



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



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## ARTICLE INFORMATION

### Article history:

Submitted 19 April 2016

Accepted 6 June 2017

Available online 11 August 2017

### Keywords:

Food waste  
Plate waste  
School lunch  
Consumption  
Diet

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<http://dx.doi.org/10.1016/j.jand.2017.06.008>

## 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.

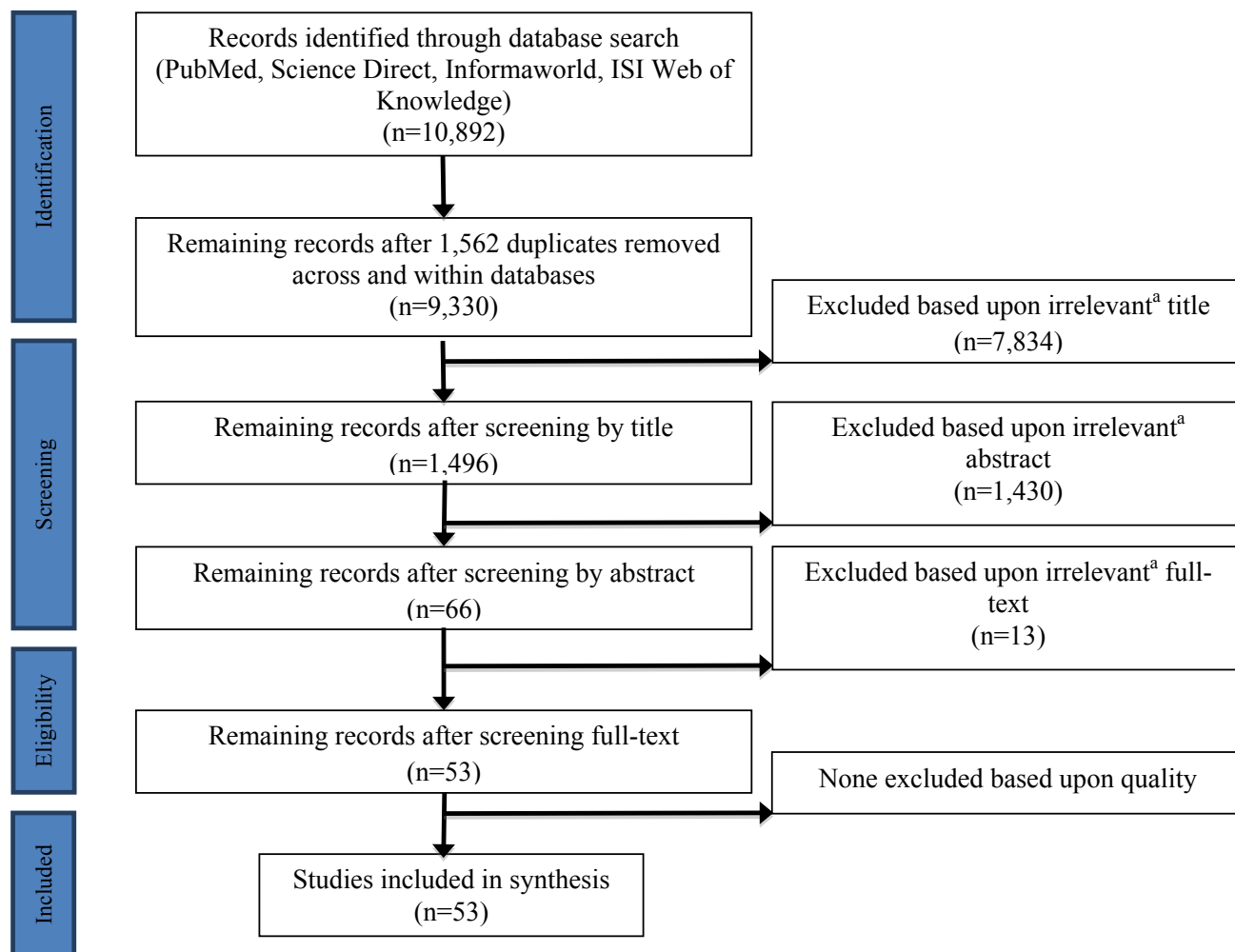
**Conclusions** Food waste is commonly assessed in the NSLP, but the methods are diverse and reporting metrics are variable. Future research should focus on establishing more uniform metrics to measure and report on food waste in the NSLP. Consistent food waste measurement methods will allow for better 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. *J Acad Nutr Diet.* 2017;117:1792-1807.

THE NATIONAL SCHOOL LUNCH PROGRAM (NSLP) serves more than 31 million children in more than 100,000 schools each school day.<sup>1,2</sup> 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.<sup>2</sup> 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.<sup>3</sup> 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.<sup>3</sup>

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,<sup>4</sup> 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.<sup>5</sup> Food waste methodology can measure several important food and nutrition outcomes,<sup>6</sup> 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



**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*. <sup>a</sup>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.

years, global and national food waste campaigns have further amplified the importance of reducing food waste.<sup>7,8</sup>

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.<sup>9</sup> 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

**Table 1.** In-person visual estimation through observation for food waste studies conducted in the National School Lunch Program

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

*(continued on next page)*

**Table 1.** In-person visual estimation through observation for food waste studies conducted in the National School Lunch Program (*continued*)

	Reference										
	Green and colleagues, 1987 <sup>11</sup>	Reger and colleagues, 1996 <sup>12</sup>	Auld and colleagues, 1999 <sup>13</sup>	Blom-Hoffman and colleagues, 2004 <sup>14</sup>	Just and colleagues, 2013 <sup>15</sup>	Wansink and colleagues, 2013 <sup>16</sup>	Just and colleagues, 2014 <sup>17a</sup>	Cullen and colleagues, 2015 <sup>18</sup>	Cullen and colleagues, 2015 <sup>19a</sup>	Price and colleagues, 2015 <sup>20</sup>	Wansink and colleagues, 2015 <sup>21</sup>
<b>Effective public health practice project quality rating<sup>10</sup></b>	Strong	Weak	Strong	Strong	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong

<sup>a</sup>Data were collected to assess food waste after new school lunch meal patterns were implemented beginning 2012.

<sup>b</sup>I=intervention.

<sup>c</sup>Pre-post-follow-up intervention.

<sup>d</sup>CS=cross-sectional.

<sup>e</sup>Pre-post intervention.

<sup>f</sup>RCT=randomized controlled trial.

<sup>g</sup>1/2=half waste method.

<sup>h</sup>A + sign was recorded for more than half of food wasted and – sign was recorded for less than half of food wasted.

<sup>i</sup>6=six-point scale scored as 1=ate all of food to 6=ate none of food.

<sup>j</sup>E=estimation.

<sup>k</sup>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%.

<sup>l</sup>Measured in increments of 1/2 a serving.

<sup>m</sup>1/4=quarter waste method.

<sup>n</sup>Measured in increments of none, 1/4, 1/2, 3/4, or all wasted.

<sup>o</sup>NR=not reported with specificity.

<sup>p</sup>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.

<sup>q</sup>◇=study indicated dietary component measured but not average percent wasted within dietary component.

<sup>r</sup>Specific macro- and/or micronutrients measured in whole meal.

<sup>s</sup>Measured waste of a mixed entrée.

<sup>t</sup>Measured waste of legumes.

<sup>u</sup>Data calculated as number of days reported for study multiplied by number of schools involved in food waste collections.

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

*(continued on next page)*

**Table 2.** Visual estimation through digital photography for food waste studies conducted in the National School Lunch Program (*continued*)

	Reference										
	Marlette and colleagues, 2005 <sup>22</sup>	Martin and colleagues, 2006 <sup>23</sup>	Martin and colleagues, 2010 <sup>24</sup>	Smith and colleagues, 2013 <sup>25</sup>	Williamson and colleagues, 2013 <sup>26</sup>	Bontrager and colleagues, 2014 <sup>27</sup>	Bontrager and colleagues, 2014 <sup>28</sup>	Hubbard and colleagues, 2014 <sup>29a</sup>	Alaimo and colleagues, 2015 <sup>30</sup>	Bontrager and colleagues, 2015 <sup>31a</sup>	Monlezun and colleagues, 2015 <sup>32a</sup>
<b>Effective public health project practice quality rating<sup>10</sup></b>	Weak	Weak	Weak	Weak	Strong	Weak	Weak	Moderate	Moderate	Moderate	Weak

<sup>a</sup>Data were collected to assess food waste after new school lunch meal patterns were implemented, beginning 2012.

<sup>b</sup>CS=cross-sectional.

<sup>c</sup>Cross-sectional study used for validation purposes.

<sup>d</sup>RCT=randomized controlled trial.

<sup>e</sup>I=intervention.

<sup>f</sup>Pre-post intervention.

<sup>g</sup>RP=raw percent, meaning percent of food selection and plate waste in photograph compared with reference photographed and weighed portion.

<sup>h</sup>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.

<sup>i</sup>NR=not reported with specificity.

<sup>j</sup>Data calculated as number of days reported for study multiplied by number of schools involved in food waste collections.

<sup>k</sup>◇=study indicated dietary component measured but not average percent wasted within dietary component.

<sup>l</sup>Fruits and vegetables combined.

<sup>m</sup>Measured waste of a mixed entrée.

<sup>n</sup>Specific macro- and/or micronutrients measured in whole meal.

<sup>o</sup>Measured waste of legumes.

<sup>p</sup>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.

<sup>q</sup>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<sup>a</sup>

	Reference										
	Jansen and colleagues, 1978 <sup>33</sup>	Davidson and colleagues, 1979 <sup>34</sup>	Comstock and colleagues, 1982 <sup>35</sup>	Getlinger and colleagues, 1996 <sup>36</sup>	Whatley and colleagues, 1996 <sup>37</sup>	Adams and colleagues, 2005 <sup>38</sup>	Toma and colleagues, 2009 <sup>39</sup>	Hoffman and colleagues, 2010 <sup>40</sup>	Lazor and colleagues, 2010 <sup>41</sup>	Chu and colleagues, 2011 <sup>42</sup>	Hoffman and colleagues, 2011 <sup>43</sup>
<b>Study design</b>	Q <sup>b</sup>	CS <sup>c</sup>	CS	I <sup>d,e</sup>	I <sup>f</sup>	CS	I <sup>e</sup>	I <sup>f</sup>	CS	CS	L <sup>g</sup>
<b>Specific data collection method</b>	DW <sup>j,k</sup>	DW <sup>l</sup>	DW <sup>k</sup>	DW <sup>k</sup>	DW <sup>l</sup>	DW <sup>m</sup>	DW <sup>k</sup>	DW <sup>k</sup>	DW <sup>k</sup>	DW <sup>k</sup>	DW <sup>k</sup>
<b>Type and no. of schools</b>											
Elementary	29	23	11	1	2	4	1	4		12	4
Middle									5	3	
High	29									2	
<b>Grade level</b>	5 and 10	1-3	1-5 or 6	1-3	3-5	1-5	Kindergarten-6	Kindergarten-1	NR <sup>r</sup>	NR	Kindergarten-1
<b>Average percent wasted for dietary components measured<sup>e</sup></b>											
Grains/bread	21		◇ <sup>t</sup>	18			◇			35	
Vegetables	51		◇	16		◇		◇			◇
Fruits/fruit juice	30		◇	12		◇		◇			◇
Meat/meat alternate	18		◇	18					◇		
Milk	9		◇	82							
Other	32 <sup>u</sup>	◇ <sup>uv</sup>	◇	2	◇ <sup>v</sup>		◇ <sup>u</sup>		◇ <sup>v</sup>		
<b>Days of food waste data collection<sup>w</sup></b>	10	NR	33	8	76	4	7	36	NR	NR	60
<b>No. of waste observations<sup>x</sup></b>	130,000	230	13,749	NR	560	294	NR	1,414	1,933	NR	1,060
<b>Effective public health practice project quality rating<sup>10</sup></b>	Weak	Weak	Weak	Moderate	Moderate	Weak	Moderate	Moderate	Weak	Weak	Strong

<sup>a</sup>Data were collected to assess food waste after new school lunch meal patterns implemented beginning 2012.

<sup>b</sup>Q=quasiexperimental.

<sup>c</sup>CS=cross-sectional.

<sup>d</sup>I=intervention.

<sup>e</sup>Pre-post intervention.

<sup>f</sup>Pre-post-follow-up intervention.

<sup>g</sup>L=longitudinal.

<sup>h</sup>MM=mixed methods.

<sup>i</sup>RCT=randomized controlled trial.

<sup>j</sup>DW=direct weighing.

<sup>k</sup>Difference weight of plate waste for each food minus weight of average selected serving.

<sup>l</sup>Percent plate waste calculated by dividing the weight of edible food waste by the mean serving weight.

<sup>m</sup>Difference weight of plate waste for each food minus pre consumption selections for all students' plates.

<sup>n</sup>Weight of fluid milk remaining was determined using the full weight and empty container weight of the carton.

<sup>o</sup>Fruit and vegetable consumption was calculated by weighing all produce prepared and subtracting unserved and waste weights, divided by number of students.

<sup>p</sup>Waste was sorted by hand and weighed on a digital scale.

<sup>q</sup>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.

<sup>r</sup>NR=not reported with specificity.

<sup>s</sup>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.

<sup>t</sup>◇=study indicated dietary component measured but not average percent wasted within dietary component.

<sup>u</sup>Measured waste of a mixed entrée.

<sup>v</sup>Specific macro- and/or micronutrients measured in whole meal.

<sup>w</sup>Data calculated as number of days reported for study multiplied by number of schools involved in food waste collections.

<sup>x</sup>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<sup>a</sup> (continued)

Reference											
Cohen and colleagues, 2012 <sup>44</sup>	Yon and colleagues, 2012 <sup>45</sup>	Cohen and colleagues, 2013 <sup>46</sup>	Ramsay and colleagues, 2013 <sup>47</sup>	Byker and colleague, 2014 <sup>5</sup>	Cohen and colleagues, 2014 <sup>48</sup>	Hunsberger and colleagues, 2014 <sup>49</sup>	Jones and colleagues, 2014 <sup>50</sup>	Jones and colleagues, 2014 <sup>51</sup>	Cohen and colleagues, 2015 <sup>52</sup>	Miller and colleagues, 2015 <sup>53</sup>	Wilkie and colleagues, 2015 <sup>54</sup>
CS DW <sup>k</sup>	MM <sup>h</sup> DW <sup>g</sup>	CS DW <sup>k</sup>	Q DW <sup>k</sup>	CS DW <sup>k</sup>	I <sup>e</sup> DW <sup>k</sup>	MM DW <sup>k</sup>	I <sup>e</sup> DW <sup>o</sup>	I <sup>e</sup> DW <sup>o</sup>	RCT <sup>l</sup> DW <sup>k</sup>	I <sup>e</sup> DW <sup>k</sup>	CS DW <sup>p</sup>
4	9	4	1	1	4 <sup>q</sup>	1	1 <sup>q</sup>	1	7 7	1	1
NR	3-5	6-8	K	Prekindergarten- Kindergarten	1-8 Kindergarten	Kindergarten-2	Kindergarten-8	1-5	3-8	Kindergarten-5	Kindergarten-12
◇			◇								
◇		73	◇	51	67	◇	◇	◇	73	◇	
◇		47	◇	33	43	◇	◇	◇	36	◇	
			◇								
75 18 <sup>u</sup>	◇	25 19 <sup>u</sup>	◇	46 51 <sup>u</sup>	41 20 <sup>u</sup>	◇ ◇ <sup>u</sup>			27 <sup>u</sup>		◇
8	9	8	4	5	16	5	23	64	84	3	20
3,049	793	3,049	473	304	1,030	261	180	251	2,638	2,027	NR
Moderate	Weak	Moderate	Moderate	Weak	Strong	Strong	Moderate	Moderate	Strong	Strong	Weak



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.<sup>10</sup> 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, withdrawals 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](#)).<sup>11–21</sup> 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,<sup>11,15,20</sup> quarters (eg, none, half, three-quarters, or all),<sup>16–19,21</sup> or a 6-point scale (eg, 0=0% to 10% and 5=91% to 100%),<sup>12,14</sup> or a percent estimation (eg, on a scale of 0% to 100%).<sup>13</sup> 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.<sup>12</sup> 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<sup>11,13,14,21</sup> or changes in nutrition requirements.<sup>18,19</sup> In addition, studies examined the effects of lunchtime procedures or the food environment or infrastructure<sup>15,16,20</sup> and food acceptability on consumption levels.<sup>17</sup> Studies were concentrated in the West,<sup>15,20</sup> Northeast,<sup>14,16,17,21</sup> and South,<sup>12,18,19</sup> with two studies not reporting geographic location.<sup>11,13</sup> Three studies examined schools with free and reduced lunch eligibility rates of more than 80%.<sup>12–14</sup>

By far, fruits and vegetables were the most frequently studied food groups.<sup>12–21</sup> Nutrition education was minimally effective in decreasing the amount of food waste.<sup>11,13,14,21</sup> Modifying lunchtime procedures or the food itself increased consumption of foods and decreased waste.<sup>15–17,20</sup> New nutrition standards resulted in no significant differences in the percentage of fruits, vegetables, or whole grains

consumed or wasted.<sup>19</sup> Sex and age significantly influenced waste in Reger's study.<sup>12</sup>

### Visual Estimation of Food Waste through Digital Photography

Visual estimation through digital photography was used in 11 studies (Table 2).<sup>22-32</sup> 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<sup>22-24</sup> or in increments of 10%,<sup>25,26,32</sup> 25%,<sup>27-31</sup> or 0% to 10% to 25% to 50% to 100%.<sup>26,27</sup> 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<sup>22,31</sup> and food consumption,<sup>25,27,28</sup> modification of food environment or lunchtime procedures,<sup>26,29</sup> instrument validity,<sup>23</sup> compliance with nutrition recommendations,<sup>24</sup> and nutrition education.<sup>30,32</sup> Studies were conducted in the West,<sup>25,26</sup> Midwest,<sup>27,28,30,31</sup> Northeast,<sup>29</sup> and South,<sup>22,24,32</sup> although one did not report geographic location.<sup>23</sup> Alaimo and colleagues<sup>30</sup> and Monlezun and colleagues<sup>32</sup> 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.<sup>25,29,31</sup> Two studies reported that waste of fruit and vegetables was the highest when compared with other dietary components.<sup>22,24</sup> Three studies reported a decrease in waste of fruit and vegetables and other dietary components as a result of an intervention.<sup>25,27,29</sup> Several studies expressed food waste in terms of calories rather than as a percentage of food wasted.<sup>26,28,32</sup>

### Direct Weighing of Food Waste

Direct weighing of food waste was used as the main research method in 23 studies (Table 3).<sup>5,33-54</sup> 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,<sup>5,33-36,44,46-49,53,54</sup> whereas others focused on collecting waste data about specific foods or food components.<sup>37,39-43,45,50-52</sup> 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.<sup>38,50,51</sup> 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,<sup>40,43,50,51</sup> changes in nutrition requirements,<sup>47</sup> lunchtime procedures or the food environment,<sup>36,38,49,52</sup> or food acceptability on consumption levels.<sup>37,39,41,42,44,45,52,53</sup> Six studies specifically aimed to directly measure the amount of waste produced in the NSLP.<sup>5,33-35,46,48,54</sup> Studies were concentrated in the West,<sup>38,39,49-51</sup> Midwest,<sup>36,42,53</sup> Northeast,<sup>40,43,44,46,48,52</sup> South,<sup>5,34,32,54</sup> and mixed locations,<sup>33,35,41,45</sup> with two studies not reporting geographic location.<sup>37,47</sup> Seven studies reported free and reduced lunch eligibility rates above 80%.<sup>42-44,46,48,49,52</sup>

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.<sup>38,39,41,42,45</sup> Two studies found a reduction in food waste from changing recess to before lunch.<sup>36,49</sup> 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).<sup>55-62</sup> One study used direct weighing, visual observation, and children's ratings.<sup>55</sup> Three studies used direct weighing and visual observation.<sup>56,58,59</sup> Three studies used direct weighing and digital photography.<sup>57,61,62</sup> One study used direct weighing, two types of visual observation, and visual photography.<sup>60</sup>

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

Studies were concentrated in the West,<sup>58,59</sup> Northeast,<sup>62</sup> South,<sup>57</sup> with four studies not reporting the geographic location in the United States.<sup>55,56,60,62</sup> Rates for free or reduced school lunch eligibility ranged from 35.0%<sup>61</sup> to 93.6%<sup>58</sup>; 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.<sup>57</sup> 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%<sup>61</sup> agreement and the quarter-waste method had a reliability measure of 0.9,<sup>60</sup> both showing promise as

**Table 4.** Combination of methodologies for food waste studies conducted in the National School Lunch Program (visual estimation, digital photography, direct weighing)<sup>a</sup>

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

*(continued on next page)*

**Table 4.** Combination of methodologies for food waste studies conducted in the National School Lunch Program (visual estimation, digital photography, direct weighing)<sup>a</sup> (continued)

	Reference							
	Comstock and colleagues, 1981 <sup>55</sup>	Graves and colleagues, 1983 <sup>56</sup>	Templeton and colleagues, 2005 <sup>57</sup>	Wallen and colleagues, 2011 <sup>58</sup>	Gase and colleagues, 2014 <sup>59</sup>	Hanks and colleagues, 2014 <sup>60</sup>	Taylor and colleagues, 2014 <sup>61</sup>	Schwartz and colleagues, 2015 <sup>62</sup>
<b>Effective public health practice project quality rating<sup>10</sup></b>	Weak	Weak	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

<sup>a</sup>Data were collected to assess food waste after new school lunch meal patterns were implemented beginning 2012.

<sup>b</sup>CS=cross-sectional.

<sup>c</sup>Cross-sectional study used for validation purposes.

<sup>d</sup>I=intervention.

<sup>e</sup>Pre-post intervention.

<sup>f</sup>W=direct weighing.

<sup>g</sup>VO=visual observation.

<sup>h</sup>Difference weight of plate waste for each food minus weight of average selected serving.

<sup>i</sup>Quarter waste method (none, half, three-quarters, or all).

<sup>j</sup>DP=digital photography.

<sup>k</sup>Estimate percent of food selected and plate waste in photograph compared with reference photograph or a sample tray.

<sup>l</sup>NR=not reported with specificity.

<sup>m</sup>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 percentage waste by subtracting the percentage consumed from 100% and, when necessary, averaged across multiple intervention periods or groups.

<sup>n</sup>◇=Study indicated dietary component measured but not average percentage wasted within dietary component.

<sup>o</sup>Measured waste of a mixed entrée.

<sup>p</sup>Specific macro- and/or micronutrients measured in whole meal.

<sup>q</sup>Data calculated as number of days reported for study multiplied by number of schools involved in food waste collections.

<sup>r</sup>Data reported according to study as individual food items or entire student tray.

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.<sup>58</sup>

## 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.<sup>15,20,27,29,32</sup> In one study using direct weighing, findings were presented by cost and the percentage of the total food budget wasted.<sup>46</sup> 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,<sup>30</sup> 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.<sup>63</sup> 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<sup>64</sup> 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.<sup>55,56,58,60,61</sup>

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.<sup>65</sup> 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.<sup>66,67</sup>

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,<sup>66</sup> 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.<sup>68,69</sup>

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<sup>10</sup> 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<sup>6</sup> 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.<sup>70</sup>

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## STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

## FUNDING/SUPPORT

Research reported in this publication was partially supported by the National Institute of General Medical Sciences of the National Institutes of Health under award nos. P20GM103474 and 5P20GM104417. Research reported in this publication was partially supported by Cornell Behavioral Economics in Child Nutrition Programs (BEN) Center Grants Program under award no. 77867-10660. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or Cornell BEN Center.

## ACKNOWLEDGEMENTS

The authors thank Lindsay Kummer, RDN; Susan Chen; Chloe Panizza, MS; Rise Morisato; Alicia Leitch, MS; Bonnie Billingsley, RDN; Allison Milodragovich, MS; and Erin Smith for their contributions to the article.