Food waste in school canteens: A reference methodology for large-scale studies

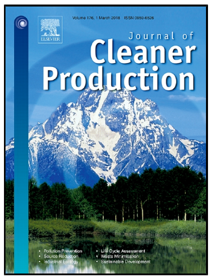


*Published Version:*
Matteo Boschini, Luca Falasconi, Claudia Giordano, Fabrizio Alboni (2018). Food waste in school canteens: A reference methodology for large-scale studies. JOURNAL OF CLEANER PRODUCTION, 182, 1024-1032 [10.1016/j.jclepro.2018.02.040].

*Availability:*
This version is available at: https://hdl.handle.net/11585/632445 since: 2021-09-09

*Published:*
DOI: http://doi.org/10.1016/j.jclepro.2018.02.040

# Accepted Manuscript




Food waste in school canteens: a reference methodology for large-scale studies.

Matteo Boschini, Luca Falasconi, Claudia Giordano, Fabrizio Alboni

| | |
|---|---|
| PII: | S0959-6526(18)30346-9 |
| DOI: | 10.1016/j.jclepro.2018.02.040 |
| Reference: | JCLP 11987 |
| To appear in: | *Journal of Cleaner Production* |
| Received Date: | 01 September 2017 |
| Revised Date: | 02 February 2018 |
| Accepted Date: | 03 February 2018 |

# Food waste in school canteens: a reference methodology for large-scale studies.

**Authors**

Matteo Boschini[a], Luca Falasconi[a], Claudia Giordano[a], Fabrizio Alboni[b].

[a] Department of Agricultural and Food Sciences, University of Bologna. Via G. Fanin, 50, Bologna, 40127, Italy.

[b] Department of Statistical Sciences, University of Bologna. Via Belle Arti, 41, Bologna, 40126, Italy.

**E-mails:**

- Corresponding author: Matteo Boschini, matteo.boschini@unibo.it, matteo.boschini5@gmail.com[1].
- Other authors: luca.falasconi@unibo.it; claudia.giordano4@unibo.it; fabrizio.alboni@unibo.it.

[1] permanent address.

**Keywords**

Food waste; school canteen; plate waste; school lunch; sustainable development; food security.

**List of abbreviations**

P = prepared (food)
PW = plate waste
NS = non-served (food)
TNC = total non-consumed (food); TNC = PW + NS
CL = (food) consumed at lunch; CL = P – TNC
R = redistributed (food)
FW = food waste
TC = total consumed (food); TC = CL + R

**Abstract**

Food waste reduction is increasingly seen as a main way to improve sustainability of food systems and efficiency of resource use. The provision of reliable data is a prior element to provide proper intervention strategies. Numerous studies carried out to date did not allow to a generalization of results obtained and the lack of standard methods limited data comparability. The most appropriate method for quantifying food waste in large-scale studies has not yet been established for this specific sector. The aim of the present study is to devise a reference methodology for quantifying food waste in school canteens suitable for large-scale studies, time-saving and able to provide reliable and comparable data. Initial servings, plate waste and non-served food are weighed with an electronic scale. Data are separated by dish type and aggregated at school level, whereas results are adjusted to provide comparable data. The data collection process (weighing and data recording) is directly performed by food service personnel, teachers and students. A pre-test in a primary school and a pilot study in four primary schools were conducted con the external support is limited to a single researcher, which coordinated different schools at the same time. Results demonstrated that data accuracy is not necessarily associated with an increase in time and costs.

## 1. Introduction

According to the FAO's estimates, one third of the global food production is lost or wasted along the food supply chain (Gustavsson et al., 2011). In September 2015, the General Assembly of the United Nations approved the new "Sustainable Development Goals", which include a significant reduction of global food losses and waste by 2030 (UN, 2015). In the advanced economies, most of the food waste occurs at the later stages of the food supply chain (Parfitt et al., 2010), generating a greater impact on the environment, due to the additional resources employed compared to previous phases of the value-added chain (Betz et al., 2014). Within this context, school food service represents a sector of major interest for intervention. As first reason, because plate waste threatens the primary goal of school meals, which is to provide students with an appropriate and balanced meal daily (Byker et al., 2014). Furthermore, since students eat at least one meal at school, a huge amount of food is handled everyday by the food service, which may represent a significant source of food wastage (Boschini et a., 2016). Only in Italy, approximately 300 million meals were served in 2014 (Oricon, 2015). As a third reason, school meals serve also an educational purpose (Silvennoinen et al., 2012). Taking action at school level gives therefore the opportunity to raise awareness among young generations with regards to more sustainable food choices.

The development of methodologies able to provide reliable and comparable data is a purpose of prior interest to undertake intervention strategies for food waste reduction and assess their efficacy overtime (Monier *et al.,* 2010; Östergren *et al.,* 2014; HLPE, 2014; Hanson et al., 2016). However, most of the studies conducted in this sector were carried out in few schools or during a limited number of days, affecting the generalization of findings (Betz et al., 2014; Eriksson et al., 2017), whereas the lack of standard protocols limited the comparability of results. In some cases, data refer to dish types instead of food items (Ferreira et al., 2012), different food categories (e.g. meat and fish) have been considered as one (Engström and Carlsson-Kanyama, 2004; Betz et al., 2014; Derqui and Fernandez, 2017), or different choices have been adopted whether including or not the possibly avoidable and unavoidable food waste fractions (Cordingley et al., 2011; Berretta et al., 2012; Silvennoinen et al., 2012; Betz et al., 2014).

According to the existing literature, food waste in school canteens can be measured by weighing with an electronic scale (direct method), or estimated by visual estimation or questionnaires submitted to participants (indirect methods). Depending on the aim of the study and the available resources, data on food waste can be either collected at individual or aggregate level (e.g. schools or classrooms), and results can be presented as separated (selective) or not (nonselective) across food items. Lastly, in case the results refer to specific food categories, the weighing process can be performed either before or after the food is mixed. The direct methods represent the gold standard, although the visual estimations are considered a valid, reliable and time-saving alternative (Buzby and Guthrie, 2002; Martins et al., 2014; Hanks et al., 2014; Hanson et al., 2016). Nevertheless, since the measurement consists in the estimation of single plates, an individual-based approach might not be suitable for large-scale studies, which are more interested in providing a global overview and major causes of the phenomenon than analysing the plate waste of single students. Furthermore, the single-plate approach does not allow the quantification of food remaining in the serving bowls, leading to a partial analysis of food waste generated at school lunch, and it necessarily require the external support of trained observers (Hanks et al., 2014; Martins et al., 2014), which cause an increase of costs.

At the moment, the most appropriate methodology to conduct a large-scale study on food waste generated in school canteens has not yet been determined. The aim of the present study is to develop a reference methodology for quantifying food waste in school canteens, suitable for large-scale studies, time-saving, and able to provide reliable and comparable data. To validate the methodology, a pre-test in one school and a pilot study in four schools monitored at the same time were conducted. Despite the different dimension of the samples, both phases were coordinated by a single researcher. Furthermore, in a third ongoing phase of the experiment, the methodology enabled to provide data up to 19 schools simultaneously, with the same external support of one researcher. In the present study, methodological results are discussed and quantitative data from the pre-test and pilot study are summarily reported to offer some more insight into the feasibility of the methodology.

## 2. Materials and methods

### *2.1. Methodology design*

The methodology is based on a direct method and food is weighed with an electronic scale. Data are aggregated at school level and measured separately across dish types (aggregate selective food waste). The quantification includes three main food groups: prepared food (P), plate waste (PW), which is the amount of food rejected by diners and left on their plates, and non-served food (NS), which is the amount of food not distributed to diners and remaining in the serving bowls (see Fig. 1). The sum of plate waste and non-served food determines the food non-consumed at lunch ($NCL = NS + PW$), whereas the different between the prepared food and the food non-consumed at lunch determines the food consumed at lunch ($CL = P – NCL$). As already proposed by previous authors (Engström and Carlsson-Kanyama, 2004; Betz et al., 2014; Eriksson et al., 2017), beverages are not included.

The food served to diners with special diets (e.g. dietary needs, religious or ethical reasons) and adults consuming their lunch with students (e.g. teachers) are also monitored. Results of non-served food and plate waste quantities are expressed both in terms of weight and as percentages of the initial servings. In case the meals are provided in individual servings and the quantification of prepared food cannot be performed before portioning, the amount of prepared food can also be determined by multiplying the weight of a random sample of individual servings for the total number of servings (Cohen et al., 2013).

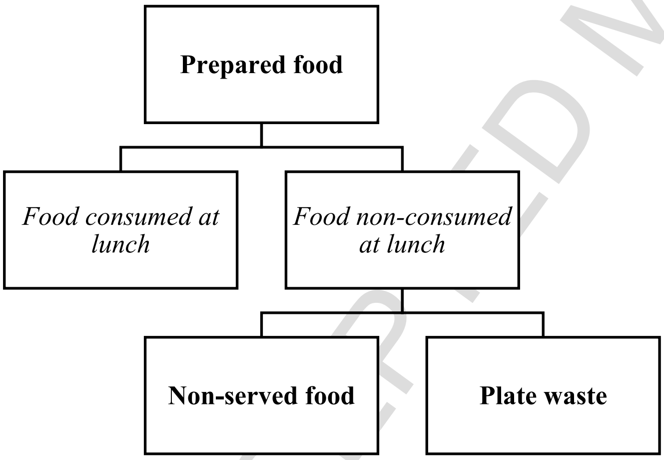



Fig. 1. Data collection system of food stream within the school food service (shown in bold food groups directly weighed and in italic those derived from sum or fraction).

### *2.2. Study design and materials*

To validate the theoretical framework of the methodology, five primary schools were recruited within the Bologna province. In April 2016, a pre-test was conducted in a primary school, monitored over a period of two weeks. The pre-test phase included also semi-structured interviews to teachers and food service personnel to clarify meal routines and lunch school habits. In October 2016, a pilot study was performed in four primary schools during a period of one week each.

The schools and the food catering companies involved are provided with specific handbooks covering the instructions for the quantification procedures and diaries where results are daily recorded. The kitchen diary records the amount of prepared food, including the name of dish types and the number of diners expected, distinguishing students from other people present at lunch (i.e.

teachers assisting students or food service personnel). Moreover, the diary includes specific fields for the quantification of special diets and it also enables to separately record condiments in order to facilitate the conversion of mixed dishes into food items. The school diary records the total amount of plate waste and non-served food by dish type, with no distinctions for special diets or dressing. School name, date, and people in charge of weighing are also recorded in both diaries. Each school is also provided with an electronic scale, trash bags, bins for the food waste collection and drawings to stick over the bins depicting the different servings, in order to guide students during the disposal of plate waste. An envelope for the shipping of the diaries to the University is also included. In the dining room, bins are grouped in stations. The number of bins composing a bin-station depends on the number of dishes served, whereas the number of bin-stations sent to the school varies according to the number of students and school facilities. The only material not provided by researchers are the scales already available within the kitchens and daily used by cooks to weigh the amount of food prepared.

*2.3 Data collection*

The data collection process is performed by the involved actors (food service personnel, teacher and students), whereas a single researcher coordinates the study. The involvement of the project coordinator is limited to a preliminary meeting, a daily remote supervision through a constant interaction via smartphone with teachers and food service personnel, and the data entry process. For each school, a teacher representative and a kitchen representative are appointed and respective responsibilities are determined. In order to limit the risk of a change in dietary intake of participants actively involved in the study, students are not made aware of the real reasons for the study and teachers are instructed to respond general answers to students inquiring about the newly introduced procedures (Hanks et al. 2014; Just and Price, 2013), with no reference to food waste. Prior to the study, the project coordinator visit the school and provide the teacher and the kitchen representative of all materials required. During the meeting, the project coordinator trains the teacher representative on the quantification procedures and advice on the best location for the bin-stations in the dining room.

The data collection process is composed of three phases (see Fig. 2). In the first phase, the food service personnel weigh the prepared food and data are daily recorded in the kitchen diary. When diners complete their meal, the second phase takes place. The food left in the plates is discarded in separated bins corresponding to the number of dish types provided by the daily menus (e.g. main course, side dish, etc.). In case the meals are provided in individual servings, the packaging is sorted with the rest of the non-food waste items (e.g. napkins) into the ordinary garbage bins, already available in the schools.

The collection is executed either by each diner or by a limited group of trained students. In the first case, the presence of a teacher in proximity of the bin-station is highly recommended to ensure a proper sorting. The last phase occurs once the diners leave the canteen and consists in weighing the plate waste and the non-served food. The procedure can be executed either by a single class or by the food service personnel, depending on previous agreements. In order to facilitate the weighing process, the standard procedure considers placing the single bin on the scale. As an alternative, teachers can opt for weighing of net waste only, provided that the choice is specified in the diary. Data are therefore recorded into the school diary.

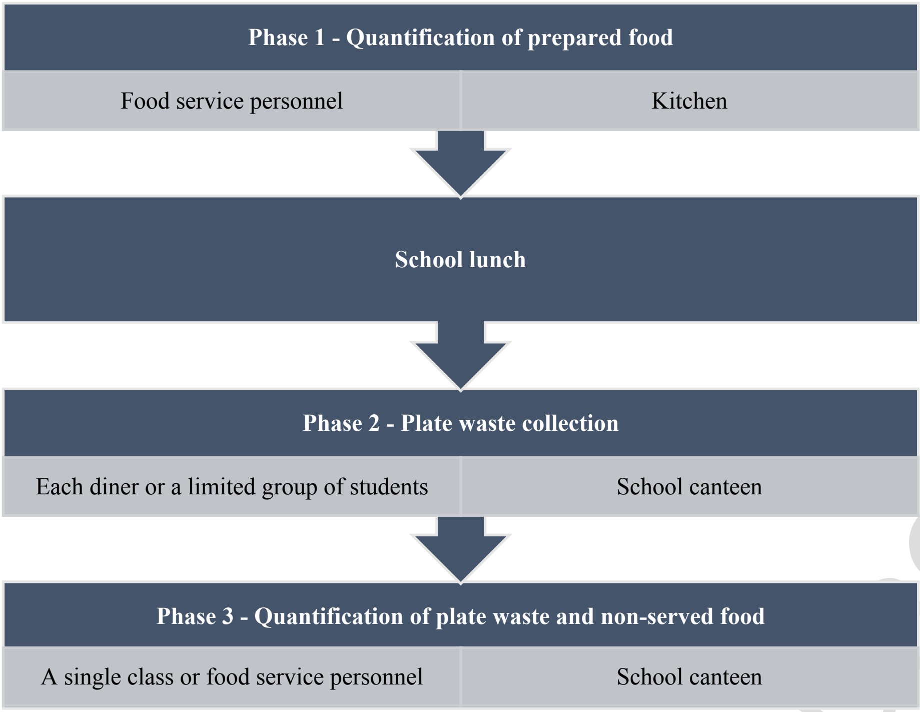



Fig. 2. Overview on the data collection process. In phase 1, the amount prepared food is weighed by the food service personnel and data are reported in the kitchen diary. In phase 2, plate waste is discarded in separated bins by each diner or a limited group of trained students. In phase the amount of non-consumed food (consisting of non-served food, plate waste, and portions of bread and fruit left in the dining room) is weighed either by a single class or by the food service personnel, and data are reported in the school diary.

During the monitoring period, both the teacher and the kitchen representatives of each school are daily requested to provide pictures of the diaries via smartphone (see Fig. 3). In case some teacher of kitchen representatives forgets to send the pictures to the project coordinator, they are promptly contacted. The connection between the project coordinator, and both teacher and kitchen representatives is provided through the desktop version of a text messaging application.

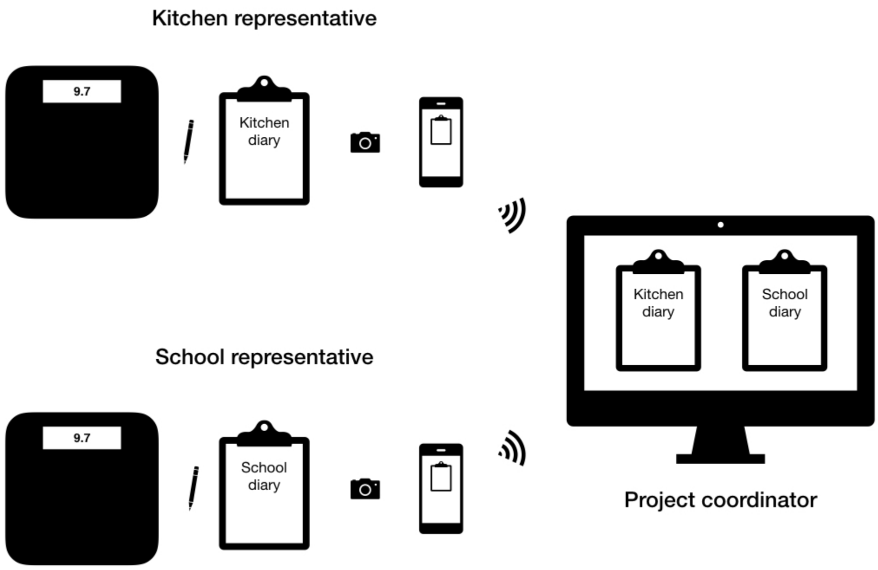



Fig. 3. Overview on the process of data sharing. The teacher and the kitchen representatives provide daily to the project coordinator pictures of the diaries via smartphone.

*2.4 Monitoring duration, study period and sample design*

The methodology provides information on the total amount of non-consumed food remaining in the school canteen at the end of the lunch. Therefore, the meal daily served at school is the statistical unit adopted for the present study. To increase the efficiency of data gathering, the detection of statistical units can be organized at school level by monitoring a determined number of lunches for each school. In this case, the schools can be therefore considered as single observation units and the statistical units necessary to produce reliable data are directly related to the number of schools engaged and the length of monitoring duration. When planning the data collection, it should be considered that a limited number of days generate results significantly dependent on the type of dishes served (Eriksson et al., 2017). Otherwise, care should be taken when considering too long monitoring duration, due to commitments required to the involved actors. In regards to the study period, menu rotations and menu changes related to seasonality (e.g. summer and winter menus) should be considered. For instance, in Italian school meal guidelines (Anelli et al., 2010) it is required a seasonal rotation twice a year (i.e. summer menu and winter menu) and set menu rotations based on four weeks. In this case, both rotations should be included in the study, covering as many menu combinations as possible.

Lastly, to achieve a representative sample of statistical units, it is necessary to take into account all the factors which can potentially lead to food waste generation at school level. The sample should be therefore stratified considering variables such as school dimension, location (urban or rural area) type of catering provider (private or public food service), kitchen location (internal or external to school facilities), students access to free mid-morning snacks brought from home, or school recess preceding or following lunch time.

*2.5 Dataset management*

At the end of the data entry, results are adjusted in order to provide comparable data: dish types are therefore converted into food categories and the avoidable and unavoidable food waste fractions are determined. Moreover, analyses on final destination food are performed.

*2.5.1 Food categories*

The conversion of dishes into food categories is not required for servings composed of single food items (e.g. bread and fruit). Otherwise, mixed dishes (i.e. dishes composed of more than one relevant component or a relevant component and a dressing) can be converted by weighing separately the components and dressings before mixing. As an alternative, it can be obtained by asking the cooks to provide proportions of the different main ingredients used to later apply a correction factor during the data analysis. The single food items are grouped in the following food categories:

- Vegetables and legumes (1);
- Fruit and processed fruit products (2);
- Meat and meat products (3);
- Fish and fish products (4);
- Eggs and egg products (5);
- Dairy products (6);
- Starch products (e.g. bread, pasta, rice and potatoes) (7);
- Desserts (e.g. sweet pastries, yoghurt and ice-creams (8);
- Confectionary and snacks (9);
- Condiments, sauces, herbs and spices (10).

*2.5.2 Avoidable and unavoidable food fractions*

Quested and Johnson (2009) defines avoidable food waste as “food and drink thrown away that was, at some point prior to disposal, edible”, possibly avoidable food waste as “food and drink that some people eat and others do not (e.g. bread crusts), or that can be eaten when a food is prepared in one way but not in another" (e.g. potato skins)", and unavoidable food waste as "waste arising from food or drink preparation that is not, and has not been, edible under normal circumstances (e.g. meat bones, egg shells, pineapple skin, tea bags)". The present methodology distinguishes between edible and inedible food parts. Therefore, since the previous definition considers possibly avoidable food waste as edible, only avoidable and unavoidable sub-categories are considered. The corresponding edible and inedible fractions can be obtained from the national food composition tables. In case the data are not available, they can be determined by weighing the inedible fraction of each food item, averaging, and subtracting from the mean item weight (Byker et al., 2014). Since the prepared food and the non-served food are composed of entire and untouched portions, the edible and inedible fractions remain constant, ensuring the distinction in their corresponding avoidable and unavoidable parts. On the contrary, the ratio is not maintained for plate waste. In this case, the edible fraction might vary, whereas the unavoidable fraction of food served to diners is assumed to be totally wasted. Therefore, the unavoidable fraction of plate waste corresponds to the unavoidable fraction of prepared food, subtracted from the unavoidable fraction of non-served food (*unavoidable PW = unavoidable P – unavoidable NS food*), whereas the difference between plate waste and the unavoidable fraction of plate waste determines the avoidable fraction of plate waste (*avoidable PW = PW – unavoidable PW*). Finally, since the food consumed at lunch is assumed to be entirely edible, it does not include an unavoidable fraction.

*2.5.3 Final destination of prepared food*

As reported by Derqui and Fernandez (2017), analysing the final destination of food can be useful to evaluate the environmental impact of food waste. Initial servings can be consumed at lunch, redistributed (R) for human consumption or animal feeding or, as last option, managed as waste (FW) (see Fig. 4). The sum between the food consumed at lunch and the redistributed food determines the total consumed food (*TC = CL + R*).

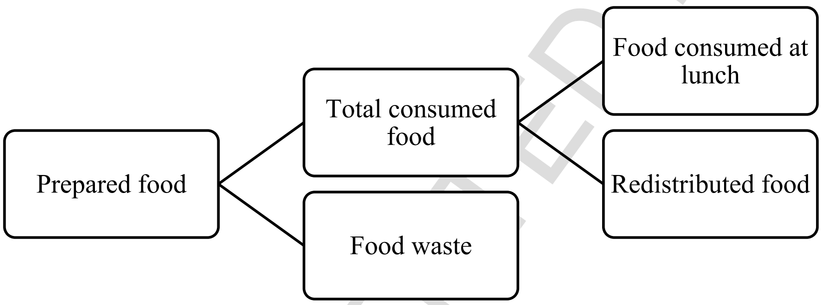



Fig. 4. Final destinations of prepared food within the school food service.

**3. Results**

*3.1 Methodological results*

*3.1.1 Methodology design*

As already observed by previous studies (Iapello et al., 2011; Saccares et al., 2014; Vezzosi et al., 2014; Falasconi et al., 2015), the lunch provided in the Italian school food service is composed by three main processed servings, a portion of bread and a portion of fruit, occasionally replaced by a dessert (e.g. cake, yoghurt, ice-cream). The main servings include a first course consisting of a carbohydrate-rich component (e.g. pasta or rice), a second course mainly based on a protein-rich component (meat, fish, eggs, cheese, legumes), and a side dish of vegetables. With the exception of one school were fruit was not served at lunch, the data collection system was based on five dishes. Therefore, each bin-station was composed of five units, each one labelled with a different illustration (see Fig. 5).


Fig 5. Drawings attached over the bins provided to the Italian schools (illustration by Giorgia Arcella).

*3.1.2 Study design, materials and costs*

The teachers and the food service personnel declared that the data collection process did not create significant disruptions to the normal flow of lunch and the commitment required could be sustained as the division of labours was distributed among all the involved actors. Both the pre-test and the pilot study were coordinated by a single researcher, which performed also the data entry. At the end of the study, data were imported into R for analysis. The pre-test included one school monitored during 10 days, whereas the pilot study included four schools monitored during 5 days, with the exception of one school involved four days only, because of impediments occurred during one day of the scheduled week. Therefore, 29 observations were collected: 10 from the pre-test *(1 school * 10 days)* and 19 from the pilot study [*(3 schools * 5 days) + (1 school * 4 days)*]. During the pilot study, meals from 2738 participants were monitored, with an average of 144 diners per day in each school (*2738 meals / 19 observations = 144.1*). Considering that data from the pilot study were collected during the same week, an average of 576 participants were monitored everyday (*144.1 diners * 4 schools = 576.4*), with a maximum peak of 670 diners in the third day of the scheduled period. The overall cost of materials required to conduct the study in a school of average dimension (two bin-stations, two weeks of monitoring) was 65.75 euros (6.6 euros per day) (see Table 1). The costs of materials required do not include the scale for weighing the prepared food, as it is already available in the kitchens. Moreover, travel costs (fuel, motorway tolls) incurred for delivering the required materials are excluded, as they can vary considerably depending on school distance and fuel price.

Table 1. Overall costs of materials required to conduct the study in a school of average dimension (two bin-stations, two weeks of monitoring).

| Materials | Unit cost (euro) | Number of items required | Final cost per each material (euro) |
|---|---|---|---|
| Scale | 20.0 | 1 | 20.0 |
| Trash bags | 0.23 | 130 | 29.9 |
| Bins | 0.9 | 10 | 9.0 |
| A4-papers | 0.01 | 50 | 0.50 |
| Printing | 0,06 | 50 | 3.0 |

| | | | |
|---|---|---|---|
| Envelope | 0.5 | 1 | 0.5 |
| Stamps | 0.95 | 3 | 2.85 |
| Total costs | | | 65.75 |

During the study period, teacher and kitchen representatives from the pilot study were asked to estimate the time required to conduct the monitoring process (plate waste separation and weighing of both plate waste and non-served food). Depending on school dimension, the time required ranged between 10 and 30 minutes, with an average of 22 minutes (1320 seconds) each day. Considering an average of 144 diners per day in each school, 9.2 seconds per person occurred (*1320 seconds / 144 diners*) to conduct the two phases.

*3.1.3 Data collection*

The application of the methodology in the Italian context required an adjustment to the data collection process, due to a common routine related to the final destination of untouched portions of bread and fruit. Since they do not need to be stored at a controlled temperature, they are frequently taken into classrooms by teachers and redistribute to the students during the afternoon break. Therefore, as these food items leave the canteen before the weighing of non-served food and plate waste (third phase), another phase had to be added to the general procedure (see Fig. 6). In this phase, bread and fruit items brought to classroom are quantified in a specific diary filled out by each class before leaving. In order to make this quantification phase less time-consuming, the items are counted and the conversion of numbers in weight is performed during data analysis. In case uncountable fruits (e.g. cherries) are served, they are deliberately excluded from the measurement. The bread and fruit portions brought into classrooms are considered as redistributed food, whereas portions left in the dining room are considered as wasted. The only exception might be for schools with internal kitchen, where fruit portions are generally recovered to be served the day after.

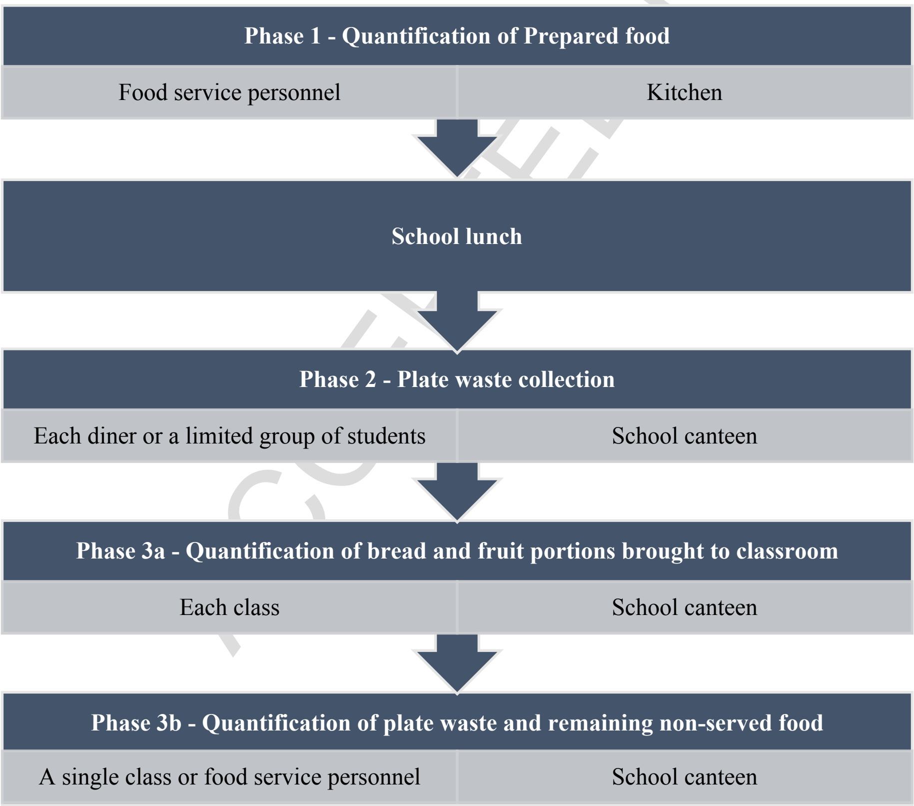



Fig. 6. Overview on the data collection process of the Italian case-study. In phase 1, the amount prepared food is weighed by the food service personnel and data are reported in the kitchen diary. In phase 2, plate waste is discarded in separated bins by each diner or a limited group of trained students. In phase 3a, portions of bread and fruit brought to classroom are counted by each class before living the dining room and data reported in a specific diary. In phase 3b, the

amount of non-consumed food (consisting of non-served food, plate waste, and portions of bread and fruit left in the dining room) is weighed either by a single class or by the food service personnel, and data are reported in the school diary.

*3.1.4 Data management*

At the end of the study, data were imported into R to perform the statistical analyses. After subtracting the tare weight (0.525 g per bin), dishes were converted into single food items. The conversion was required for the first course, the second course and the side dish, which are generally composed of a main component and a sauce (e.g. tomato sauce for pasta) or a dressing (olive oil for vegetables). In the present study, a separate weighing of components in the kitchen before cooking was practicable for a limited number of first courses, whereas for the rest of the mixed dishes the proportion of ingredients was provided by cooks or obtained from Italian school meal guidelines (Anelli et al., 2010). The only unavoidable food waste founded within the Italian school canteens were fruit peels and cores and chicken bones (Boschini et al., 2016) and their inedible fraction were therefore obtained from the Italian Food Composition Table (INRAN, 1993). During the monitoring period, neither catering company provided desserts, confectionary or snack for lunch. Therefore, no items from these food categories (groups 8 and 9) were recorded.

*3.1.5 Progressive exposition bias*

Although students are not made aware of the real aims of the experiment, a hypothetical influence on the amount of plate waste generated by participants was evaluated. The bias effect of the progressive exposition to the data collection process may be due to an increase of awareness on the amount of food waste daily produced. Therefore, to detect the presence of a significant variation in the amount of avoidable plate waste generated at school, a Kruskal-Wallis test was conducted and median values of avoidable plate waste in different days of the monitored week were compared. The school involved in the pre-test was the only one monitored during two weeks. Since a time of seventeen days occurred between the first and the second monitoring period, both the weeks were included. The results from the statistical test (chi-squared = 3.53, df = 4, p-values = 0.47) allowed to state that no significant differences emerged in the daily waste share and the initial was refused.

*3.2 Quantitative results*

Results from the pre-test and the pilot study are uniquely presented, as the information were collected using the same procedure. A confirmation of their homogeneity was provided by the Mann-Whitney test, from which no substantial discrepancies emerged. The food service was provided to the five schools by three different catering companies. With the exception of the school of the pre-test phase, meals were provided from external kitchens. In total, 4364 meals were monitored: 3999 meals were served to the students and 365 to other diners, which accounted for 8.4% of the total. The total amount of prepared food was 2189.6 kg; the avoidable fraction was 2122.2 kg and the unavoidable fraction was 67.4 kg, accounting for the 3.1% of initial servings. The total amount of plate waste (PW) was 499.2 kg; the avoidable fraction was 467 kg and the unavoidable fraction was of 35.1 kg. The total amount of non-served (NS) food was 433.5 kg; the avoidable fraction was 408.3 kg, whereas the unavoidable fraction was of 35.1 kg. Previous results refer to the avoidable fraction of food, unless otherwise specified. The PW and NS food accounted for respectively of 22.0% and 19.2% of prepared food (see Table 2). Two main trends for the five servings within the food stream emerged: the three main processed servings (first course, second course and side dish) present high percentages of food consumed at lunch and PW, but low percentages of NS food, whereas bread and fruit portions present low percentages of food consumed at lunch and PW, but high percentages of NS food, meaning that the major part of these portions are entirely rejected by diners.

Table 2. Percentages of the avoidable fraction within the food stream (CL food, NS food, PW) for the five servings.

| | Prepared food | Food consumed | Non-served food | Plate waste |
|---|---|---|---|---|

| | | at lunch | | |
|---|---|---|---|---|
| First course | 100 | 66.7 | 7.6 | 25.7 |
| Second course | 100 | 66.9 | 6.0 | 27.1 |
| Side dish | 100 | 55.4 | 9.3 | 35.3 |
| Bread | 100 | 46.2 | 45.5 | 8.3 |
| Fruit | 100 | 44.5 | 47.5 | 8.0 |
| TOTAL | 100 | 58.8 | 19.2 | 22.0 |

Regarding the final destination of prepared food, the amount of redistributed food accounted to 332.9 kg, entirely destined to human consumption. The avoidable fraction was 302.1 kg and the unavoidable fraction was 30.8 kg. The total amount of food waste (FW) was 609.8 kg; the avoidable fraction 573.2 kg and the unavoidable fraction was 36.6 kg. The same trends for the five servings emerged in reference to the final destination of food: the three main processed servings are the most wasted and less re-used, whereas bread and fruit portions are the less wasted and the most reused (see Table 3). The school with the internal kitchen was the only case where a fraction of the non-served food of the three main processed servings were redistributed and consumed, specifically by the kitchen staff.

Table 3. Percentages of the final destination of the avoidable fraction of prepared food (CL, R, FW) for the five servings.

| | Prepared food | Food consumed at lunch | Redistributed food | Food waste |
|---|---|---|---|---|
| First course | 100 | 66.7 | 2.7 | 30.6 |
| Second course | 100 | 66.9 | 3.1 | 30.0 |
| Side dish | 100 | 55.4 | 4.7 | 39.9 |
| Bread | 100 | 46.2 | 38.7 | 15.1 |
| Fruit | 100 | 44.5 | 41.1 | 14.3 |
| TOTAL | 100 | 58.8 | 14.2 | 27.0 |

On a per capita basis, 531.0 g of food were daily prepared for each diner; the edible fraction was 486.3 g and the inedible fraction was 17.8 g, accounting for x % of initial servings. The amount of plate waste per person was 114.4 g; the edible fraction was 107.0 g and the inedible fraction 7.4 g, which accounted for 6.5% of initial servings. Regarding the final destination of food, 69,6 g were redistributed, whereas 131.3 g were wasted.

The Fig. 8 shows the contribution of food categories to plate waste, whereas the Fig. 8 shows the contribution of food categories to the final destination of the prepared food, distinguishing the total consumed food (*TC = CL food + R food*) from food waste.

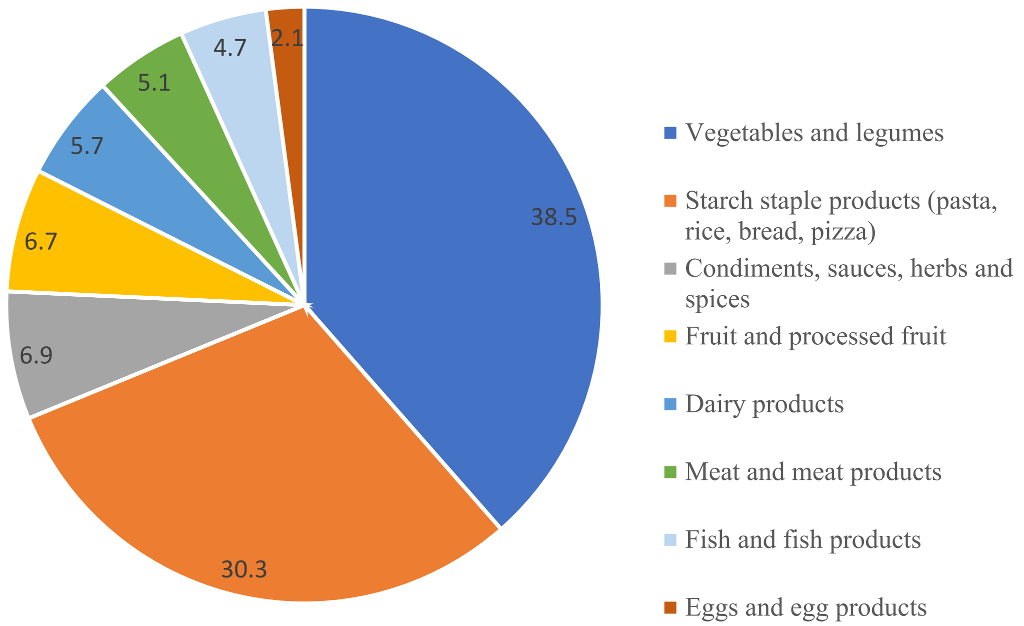



Fig. 7. Food items contribution to the avoidable fraction of plate waste (% weight).

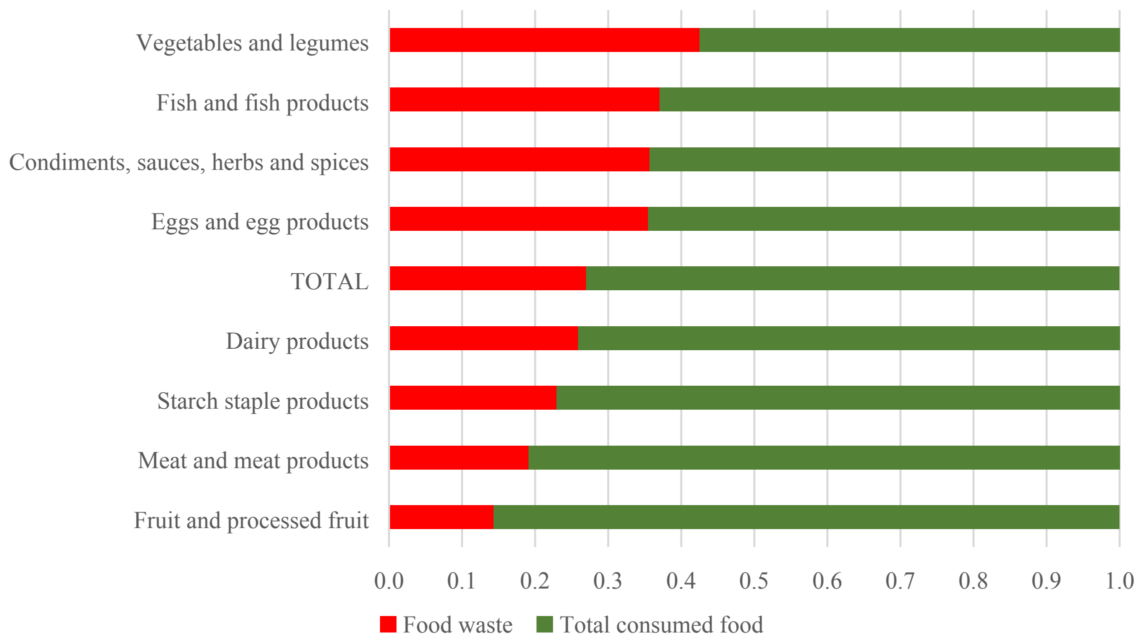



Fig. 8. Final destination of the avoidable fraction of prepared food (TC, FW) in terms of food items.

## 4. Discussion

The adoption of a direct method for weighing food waste ensures the provision of accurate and reliable data, whereas the conversion of dishes in food items, the adjustments in terms of edibility, and the analysis on the final destination of food, allow their comparability at international level. Since the weighing process is performed before the food is mixed, while the unavoidable fraction is not physically separated at all, the overall commitment is contained. The adoption of a self-reporting technique and the materials used, allowed to develop a methodology for large-scale study and significantly contributed to contain costs. Buzby and Guthrie (2002) reported that Comstock et al. (1980) considered as impractical the implementation of direct methods for samples of more than 50-100 diners, whereas the present methodology enabled monitoring up to 674 participants simultaneously. Therefore, the direct involvement of participants in the data collection process allows its potential application to larger studies. The collection of data aggregated at school level ensures a restriction of timing. In the study conducted by Hanks et al. (2014), 30 seconds occurred to weigh the tray waste of a single person, and 4 to 5 seconds when adopting the visual estimation methods. In the present study, where food waste was directly weighed and data collected at an aggregate level, an average of 9 seconds occurred for gathering data from each person. Furthermore, results from the present study include also the time required to perform the plate collection process and the weighing of non-served food, which were not included in the study conducted by Hanks et al. (2014). In conclusion, considering the time required for the single plate approach and the lower accuracy of indirect methods, the present methodology results to be more appropriate for large scale studies. Finally, a cost-effectiveness comparison of the present approach with those of previous studies has not been conducted, since no other cost-analyses were found in existing literature.

The methodology presents also some limitations. It does not include the waste of food generated in the other stages of the school food service sector (e.g. food storage and food preparation) the quantification process is limited to food consumed at lunch. Nevertheless, previous studies analysing the whole production process agreed that the main amount of food waste occurs in the school canteens (Engström and Carlsson-Kanyama; 2004; Silvennoinen et al., 2012; Derqui and Fernandez, 2017), whereas Cordingley et al. (2011), which monitored also classrooms and playgrounds, noted that school canteens percentages of food waste production were lower for these areas. One of the main bias of self-reporting techniques is the change in participants' behaviours. However, the absence of researchers during the quantification process contributed to limit the risk of bias related to the presence of external observers. Furthermore, in order to limit the risk of a change in students' dietary habits, only teachers and food service personnel were fully informed of the real reasons for this study. Finally, the test of a hypothetical progressive reduction of plate waste due to the awareness on the amount of waste daily produced did not provide relevant results. Participants with special diets are included in the data collection, even if their plate leftovers are collected in the same bins provided for standard menus. Another potential source of error might occur when food is mistakenly sorted in the wrong bin, although the procedure foresees the presence of an adult to support the students during the separation phase. The proportion of ingredients composing plate waste is assumed to be the same of initial servings. However, students might selectively eat one of the ingredients composing the dish. The conversion of dish types into food items and adjustments in terms of edibility are estimated during the data analysis. Moreover, food redistributed for human consumption or animal feeding is assumed to be totally consumed, as the methodology is not able to evaluate its finale use.

Although the current study tested the methodology on primary schools only, no relevant factor suggests hindering its application to secondary schools or university cafeterias. Otherwise, since the involvement of younger children might not be feasible, it is suggested that both plate waste sorting and weighing might be directly managed by teachers and the food service personnel in case of studies conducted in nursery schools. Finally, it is important to recall that the aim of the present study was not to provide quantitative results and the data summarily reported do not intend to be statistically significant.

## 5. Conclusions

The present study provided a methodology for quantifying food waste in school canteens suitable for large-scale studies and demonstrated that data accuracy, reliability and comparability are not necessarily associated with an increase in time and costs. The quantification of food waste within school food service presents a broad field of interest, since it allows to collect information of relevant interest for all the stakeholders. It can be a tool for food catering companies to assess meal acceptance and a useful instrument for local authorities and national institutions committed in developing strategies to prevent food waste and promoting more sustainable food services.

Moreover, since plate waste is considered an indicator of nutritional adequacy, it can be adopted by public health authorities to assess the efficacy of school meal policies. Furthermore, since the plate waste is also related to home dietary habits, it gives the opportunity to raise awareness on food waste among families providing useful insights on food consumption habits of their children at school. Lastly, since the school meal presents also a pedagogical purpose, the quantification process might also be used by school teachers as an instrument of active learning: once students are made aware of the real reasons of the study, the sorting and weighing phases create the opportunity to promote more sustainable food habits among the incoming generations.

**Akcnowledgments**

This work is part of the REDUCE Project (Ricerca, Educazione, Comunicazione: an integrated approach for food waste prevention), supported by Italian Ministry of Environment.

The authors state that there are no conflicts of interest.

Matteo Boschini participated in conception and design of the study, coordinated the acquisition and interpretation of data and drafted the manuscript.

Luca Falasconi devised the study, participated in revising the manuscript, and has given final approval for this version to be published.

Claudia Giordano supported the conception and design of the study and revised the manuscript.

Fabrizio Alboni performed the statistical analysis.

The authors would like to thank Daniela Nicoletti for the support in the experimental phase of the study and Giorgia Arcella for the valuable graphic support developed under REDUCE Project.

**References**

Anelli, S., Boni, S., Caputo, M., Caroli, M.., Ciampella, A. A., Copparoni, R., Del Balzo, V., D'Elia, R., Di Martino, E., Di Vicenzo, M. A., Galeoni, D., Ghiselli, A., Guidarelli, L., Menzano, M. T., Silvestri, M. G. Vio, P., 2010. Linee di indirizzo nazionale per la ristorazione scolastica. Ministero della Salute, Provvedimento 29 aprile 2010. Available at: http://www.salute.gov.it/portale/temi/p2_6.jsp?id=1648&area=nutrizione&menu=ristorazione. Last access: 02/07/2017.

Betz, A., Buchli, J., Göbel, C., Müller, C., 2015. Food waste in the Swiss food service industry – magnitude and potential for reduction. Waste Management. 35, 218–226. Available at: http://dx.doi.org/10.1016/j.wasman.2014.09.015.

Boschini, M., Falasconi, L., Giordano, C., Meybeck, A., 2016. Preliminary assessment of a methodology for determining food waste in primary school canteens. In: Sustainable value chain for sustainable food systems. A workshop of the FAO/UNEP Programme on Sustainable Food Systems. FAO, Rome. Available at: http://www.fao.org/3/a-i6511e.pdf. Last access: 02/07/2017.

Buzby, J., Guthrie, J., 2002. Plate waste in school nutrition programs. Final Report to Congress. Economic Research Service/USDA.

Byker, C. J., Farris, A. R., Marcenelle, M., Davis, G. C., & Serrano, E. L., 2014. Food waste in a school
nutrition program after implementation of new lunch program guidelines. Journal of Nutrition Education and
Behaveiour. 46(5), 406–411. Doi: http://dx.doi.org/10.1016/j.jneb.2014.03.009.

Cohen J. F., Richardson, S., Austin, S. B. Bryn, A., Economos, C. D., Rimm, E.B., 2013. School lunch waste among middle school students: nutrients consumed and costs. American Journal of Preventive Medicine. 44, 114–121. Doi: http://dx.doi.org/10.1016/j.amepre.2012.09.060.

Cohen, J. F., Jahn, L. J., Richardson, S., Cluggish, S. A., Parker, E., Rimm, E. B., 2016. Amount of time to eat lunch is associated with children's selection and consumption of school meal entrée, fruits, vegetables and milk. Journal of the Academy of Nutrition and Dietetics. 116, 123–128. Available at: http://jandonline.org/article/S2212-2672(15)01248-4/fulltext. Last access: 02/07/2017.

Comstock, E. M., Symington, L. E., Chmielinski, H.E., McGuire, J. S., 1979. Plate waste in school feeding programs, individual and aggregate measures. Report No. NATICK/TR-81-011. Natick, USA, Food Sciences Laboratory, US Army Natick Research and Development Command. Available at: http://www.dtic.mil/dtic/tr/fulltext/u2/a097819.pdf. Last access: 02/07/2017.

Comstock E., Pierre, S. R., Mackiernan, Y. D., 1980. Measures of Individual plate waste in school lunches: relationships among weights, Visual estimates, and child ratings. AAI Report #80-78. Cambridge MA: Abt Associates Inc., Contract No. 53- 3198-9-38.

Cordingley, F., Reeve, F., Stephenson, J., 2011. Food waste in schools. Report Prepared by WRAP (Waste & Resources Action Programme), Banbury. Available at: http://www.wrap.org.uk/sites/files/wrap/Household_food_and_drink_waste_in_the_UK_-_report.pdf. Last access: 02/07/2017.

Derqui, B., Fernandez, V. The opportunity of tracking food waste in school canteens: Guidelines for self-assessment. Waste Management (2017). Doi: http://dx.doi.org/10.1016/j.wasman.2017.07.030.

Engström, R., Carlsson-Kanyama, A., 2004. Food losses in food service institutions – examples from Sweden. Food Policy 29, 203–213. Doi: http://dx.doi.org/10.1016/j.foodpol.2004.03.004.

Eriksson, M., Osowski, C. P., Malefors, C., Björkman J., Eriksson, E., 2017. Quantification of food waste in public catering services – A case study from a Swedish municipality. Waste Management. 61, 415–422. Available at: http://www.sciencedirect.com/science/article/pii/S0956053X17300351. Last access: 02/07/2017.

Falasconi, L., Vittuari, M., Politano, A. & Segrè, A. 2015. Food waste in school catering: an Italian case study. Sustainability. 7, 14745–14760. Available at: http://www.mdpi.com/2071-1050/7/11/14745. Last access: 02/07/2017.

Ferreira, M., Martins, L. M., Rocha, A., 2012. Food waste as an index of foodservice quality. British Food Journal. 115 (11), 1827–1637. Available at: http://www.emeraldinsight.com/doi/full/10.1108/BFJ-03-2012-0051. Last access: 02/07/2017.

Gustavsson J, Cederberg C, Sonesson U. 2011. Global food losses and food waste. Rome, Italy. Available at: http://www.fao.org/docrep/014/mb060e/mb060e00.pdf. Last access: 02/07/2017.

Hanks, A. S., Wansink, B., Just, D. R., 2014. Reliability and accuracy of real-time visualization techniques for measuring school cafeteria tray waste: validating the quarter-waste method. Journal of the Academy of Nutrition and Dietetics. 114, 470–474. Available at: http://www.sciencedirect.com/science/article/pii/S2212267213013373. Last access: 02/07/2017.

Hanson, C., Lipinski, B., Robertson, K., Dias, D., Gavilan, I., Gréverath P., Ritter, S., Fonseca, J., VanOtterdijk, R., Timmermans, T., Lomax, J., O'Connor, C., Dawe, A., Swannell, R., Berger, V., Reddy, M., Somogyi, D., 2016. Food losses and waste accounting and reporting standard. Available at: https://www.wri.org/sites/default/files/REP_FLW_Standard.pdf. Last access: 02/07/2017.

HLPE, 2014. Food losses and waste in the context of sustainable food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2014. Available at: http://www.fao.org/3/a-i3901e.pdf. Last access: 02/07/2017.

Iapello, A., Quaglia, G.B., Di Renzo, L., De Lorenzo, A. & Bucarelli, F.M., 2011. Indagine quali-quantitativa dello scarto alimentare nella refezione scolastica, con particolare riferimento agli aspetti nutrizionali. La rivista di scienza dell'alimentazione. III (Oct–Dec), anno 40. Available at: http://www.fosan.it/system/files/Anno_40_4_2.pdf. Last access: 02/07/2017.

INRAN. 1993. Banca Dati di Composizione degli Alimenti. Available at: http://nut.entecra.it/646/tabelle_di_composizione_degli_alimenti.html. Last access: 02/07/2017.

Just, D., Price, J., 2013. Default options, incentives and food choices: evidence from elementary-school children. Public Health Nutrition. 16 (12), 2281–2288. Doi: http://dx.doi.org/10.1017/S1368980013001468.

Martins, M. L., Cunha, L., Rodrigues, S., Rocha, A., 2014. Determination of plate waste in primary school lunches by weighing and visual estimation methods: a validation study. Waste Management. 34, 1362–1368. Available at: http://www.sciencedirect.com/science/article/pii/S0956053X14001299. Last access: 02/07/2017.

Martins, M. L., Rodriguez, S. P., Cunha, L. M., Rocha, A., 2015. Strategies to reduce plate waste in primary schools – experimental evaluation. Public Health Nutrition. 19 (8), 1517–1525. Doi: http://dx.doi.org/10.1017/S1368980015002797.

Monier, V., Escalon, V., O'Connor, C., European Commission, 2010. Preparatory Study on Food Waste Across EU 27 October 2010. Doi: http://dx.doi.org/10.2779/85947.

Oricon, 2015. Gli sprechi nella ristorazione scolastica. Osservatorio Ristorazione Collettiva e Nutrizione, Roma. Available at: http://oricon.it/wp-content/uploads/2015/11/Indagine-esplorativa-Sprechi-scuole.pdf. Last access: 02/07/2017.

Östergren K., Gustavsson, J., Bos-Brouwers, H., Timmermans, T., Hansen, O.-J. Møller, H., Research, O., Anderson G., O'Connor, C., Soethoudt, H., Quested, T., Easteal, S., Politano, A., Bellettato, C., Canali, M., Falasconi, L., Gaiani, S., Vittuari, M., Schneider, F., Moates, G., Waldron, K. & Redlingshöfer, B., 2014. FUSIONS Definitional Framework for Food Waste. Available at: http://www.eu-fusions.org/phocadownload/Publications/FUSIONS%20Definitional%20Framework%20for%20Food%20Waste%202014.pdf. Last access: 02/07/2017.

Parfitt J., Barthel M., Macnaughton S., 2010. Food waste within food supply chains: quantification and potential for change to 2050, Philosohical Transactions of the Royal Society B. 365, 3065–3081. Doi: http://dx.doi.org/10.1098/rstb.2010.0126.

Quested, T., Johnson, H., 2009. Household Food and Drink Waste in the UK: A Report Containing Quantification of the Amount and types of Household Food and Drink Waste in the UK. Report Prepared by WRAP (Waste and Resources Action Programme), Banbury. Available at: http://www.wrap.org.uk/sites/files/wrap/Household_food_and_drink_waste_in_the_UK_-_report.pdf. Last access: 02/07/2017.

Saccares, S., Scognamiglio, U., Moroni, C., Marani, A., Calcaterra, V., Amendola, M., Civitelli, G., Cattaruzza, A. S., Ermenegildi, A., Morena, V., 2014. Evaluation model of plate waste to monitor food consumption in two different catering settings. Italian Journal of Food Safety. 3(1669): 107–110. Doi: https://doi.org/10.4081/ijfs.2014.1669

Silvennoinen, K., Koivupuro, H.-K., Katajajuuri, J.-M., Jalkanen, L., Reinikainen, A., 2012. Food Waste Volume and Composition in Finnish Food Chain. MTT Report 41. Jokioinen. Available at: https://portal.mtt.fi/portal/page/portal/mtt/hankkeet/foodspill/Food%20Waste%20Volume%20and%20Composition%20Focus%20on%20Food%20Service%20Sector.pdf. Last access: 02/07/2017.

UN, 2016. United Nations Sustainable Development Goals, Goal 12: Ensure sustainable consumption and production patterns, United Nations, New York. Available at: http://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf. Last access: 02/07/2017.

Vezzosi S., Bonaccorsi, G., Picciolli, P., Santomauro, F. 2014. Ancora troppi scarti nelle mense scolastiche. *Ecoscienza, sostenibilità e controllo ambientale*, 1: 30–31. Available at: https://www.arpae.it/cms3/documenti/_cerca_doc/ecoscienza/ecoscienza2014_5/vezzosi_santomauro_et_al_es05_14.pdf. Last access: 02/07/2017.

Large-sample studies are crucial to provide national and comparable data on food waste

A methodology to quantify FW in school canteens in large-scale studies is presented

An average of 576 students were daily monitored under the supervision of a researcher

An average of 107 g of avoidable plate waste was produced daily by each participant