sizes, the school environment, and what and how much children eat before the meal and in the home environment. However, how can food waste be minimized? This is long-standing question and a complex issue that should be addressed by the NSLP and food waste researchers strategically.[68,69]

Summarizing and aggregating data will become easier when researchers establish standardized food waste data collection measures and reporting techniques. Selection of a uniform metric to report results is an important consideration for researchers because consistent reporting may allow for comparison of findings.

Further, the EPHPP Quality Assessment Tool[10] ratings were fairly mixed between strong, moderate, and weak. Weaker ratings raise questions about the validity of the findings, potentially due to bias in the selection of subjects, lack of description in the measurement of outcomes, or bias in methods or reporting. Therefore, a standardized food waste data collection measure and reporting technique has the potential to simultaneously increase quality assessment ratings.

Limitations exist in this systematic review. The search terms used may not have retrieved all articles relevant to food waste in the NSLP. Therefore, conclusions made in this research are limited to the publications retrieved during the search process. Excluding non–peer-reviewed research may have overlooked important work conducted addressing food waste in schools.

For example, Buzby and colleagues[6] published a Report to Congress about plate waste amounts and measures in the NSLP before 2002. In addition, food waste connected to other food programs for children have been studied, including the School Breakfast Program and the Summer Food Service Program.

CONCLUSIONS

Generally, studies of food waste and consumption in the NSLP through the use of in-person visual estimation, digital photography, and/or weighing over the past 40 years has yielded mixed results about the amounts of food waste yielded within differing dietary components. The NSLP has the important purpose of feeding a large majority of our nation's children with balanced and nutritious meals. As such, improving measurement methods to understand the amount of foods consumed and wasted in the lunchroom is an important charge for the public health and dietetics fields. There is a need for development of methods using technology that are low cost, have a low subject burden, and allow for measurement of food waste with limited involvement of researchers. Researchers need to better understand the causes and consequences of food waste on the school lunch tray by designing studies with consistent research protocols that examine dietary quality and food preferences of students. The ultimate goal should be to produce food waste data and implementable strategies that promote continuous improvement in the cafeteria food environment and healthful eating habits among students, especially since wasted food is wasted nutrients.[70]

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References

1. US Department of Agriculture, Food and Nutrition Service. Child nutrition programs. http://www.fns.usda.gov/school-meals/child-nutrition-programs. Published February 2016. Accessed March 2016
2. US Department of Agriculture, Food and Nutrition Service. National School Lunch Program fact sheet. http://www.fns.usda.gov/cnd/lunch/AboutLunch/NSLPFactSheet.pdf. Published September 2013. Accessed March 2016
3. US Government Publishing Office. Nutrition standards in the national school lunch and school breakfast programs: Final rule. http://www.gpo.gov/fdsys/pkg/FR-2012-01-26/html/2012-1010.htm. Published January 26, 2012. 77. Accessed March 2016
4. US Department of Agriculture, Food and Nutrition Service. General Guidelines for Determining Food Acceptability: Procedures for Plate Waste Studies. Washington, DC: US Department of Agriculture; 1975.
5. Byker CJ, Farris AR, Marcenelle M, Davis GC, Serrano EL. Food waste in a school nutrition program after implementation of new lunch program guidelines. J Nutr Educ Behav. 2014; 46(5): 406–411. [PubMed: 24857599]

6. Buzby, JC., Guthrie, JF. Plate Waste in School Nutrition Programs: Final Report to Congress. Mar. 2002 Publication no. EFAN-02-009https://www.ers.usda.gov/webdocs/publications/43131/31216_efan02009.pdf?v=41423. Accessed June 2, 2017
7. Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., Meybeck, A. Global Food Losses and Food Waste—Extent, Causes and Prevention. Rome, Italy: Food and Agriculture Organization of the United Nations; 2011.
8. Buzby, JC., Wells, HF., Hyman, J. The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States. Washington, DC: US Department of Agriculture Economic Research Service; 2014.
9. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Med. 2009; 6(7):e1000097. [PubMed: 19621072]
10. Effective Public Health Practice Project Quality Assessment Tool. http://www.ephpp.ca/tools.html. Accessed May 1, 2017
11. Green NR, Munroe SG. Evaluating nutrient-based nutrition education by nutrition knowledge and school lunch plate waste. Sch Food Service Res Rev. 1987; 11(2):112–115.
12. Reger C, O'Neil CE, Nicklas TA, Myers L, Berenson GS. Plate waste of school lunches served to children in a low socioeconomic elementary school in South Louisiana. Sch Food Service Res Rev. 1996; 20(suppl):13–19.
13. Auld GW, Romaniello C, Heimendinger J, Hambidge C, Hambidge M. Outcomes from a school-based nutrition education program alternating special resource teachers and classroom teachers. J Sch Health. 1999; 69(10):403–408. [PubMed: 10685377]
14. Blom-Hoffman J, Kelleher C, Power TJ, Leff SS. Promoting healthy food consumption among young children: Evaluation of a multicomponent nutrition education program. J Sch Psychol. 2004; 42(1):45–60.
15. Just D, Price J. Default options, incentives and food choices: Evidence from elementary-school children. Public Health Nutr. 2013; 16(12):2281–2288. [PubMed: 23711192]
16. Wansink B, Just DR, Hanks AS, Smith LE. Pre-sliced fruit in school cafeterias: Children's selection and intake. Am J Prev Med. 2013; 44(5):477–480. [PubMed: 23597811]
17. Just DR, Wansink B, Hanks AS. Chefs move to schools. A pilot examination of how chef-created dishes can increase school lunch participation and fruit and vegetable intake. Appetite. 2014; 83:242–247. [PubMed: 25173063]
18. Cullen KW, Chen TA, Dave JM, Jensen H. Differential improvements in student fruit and vegetable consumption in response to the new National School Lunch Program regulations: A pilot study. J Acad Nutr Diet. 2015; 115(5):743–750. [PubMed: 25556770]
19. Cullen KW, Chen TA, Dave JM. Changes in foods selected and consumed after implementation of the new National School Lunch Program meal patterns in southeast Texas. Prev Med Rep. 2015; 2:440–443. [PubMed: 26101737]
20. Price J, Just DR. Lunch, recess and nutrition: Responding to time incentives in the cafeteria. Prev Med. 2015; 71:27–30. [PubMed: 25459372]
21. Wansink B, Hanks AS, Just DR. A plant to plate pilot: A cold-climate high school garden increased vegetable selection but also waste. Acta Paediatr. 2015; 104(8):823–826. [PubMed: 25892710]
22. Marlette MA, Templeton SB, Panemangalore M. Food type, food preparation, and competitive food purchases impact school lunch plate waste by sixth-grade students. J Am Diet Assoc. 2005; 105(11):1779–1782. [PubMed: 16256763]
23. Martin CK, Newton RL, Anton SD, et al. Measurement of children's food intake with digital photography and the effects of second servings upon food intake. Eat Behav. 2007; 8(2):148–156. [PubMed: 17336784]
24. Martin CK, Thomson JL, LeBlanc MM, et al. Children in school cafeterias select foods containing more saturated fat and energy than the Institute of Medicine Recommendations. J Nutr. 2010; 140(9):1653–1660. [PubMed: 20668251]
25. Smith SL, Cunningham-Sabo L. Food choice, plate waste and nutrient intake of elementary- and middle-school students participating in the US National School Lunch Program. Public Health Nutr. 2013; 17(6):1255–1263. [PubMed: 23866827]

26. Williamson DA, Han H, Johnson WD, Martin CK, Newton RL. Modification of the school cafeteria environment can impact childhood nutrition: Results from the Wise Mind and LA Health studies. Appetite. 2013; 61(1):77–84. [PubMed: 23154216]
27. Bontrager Yoder AB, Liebhart JL, McCarty DJ, et al. Farm to elementary school programming increases access to fruits and vegetables and increases their consumption among those with low intake. J Nutr Educ Behav. 2014; 46(5):341–349. [PubMed: 24953435]
28. Bontrager Yoder AB, Schoeller DA. Fruits and vegetables displace, but do not decrease, total energy in school lunches. Child Obes. 2014; 10(4):357–364. [PubMed: 24988122]
29. Hubbard KL, Bandini LG, Folta C, et al. Impact of a Smarter Lunchroom intervention on food selection and consumption among adolescents and young adults with intellectual and developmental disabilities in a residential school setting. Public Health Nutr. 2015; 18(2):361–371. [PubMed: 24636533]
30. Alaimo K, Carlson JJ, Pfeiffer KA, et al. Project FIT: A school, community and social marketing intervention improves healthy eating among low-income elementary school children. J Community Health. 2015; 40(4):815–826. [PubMed: 25940937]
31. Bontrager Yoder AB, Foecke LL, Schoeller DA. Factors affecting fruit and vegetable school lunch waste in Wisconsin elementary schools participating in Farm to School programs. Public Health Nutr. 2015; 18(15):2855–2863. [PubMed: 25728060]
32. Monlezun DJ, Ly D, Rolfsen M, et al. Digital photography assessment of 1,750 elementary and middle school student lunch meals demonstrates improved nutrition with increased exposure to hands-on cooking and gardening classes. J Med Pers. 2015; 13(2):129–134.
33. Jansen GR, Harper JM. Consumption and plate waste of menu items served in the National School Lunch Program. J Am Diet Assoc. 1978; 73(4):395–400. [PubMed: 701669]
34. Davidson FRR. Critical factors for school lunch acceptance in Washington, D.C. Ecol Food Nutr. 1979; 8(1):3–9.
35. Comstock EM, Symington LE. Distributions of serving sizes and plate waste in school lunches: Implications for measurement. J Am Diet Assoc. 1982; 81(4):413–422. [PubMed: 7119320]
36. Getlinger MJ, Laughlin VT, Bell E, Akre C, Arjmandi BH. Food waste is reduced when elementary-school children have recess before lunch. J Am Diet Assoc. 1996; 96(9):906–908. [PubMed: 8784336]
37. Whatley JE, Donnelly JE, Jacobsen DJ, Hill JO, Carlson MK. Energy and macronutrient consumption of elementary school children served modified lower fat and sodium lunches or standard higher fat and sodium lunches. J Am Coll Nutr. 1996; 15(6):602–607. [PubMed: 8951738]
38. Adams MA, Pelletier RL, Zive MM, Sallis JF. Salad bars and fruit and vegetable consumption in elementary schools: A plate waste study. J Am Diet Assoc. 2005; 105(11):1789–1792. [PubMed: 16256765]
39. Toma A, Omary MB, Marquart LF, et al. Children's acceptance, nutritional, and instrumental evaluations of whole grain and soluble fiber enriched foods. J Food Sci. 2009; 74(5):H139–H146. [PubMed: 19646047]
40. Hoffman JA, Franko DL, Thompson DR, Power TJ, Stallings VA. Longitudinal behavioral effects of a school-based fruit and vegetable promotion program. J Pediatr Psychol. 2010; 35(1):61–71. [PubMed: 19439567]
41. Lazor K, Chapman N, Levine E. Soy goes to school: Acceptance of healthful, vegetarian options in Maryland middle school lunches. J Sch Health. 2010; 80(4):200–206. [PubMed: 20433646]
42. Chu L, Warren CA, Sceets CE, et al. Acceptance of two US Department of Agriculture commodity whole-grain products: A school-based study in Texas and Minnesota. J Am Diet Assoc. 2011; 111(9):1380–1384. [PubMed: 21872702]
43. Hoffman JA, Thompson DR, Franko DL, et al. Decaying behavioral effects in a randomized, multi-year fruit and vegetable intake intervention. Prev Med. 2011; 52(5):370–375. [PubMed: 21371499]
44. Cohen JFW, Smit LA, Parker E, et al. Long-term impact of a chef on school lunch consumption: Findings from a 2-Year pilot study in Boston middle schools. J Acad Nutr Diet. 2012; 112(6):927–933. [PubMed: 22504283]

45. Yon BA, Johnson RK, Stickle TR. School children's consumption of lower-calorie flavored milk: A plate waste study. J Acad Nutr Diet. 2012; 112(1):132–136. [PubMed: 22709643]
46. Cohen JFW, Richardson S, Austin SB, Economos CD, Rimm EB. School lunch waste among middle school students: Nutrients consumed and costs. Am J Prev Med. 2013; 44(2):114–121. [PubMed: 23332326]
47. Ramsay S, Safaii S, Croschere T, Branen LJ, Weist M. Kindergarteners' entrée intake increases when served a larger entrée portion in school lunch: A quasi-experiment. J Sch Health. 2013; 83(4):239–242. [PubMed: 23488883]
48. Cohen JFW, Richardson S, Parker E, Catalano PJ, Rimm EB. Impact of the new US Department of Agriculture school meals standards on food selection, consumption and waste. Am J Prev Med. 2014; 46(4):388–394. [PubMed: 24650841]
49. Hunsberger M, McGinnis P, Smith J, Beamer BA, O'Malley J. Elementary school children's recess schedule and dietary intake at lunch: A community-based participatory research partnership pilot study. BMC Public Health. 2014; 14:156. [PubMed: 24520852]
50. Jones BA, Madden GJ, Wengreen HJ, Aguilar SS, Desjardins EA. Gamification of dietary decision-making in an elementary-school cafeteria. PLoS One. 2014; 9(4):e93872. [PubMed: 24718587]
51. Jones BA, Madden GJ, Wengreen HJ. The FIT Game: Preliminary evaluation of a gamification approach to increasing fruit and vegetable consumption in school. Prev Med. 2014; 68:76–79. [PubMed: 24768916]
52. Cohen JFW, Richardson SA, Cluggish SA, et al. Effects of choice architecture and chef-enhanced meals on the selection and consumption of healthier school foods: A randomized clinical trial. JAMA Pediatr. 2015; 169(5):431–437. [PubMed: 25798990]
53. Miller N, Reicks M, Redden JP, et al. Increasing portion sizes of fruits and vegetables in an elementary school lunch program can increase fruit and vegetable consumption. Appetite. 2015; 91:426–430. [PubMed: 25958117]
54. Wilke AC, Graunke RE, Cornejo C. Food waste auditing at three Florida schools. Sustainability. 2015; 7(2):1370–1387.
55. Comstock EM, St Pierre RG, Mackiernan YD. Measuring individual plate waste in school lunches: Visual estimation and children's ratings vs. actual weighing of plate waste. J Am Diet Assoc. 1981; 79(3):290–296. [PubMed: 7264115]
56. Graves K, Shannon B. Using visual plate waste measurement to assess school lunch food behavior. J Am Diet Assoc. 1983; 82(2):163–165. [PubMed: 6822701]
57. Templeton SB, Marlette MA, Panemangalore M. Competitive foods increase the intake of energy and decrease the intake of certain nutrients by adolescents consuming school lunch. J Am Diet Assoc. 2005; 105(2):215–220. [PubMed: 15668677]
58. Wallen V, Cunningham-Sabo L, Auld G, Romaniello C. Validation of a group-administered pictorial dietary recall with 9- to 11-year old children. J Nutr Educ Behav. 2011; 43(1):50–54. [PubMed: 21216366]
59. Gase LN, McCarthy WJ, Robles B, Kuo T. Student receptivity to new school meal offerings: Assessing fruit and vegetable waste among middle school students in the Los Angeles Unified School District. Prev Med. 2014; 67(suppl 1):S28–S33. [PubMed: 24747044]
60. Hanks AS, Wansink B, Just DR. Reliability and accuracy of real-time visualization techniques for measuring school cafeteria tray waste: Validating the quarter-waste method. J Acad Nutr Diet. 2014; 114(3):470–474. [PubMed: 24135053]
61. Taylor JC, Yon BA, Johnson RK. Reliability and validity of digital imaging as a measure of school children's fruit and vegetable consumption. J Acad Nutr Diet. 2014; 114(9):1359–1366. [PubMed: 24751663]
62. Schwartz MB, Henderson KE, Read M, Danna N, Ickovics JR. New school regulations increase fruit consumption and do not increase total plate waste. Child Obes. 2015; 11(3):242–247. [PubMed: 25734372]
63. Byker C, Pinard C, Yaroch A, Serrano E. New NSLP guidelines: Challenges and opportunities for nutrition education practitioners and researchers. J Nutr Educ Behav. 2013; 45(6):683–968. [PubMed: 23886776]

64. Hanks AR, Just DR, Wansink B. Smarter lunchrooms can address new school lunchroom guidelines and childhood obesity. Pediatrics. 2013; 162(4):867–869.

65. Creswell, JW., Plano Clark, VL. Designing and Conducting Mixed Methods Research. London, UK: Sage Publications; 2007.

66. Birch LL, Fisher JO. Development of eating behaviors among children and adolescents. Pediatrics. 1998; 101(2):539–549. [PubMed: 12224660]

67. Birch L. Development of food preferences. Annu Rev Nutr. 1999; 19(1):41–62. [PubMed: 10448516]

68. Waste from School Lunches. Washington, DC: US General Accounting Office; 1996. Publication no. GAO/RCED-96-128R

69. US Department of Agriculture. Let's talk trash. http://www.choosemyplate.gov/lets-talk-trash. Published September 2015. Accessed March 2016

70. Spiker ML, Hiza HA, Siddiqi SM, Neff RA. Wasted food, wasted nutrients: Nutrient loss from wasted food in the United States and comparison to gaps in dietary intake. J Acad Nutr Diet. 2017; 117(7):1031–1040. [PubMed: 28522208]

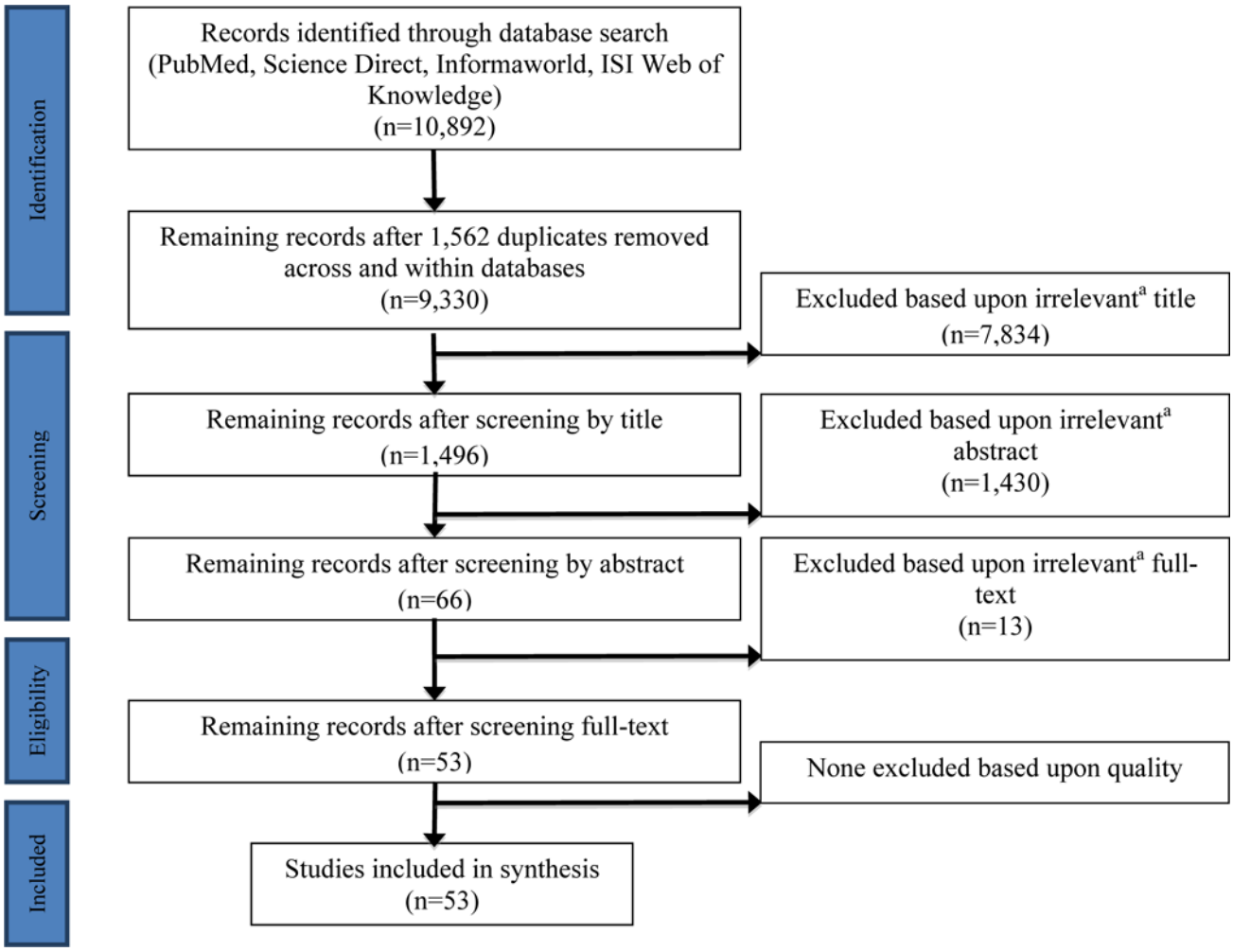

Figure.

Preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2009 flow diagram for selecting studies to include in the systematic review of food waste in the National School Lunch Program across time. Terms used in this search included a combination of the following: *waste, school lunch, plate waste, food waste, kitchen waste, half method, quarter method, weight, and photography*. [a]Relevance determined by inclusion and exclusion criteria. Inclusion criteria for articles were peer reviewed, English language, and conducted in US National School Lunch Program (NSLP). Exclusion criteria for articles were no focus on the US NSLP, food waste not used as a measurement tool, review of literature, or a conference meeting abstract. ISI=Institute for Scientific Information.

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Table 1

In-person visual estimation through observation for food waste studies conducted in the National School Lunch Program

	Reference										
	Green and colleagues, 1987[11]	**Reger and colleagues, 1996[12]**	**Auld and colleagues, 1999[13]**	**Blom-Hoffman and colleagues, 2004[14]**	**Just and colleagues, 2013[15]**	**Wansink and colleagues, 2013[16]**	**Just and colleagues, 2014[17]*a***	**Cullen and colleagues, 2015[18]**	**Cullen and colleagues, 2015[19]*a***	**Price and colleagues, 2015[20]**	**Wansink and colleagues, 2015[21]**
Study design	I*bc*	CS*d*	I*e*	RCT*f*	I*e*	RCT	I*e*	RCT	I*e*	I*e*	I*e*
Specific data collection method	½*gh*	6*i*	E*j*	6*k*	½*l*	¼*mn*	¼*n*	¼*n*	¼*n*	½*l*	¼*n*
Type and no. of schools											
Elementary	1	1	4	1	18			8	8	7	
Middle						6		4			
High							1				1
Grade level	3	3–6	2–4	Kindergarten-1	NR*o*	NR	NR	Kindergarten-8	NR	1–6	NR
Average percent wasted for dietary components measured*p*											
Grains/bread		37						27	34		
Vegetables		12	58	◇*q*	◇		19	48	32	◇	19
Fruits/fruit juice		31	39		◇	41*r*	15	27	23	◇	
Meat/meat alternate								1	18		
Milk		50					17	18	27		
Other	33*r*	62*s*					11*s*	95*t*	64*t*		
Days of food waste data collection*u*	70	20	NR	3	NR	6	3	NR	NR	14	3
No. of waste observations*v*	123	240	502	NR	47,414	640	3,330	1,576	1,045	22,939	554
Effective public health practice project quality rating[10]	Strong	Weak	Strong	Strong	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong

*a*Data were collected to assess food waste after new school lunch meal patterns were implemented beginning 2012.

*b*I=intervention.

[c] Pre-post-follow-up intervention.

[d] CS=cross-sectional.

[e] Pre-post intervention.

[f] RCT=randomized controlled trial.

[g] ½=half waste method.

[h] A + sign was recorded for more than half of food wasted and − sign was recorded for less than half of food wasted.

[j] 6=six-point scale scored as 1=ate all of food to 6=ate none of food.

[j] E=estimation.

[k] Measured with 6-point scale: 5=91% to 100%; 4=76% to 90%; 3=51% to 75%; 2=26% to 50%; 1=11% to 25%; 0=0% to 10%.

[l] Measured in increments of ½ a serving.

[m] ¼=quarter waste method.

[n] Measured in increments of none, ¼, ½, ¾, or all wasted.

[o] NR=not reported with specificity.

[p] In some cases, the average percent waste within a dietary component was reported within the cited article. In other cases, this study's authors calculated average percent wasted within a dietary component when research design collected waste across multiple intervention periods. When percent consumed was reported (instead of percent waste), this study's authors calculated average percent waste by subtracting the percent consumed from 100% and, if necessary, averaged across multiple intervention periods or groups.

[q] ◇=study indicated dietary component measured but not average percent wasted within dietary component.

[r] Specific macro- and/or micronutrients measured in whole meal.

[s] Measured waste of a mixed entrée.

[t] Measured waste of legumes.

[u] Data calculated as number of days reported for study multiplied by number of schools involved in food waste collections.

[v] Data reported according to study as individual food items or entire student tray.

Table 2

Visual estimation through digital photography for food waste studies conducted in the National School Lunch Program

	Reference										
	Marlette and colleagues, 2005[22]	**Martin and colleagues, 2006[23]**	**Martin and colleagues, 2010[24]**	**Smith and colleagues, 2013[25]**	**Williamson and colleagues, 2013[26]**	**Bontrager and colleagues, 2014[27]**	**Bontrager and colleagues, 2014[28]**	**Hubbard and colleagues, 2014[29]*a***	**Alaimo and colleagues, 2015[30]**	**Bontrager and colleagues, 2015[31]*a***	**Monlezun and colleagues, 2015[32]*a***
Study design	CS*b*	CS*c*	CS	CS	RCT*d*	I*ef*	CS	I*f*	I*f*	I*f*	CS
Specific data collection method*e*	RP*g*	RP	RP	PI*h*	PI	PI	PI	PI	PI	PI	PI
Type and no. of schools											
Elementary			33	3	21	8	9		6	11	1
Middle	3	1		2							1
Other								1			
Grade level	6	6	4–6	1–8	4–6	3–5	3–5	NR*i*	3–5	3–5	Kindergarten-8
Average percent wasted for dietary components measured*j*											
Grains/bread	16	◇*k*	27	32					◇		◇
Vegetables	32	◇	37*l*	32		◇	◇	◇	◇	◇	◇
Fruits/fruit juice	38	◇		40		◇	◇	◇	◇	◇	◇
Meat/meat alternate	21								◇		◇
Milk	15	◇	30	27				◇	◇		◇
Other	32*m*	◇*mn*	◇*n*	22*m*	◇*n*			◇	◇*o*	◇*m*	◇*mn*
Days of food waste data collection*p*	24	5	3	23	3	64	32	10	12	NR	5
No. of waste observations*q*	743	215	2,049	899	NR*f*	4,451	2,292	644	1,192	7,117	1,750
Effective public health project practice quality rating[10]	Weak	Weak	Weak	Weak	Strong	Weak	Weak	Moderate	Moderate	Moderate	Weak

*a*Data were collected to assess food waste after new school lunch meal patterns were implemented, beginning 2012.

*b*CS=cross-sectional.

[c] Cross-sectional study used for validation purposes.

[d] RCT=randomized controlled trial.

[e] I=intervention.

[f] Pre-post intervention.

[g] Rp=raw percent, meaning percent of food selection and plate waste in photograph compared with reference photographed and weighed portion.

[h] PI=percent increments, meaning percent increments (eg, in 10% or 25% increments) of food selection and plate waste in photograph compared with reference photographed and weighed portion.

[i] NR=not reported with specificity.

[j] Data calculated as number of days reported for study multiplied by number of schools involved in food waste collections.

[k] ◇=study indicated dietary component measured but not average percent wasted within dietary component.

[l] Fruits and vegetables combined.

[m] Measured waste of a mixed entrée.

[n] Specific macro- and/or micronutrients measured in whole meal.

[o] Measured waste of legumes.

[p] In some cases, the average percent waste within a dietary component was reported within the cited article. In other cases, this study's authors calculated average percent wasted within a dietary component when research design collected waste across multiple intervention periods. When percent consumed was reported (instead of percentage waste), this study's authors calculated average percent waste by subtracting the percent consumed from 100% and, if necessary, averaged across multiple intervention periods or groups.

[q] Data reported according to study as individual food items or entire student tray.

Table 3

Direct weighing for food waste studies in the National School Lunch Program[a]

	Reference																				
	Jansen and colleagues, 1978[33]	Davidson and colleagues, 1979[34]	Comstock and colleagues, 1982[35]	Getlinger and colleagues, 1996[36]	Whatley and colleagues, 1996[37]	Adams and colleagues, 2005[38]	Toma and colleagues, 2009[39]	Hoffman and colleagues, 2010[40]	Lazor and colleagues, 2010[41]	Chu and colleagues, 2011[42]	Hoffman and colleagues, 2011[43]	Cohen and colleagues, 2012[44]	Yon and colleagues, 2012[45]	Cohen and colleagues, 2013[46]	Ramsay and colleagues, 2013[47]	Byker and colleague, 2014[5]	Cohen and colleagues, 2014[48]	Humberger and colleagues, 2014[49]	Jones and colleagues, 2014[50]	Jones and colleagues, 2014[51]	Cohen and colleagues, 2015[52]	Miller and colleagues, 2015[53]	Wilkie and colleagues, 2015[54]
Study design	[c]b	CS[c]	CS	[d]de	[f]	CS	[e]	[f]	CS	CS	[g]	CS	[h]	CS	Q	CS	[e]	MM	[e]	[e]	RCT[i]	[e]	CS
Specific data collection method	DW[j]k	DW	DW[k]	DW[k]	DW[l]	DW[m]	DW[k]	DW[k]	DW[k]	DW[k]	DW[k]	DW[k]	DW[n]	DW[k]	DW[k]	DW[k]	DW[k]	DW[k]	DW[o]	DW[o]	DW[k]	DW[k]	DW[p]
Type and no. of schools																							
Elementary	29	23	11	1	2	4	1	4		12	4		9		1	1	[q]	1	[q]	1	7	1	1
Middle									5	3		4		4							7		
High	29									2													[q]
Grade level	5 and 10	1–3	1–5 or 6	1–3	3–5	1–5	Kindergarten-6	Kindergarten-1	NR[r]	NR	Kindergarten-1	NR	3–5	6–8	K	Prekindergarten-Kindergarten	1–8	Kindergarten-2	Kindergarten-8	1–5	3–8	Kindergarten-5	Kindergarten-12
Average percent wasted for dietary components measured[s]																							
Grains/bread	21		[t]◇	18			◇			35		◇			◇								
Vegetables	51		◇	16		◇		◇			◇	◇		73	◇	51	67	◇	◇	◇	73	◇	
Fruits/fruit juice	30		◇	12		◇		◇			◇	◇		47	◇	33	43	◇	◇	◇	36	◇	
Meat/meat Alternate	18		◇	18					◇						◇								
Milk	9		◇	82								75	◇	25	◇	46	41	◇					
Other	[u]32	◇[u,v]	◇	2	◇[v]		◇[u]		◇[v]			[u]18		[u]19		[u]51	[u]20	◇[u]			[u]27		◇
Days of food waste data collection[w]	10	NR	33	8	76	4	7	36	NR	NR	60	8	9	8	4	5	16	5	23	64	84	3	20
No. of waste observations[x]	130,000	230	13,749	NR	560	294	NR	1,414	1,933	NR	1,060	3,049	793	3,049	473	304	1,030	261	180	251	2,638	2,027	NR
Effective public health practice project quality rating[10]	Weak	Weak	Weak	Moderate	Moderate	Weak	Moderate	Moderate	Weak	Weak	Strong	Moderate	Weak	Moderate	Moderate	Weak	Strong	Strong	Moderate	Moderate	Strong	Strong	Weak

[a] Data were collected to assess food waste after new school lunch meal patterns implemented beginning 2012.

[b] Q=quasiexperimental.

[c] CS=cross-sectional.

[d] I=intervention.

[e] Pre-post intervention.

[f] Pre-post-follow-up intervention.

[g] L=longitudnal.

[h] MM=mixed methods.

[i] RCT=randomized controlled trial.

[j] DW=direct weighing.

[k] Difference weight of plate waste for each food minus weight of average selected serving.

[l] Percent plate waste calculated by dividing the weight of edible food waste by the mean serving weight.

[m] Difference weight of plate waste for each food minus pre consumption selections for all students' plates.

[n] Weight of fluid milk remaining was determined using the full weight and empty container weight of the carton.

[o] Fruit and vegetable consumption was calculated by weighing all produce prepared and subtracting unserved and waste weights, divided by number of students.

[p] Waste was sorted by hand and weighed on a digital scale.

[q] At least one study school was not identified as elementary or middle, but identified kindergarten through eighth grade or was not identified as middle or high, but identified as grades six through 12.

[r] NR=not reported with specificity.

[s] In some cases, the average percent waste within a dietary component was reported within the cited article. In other cases, this study's authors calculated average percent wasted within a dietary component when research design collected waste across multiple intervention periods. When percent consumed was reported (instead of percentage waste), this study's authors calculated average percent waste by subtracting the percent consumed from 100% and, if necessary, averaged across multiple intervention periods or groups.

[t] ◇=study indicated dietary component measured but not average percent wasted within dietary component.

[u] Measured waste of a mixed entrée.

[v] Specific macro- and/or micronutrients measured in whole meal.

[w] Data calculated as number of days reported for study multiplied by number of schools involved in food waste collections.

[x] Data reported according to study as individual food items or entire student tray.

Table 4

Combination of methodologies for food waste studies conducted in the National School Lunch Program (visual estimation, digital photography, direct weighing)[a]

	Reference							
	Comstock and colleagues, , 1981[55]	**Graves and colleagues, , 1983[56]**	**Templeton and colleagues, , 2005[57]**	**Wallen and colleagues, , 2011[58]**	**Gase and colleagues, , 2014[59]**	**Hanks and colleagues, , 2014[60]**	**Taylor and colleagues, , 2014[61]**	**Schwartz and colleagues, , 2015[62]**
Study design	CS[bc]	CS[c]	CS	CS[c]	CS	CS[c]	CS[c]	I[de]
Specific data collection method	W[f] VO[g]	W[h] VO[i]	W[h] DP[jk]	W[h] VO[i]	W VO[i]	W VO[i] DP[k]	W[h] DP[k]	W[h] DP
Type and no. of schools								
Elementary	5	1		2		1	2	
Middle			3		4			12
Grade level	Kindergarten-6	1–6	6	4	NR[l]	Kindergarten-5	3–5	5–7
Average percent wasted for dietary components measured[m]								
Grains/bread	◇[n]	◇		◇		◇		
Vegetables	◇	◇		◇	◇	◇	◇	51
Fruits/fruit juice	◇	◇		◇	◇	◇	◇	31
Meat/meat alternate	◇	◇						
Milk	◇			◇		◇		45
Other	◇[o]	◇[o]	◇[p]	◇[o]		◇[o]	◇[o]	26[o]
Days of food waste data collection[q]	4	8	24	1	20	1	8	36
No. of waste observations[r]	2,000	450	743	125	2,228	197	276	1,340
Effective public health practice project quality rating[10]	Weak	Weak	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

[a] Data were collected to assess food waste after new school lunch meal patterns were implemented beginning 2012.

[b] CS=cross-sectional.

[c] Cross-sectional study used for validation purposes.

[d] I=intervention.

[e] Pre-post intervention.

[f] W=direct weighing.

[g] VO=visual observation.

[h] Difference weight of plate waste for each food minus weight of average selected serving.

[i] Quarter waste method (none, half, three-quarters, or all).

[j] DP=digital photography.

[k] Estimate percent of food selected and plate waste in photograph compared with reference photograph or a sample tray.

[l] NR=not reported with specificity.

[m] In some cases, the average percent waste within a dietary component was reported within the cited article. In other cases, this study's authors calculated average percentage wasted within a dietary component when research design collected waste across multiple intervention periods. When percent consumed was reported (instead of percentage waste), this study's authors calculated average percetage waste by subtracting the percentage consumed from 100% and, when necessary, averaged across multiple intervention periods or groups.

[n] ◇=Study indicated dietary component measured but not average percentage wasted within dietary component.

[o] Measured waste of a mixed entrée.

[p] Specific macro- and/or micronutrients measured in whole meal.

[q] Data calculated as number of days reported for study multiplied by number of schools involved in food waste collections.

[r] Data reported according to study as individual food items or entire student tray.