

# Reliability and Accuracy of Real-Time Visualization Techniques for Measuring School Cafeteria Tray Waste: Validating the Quarter-Waste Method<sup>☆</sup>

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## ARTICLE INFORMATION

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## ABSTRACT

Measuring food waste is essential to determine the impact of school interventions on what children eat. There are multiple methods used for measuring food waste, yet it is unclear which method is most appropriate in large-scale interventions with restricted resources. This study examines which of three visual tray waste measurement methods is most reliable, accurate, and cost-effective compared with the gold standard of individually weighing leftovers. School cafeteria researchers used the following three visual methods to capture tray waste in addition to actual food waste weights for 197 lunch trays: the quarter-waste method, the half-waste method, and the photograph method. Inter-rater and inter-method reliability were highest for on-site visual methods (0.90 for the quarter-waste method and 0.83 for the half-waste method) and lowest for the photograph method (0.48). This low reliability is partially due to the inability of photographs to determine whether packaged items (such as milk or yogurt) are empty or full. In sum, the quarter-waste method was the most appropriate for calculating accurate amounts of tray waste, and the photograph method might be appropriate if researchers only wish to detect significant differences in waste or consumption of selected, unpackaged food.

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**R**ELIABLY AND ACCURATELY MEASURING TRAY waste, especially in a school cafeteria, is a key tool to measuring the impacts of food-behavior interventions. Waste measurement has become even more important with the new regulations for the 2012 National School Lunch Program. In the first couple of weeks of the 2012-2013 school year, reports emerged that students were wasting large quantities of foods, especially fruits and vegetables. Although the end result of the regulations is to improve child nutrition, understanding how much food students throw away has become a topic of serious interest.<sup>1</sup> In large-scale studies, it is important to be able to make waste measurements quickly and accurately in order to reduce costs to the researchers and hassle for the schools.

Currently, there are multiple useful methods for measuring tray waste, yet the appropriate method for a study depends on available resources, research questions, and the specific setting. Weighing tray waste, the most reliable method, is highly accurate, but requires a significant amount of space and labor, often severely restricting the number of observations that can be obtained. Visual-measurement methods, on

the other hand, require less labor, space, and can be reliable and accurate relative to weighing waste. In addition, school foodservice managers can easily use these visual methods to better understand the consumption patterns in their own schools. This study identifies one particular on-site visual tray waste measurement method, the quarter-waste method, as preferable to two other visual methods due to its reliability, accuracy, and cost effectiveness.

A large body of literature has been devoted to the use of and reliability of various methods for measuring the amount of foods people consume.<sup>2-5</sup> Survey methods, a common technique,<sup>6,7</sup> suffer from reporting biases. Food frequency questionnaires are not only costly but respondents—especially children—have difficulty recalling past food consumption.<sup>8</sup> Manually weighing food waste (weighing method) is highly accurate but costly.<sup>9,10</sup> The weighing method, though, serves as a baseline gold standard against which alternative methods are validated.<sup>4</sup>

Visual estimation methods<sup>4,11,12</sup> are increasing in popularity because of their ease of implementation and cost effectiveness. With visual methods, tray waste can be estimated either on-site<sup>13</sup> or remotely using photographs.<sup>5,14</sup> Yet little is understood regarding the reliability and accuracy of these on- and off-site methods relative to the weighing method, although there is evidence of high inter-method reliability between visual estimation methods.<sup>15</sup>

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This study compares three common estimation methods to the weighing method in school cafeterias. Inter-method and inter-rater agreement methods were used to identify the relatively more reliable visual method. In addition, we assess the level of precision inherent in each method. Finally, in the context of an intervention study, results from a power test show which method requires the least number of observations necessary for detecting a 10% decrease in fruit or vegetable waste.

## METHODS

This study was conducted with approval from the Cornell University Institutional Review Board. To avoid contamination of waste measures, students were not informed of the study before the implementation date. In a corner of the participating elementary school (kindergarten to grade 5) cafeteria, a series of tables were linked together. Students were instructed to place their trays on one end of the tables when they had completed their meal. From there, trays would move along the tables in assembly-line fashion. Once a tray was left at the station, a researcher placed a sticky note with an identification number on the tray and another researcher took a photograph of the tray. After being photographed, another researcher estimated the amount of each individual item wasted using a visual method that reports whether none, some, or all of a food item is wasted (half-waste method). Another researcher estimated tray waste using a visual method that reports whether none,  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{3}{4}$ , or all of a food item is wasted (quarter-waste method). In both cases, when a packaged product, such as a milk carton or a yogurt container, was closed and could not be visually estimated, it was picked up to determine whether empty, full, or in between.

These two researchers recorded their estimates on sheets of paper with a list of each possible item next to the tray identification number. The tray then moved to the final location where one of two researchers placed each individual remaining food item on a standard paper plate and weighed the amount of each food item remaining. In order to obtain inter-rater reliability measures for the half-waste and quarter-waste methods, an additional researcher measured tray waste on a random sample of the trays using either the half-waste ( $n=26$ ) or quarter-waste method ( $n=27$ ). Items from students who did not purchase a full school lunch were not measured.

Individuals measuring tray waste were internal to the research team. Those conducting the visual-estimation methods either had previous experience measuring tray waste or were trained using protocols and photographed examples. Before the lunch period, researchers assigned to measure waste visually examined a serving of each food item offered and weighed five complete and uneaten servings of each item to generate an average weight per serving. Container and carton weights were also taken for items such as carrots or salad, which were served in small plastic cups, or milk and juice, which were served in cartons. These procedures served two purposes. First, researchers using the visual-estimation methods knew the size of a standard serving and used this to estimate tray waste. Second, average serving weights were used to generate estimates of the grams wasted for each of the visual-estimation techniques.

Several days after the on-site measurements were completed, a researcher used a 10% scale to estimate waste appearing in the tray photographs (none, 0.10, 0.20, . . . , 0.90, or all wasted). For inter-rater reliability, a separate researcher used the same method to estimate tray waste in 40 randomly selected photographs.

## Data and Analysis

Tray waste was collected for 197 total trays. This was the total number of students who received a school lunch that day. The menu for the day included four entrée items: chicken nuggets, chicken strips (served once the nuggets were gone), peanut butter and jelly sandwiches, and yogurt. Fruit options included applesauce and oranges. Vegetable options included green beans, salad, and carrots. Grain choices included rice and a bagel. Students could also choose a cookie, a package of sunflower seeds, or a small bag of chips. Beverage options included fat-free milk, 1% white milk, 1% chocolate milk, orange juice, and apple juice.

Inter-method and inter-rater reliability were measured using methods used in previous studies.<sup>16,17</sup> Specifically, correlation coefficients of amounts wasted were calculated to compare the weighing method and the three visual-estimation methods, providing an inter-method reliability score. In addition, correlations of measured waste between researchers, but for the same method, were calculated as an inter-rater reliability score. As a second test of inter-method reliability, correlations between waste measured using the weighing method and the three visual-estimation techniques were calculated for each food item offered.

To test accuracy in waste measures, *t* tests were used to estimate the difference in measured waste between the weighing method and the three visual-estimation methods. This comparison was carried out for each food item offered in the cafeteria that day. Finally, power tests were used to calculate the number of observations necessary to detect a 10% decrease in waste for the weighing method and the three visual methods. In these power tests, average waste for all fruits and all vegetables, as measured with the weighing method, are used. Because intervention studies rely on before-and-after measures, the power tests are based on independent two-sample *t* tests with equal sample sizes and equal standard deviations assumed both before and after the waste decrease.

## RESULTS

To demonstrate the reliability, accuracy, and statistical power for each visual estimation technique, results from these methods are reported and compared with the weighing method.

### Reliability

Reliability measures (correlations) reveal how closely each visual method's waste measures compare with the weighing method. The quarter-waste method has a reliability measure of 0.90 ( $P<0.001$ ) and the half-waste and photograph methods have reliability measures of 0.83 ( $P<0.001$ ) and 0.48 ( $P<0.001$ ), respectively. Low reliability for the photograph method is due to difficulty in estimating waste in milk and juice cartons as well as other foods that are served in packages or containers that obstruct the view of the remaining

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