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Why the waste? A large-scale study on the causes of food waste at school canteens

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Keywords

Food waste; plate waste; non-served food; school canteen; food waste cause; school kitchen; foodservice.

Abstract

Several studies have recalled the need to reduce food waste across all the stages of the food supply chain. To undertake effective intervention strategies for food waste prevention and reduction, it is important to better understand the main causes of this phenomenon. In this study, a wide range of factors potentially related to food waste generation in primary school canteens were analysed. The data was obtained from a large-scale study carried out involving 78 Italian primary schools, where the food waste occurring at lunchtime was measured on 11,518 diners, for a total of almost 110,000 meals. The assessment included the quantification of prepared food, plate leftovers and non-served food, which were all weighed with an electronic scale and measured separately for each meal course. The food rejected by diners and the quantity of food remaining unserved at the end of the lunch were studied against a set of potential factors, including the location and size of the school, the location of the kitchen, the type of menu provided to diners, the quantity of food prepared and served. Findings obtained through the analyses of the single variables show that most of the variables have a role in influencing the quantity of food that remains non-consumed. Multivariate models were used to assess the relative importance of the factors over the quantity of food waste. The foodservice provider emerges as the most significant factor in influencing the generation of food waste at schools; other relevant factors are the amount of food prepared and the serving size, the kitchen location, the food provided for the mid-morning break, the menu composition and the geographical area.

1. Introduction

Reducing food losses and waste is broadly considered as a main way to improve sustainability of food supply and consumption chains, as well as to tackle their negative consequences on the environment and on the socio-economic system. In September 2015, the General Assembly of the United Nations approved the new “Sustainable Development Goals”, which included the objective

to “halve per capita global food waste at the retail and consumer level by 2030” (UN, 2016). The new Directive 2018/851 of the European Parliament and of the Council on waste legislation called on Member States to take action to monitor and reduce food waste levels and to report about progresses made. In the advanced economies, most of the food waste occurs at the later stages of the food chain and it is mainly due to behavioral issues (Parfitt et al., 2010; Gustavsson et al., 2011).

The food waste generated in the school foodservice sector is attracting increasing attention both from the academic literature and the public opinion. Studies tackling food waste generation in the foodservice are increasing in number, but more research based on reliable data is required to better understand the potential determinants of food waste in school canteens (Byker et al., 2014; Kinasz et al., 2015). One of the first studies that analysed the causes of food waste at school canteens was conducted by WRAP (Cordingley et al., 2011). Interviews with school and kitchen staff highlighted three main categories of causes. First, operational issues related to catering provider policies and organization of the foodservice at school, such as the absence of an ordering system for school meals, lack of flexibility to adapt centrally planned menus to meet student’s preferences and excessive size of portions with respect to children’s nutritional needs. Second, situational reasons not directly connected to food, such as an unpleasant environment in the dining room, the short time available to pupils to eat their lunch and practical difficulties with eating food that need be peeled, such as fruit. Third, some behavioural reasons emerged, in connection with individual choices, e.g. lack of hungry or limited appreciation of meal options. In another study that investigated stakeholders’ perceptions on school food waste, the phenomenon was attributed to three explanatory factors (Blondin et al., 2014) related to (i) food (palatability and accessibility), (ii) children (taste preferences and satiation) and (iii) organization of the service (lunch duration, foodservice policies and coordination). Another potential factor related to the foodservice management is overproduction, as excessive serving sizes might cause an increase of food waste (Byker et al., 2014; Painter et al., 2016; Steen et al., 2018). The potential reasons for plate waste identified by Martins et al. (2015) were related to children’s preferences and dissatisfaction with the sensory characteristics of the meal and to a high level of noise at the canteen, with potential impact on the students’ dietary intake. Many authors highlighted also the importance of the ambience of the dining hall, namely the lack of time to eat and the pressure on children to finish their meals (Engstrom and Carlsson-Kanyama, 2004; Betz et al., 2015; Silvennoinen et al., 2015; Wilkie et al., 2015). Cohen et al. (2016) found an association between lunch duration and plate waste and suggested that policies enabling students to have at least 25 minutes of seated time might lead to improvements in children’s dietary intakes. Another relevant aspect is the timing of lunch recess: some studies noted that when recess is scheduled before lunch, students consume significantly more food (Getlinger et al., 1996; Bergman et al., 2004). A possible explanation is that scheduling the recess after lunch might increase the risk for children to eat quickly their meals for the desire to go out and socialize. However, early studies yielded conflicting results and the research on this topic remains limited (Hunsberger et al., 2014). In a study conducted by Marlette et al. (2005), higher levels of food waste were found among the participants buying food from the vending machines, suggesting that competitive food items might affect the level of hunger during lunchtime. In recent years, two studies conducted in the Swedish foodservice sector also analysed the role of kitchens in determining food waste quantities and found that schools receiving food from satellite kitchens produced higher levels of food waste compared to those preparing all food by themselves (Eriksson et al., 2017; Steen et al., 2018). Another parameter that might have an influence on the amount of food waste generated in educational establishments is children’s age. According to Cordingley et al. (2011), children attending primary school produced higher amounts of plate waste than children in secondary school, whereas Niaki et al., (2017) found that students attending pre-school had significantly higher food waste than children in subsequent school years. The lack of awareness on the environmental and socio-economic implications of food waste among students has also been suggested as a potential cause (Whitehair et al., 2013; Painter et al., 2016). The location of the

school was also analysed in the literature as a potential factor of food waste, but findings were inconclusive. Buzby and Guthrie (2002) found no difference in the percentage of calories wasted by students of schools with different location, whereas another study found a decreased food consumption across children from school located in rural areas with respect to students enrolled in urban schools (Turner and Chaloupka, 2014).

Most of the mentioned studies tackled the factors influencing plate waste in the school foodservice, whereas the causes potentially related to the quantities of surplus servings were much less investigated. According to Falasconi et al. (2015), the non-served food can be caused by the need to ensure any request for additional portions and to facilitate the portioning activity. Other possible causes identified by Cordingley et al. (2018) were the need to ensure a second option to all the diners, the possibility for children to refuse entirely one of the meal courses and the lack of on ordering systems that allows the kitchens to know the exact number of students eating at school.

Within this framework, the aim of the present study is to analyse the causes of all the food remaining uneaten at the end of the lunch (plate waste and non-served food). The set of quantitative data was collected from 78 Italian primary schools monitored for a period of two weeks, for a total of almost 110,000 monitored meals.

2. Materials and methods

2.1 Study design

A sample of schools was recruited during the 2016/2017 school year from three Italian regions: Emilia-Romagna, Lazio and Friuli-Venezia Giulia. The total reference population counted 2,013 schools, that were all sent an e-mail by the Regional School Office containing general information about the study. Within this email, schools were asked to fill-in an online questionnaire focused on the features of the school itself (e.g. number of students enrolled, kitchen location, etc.) and the type of foodservice provided to pupils (daily or not, foodservice company, location of the kitchen, etc.), whose answers are not included in this study. The questionnaire ended with a specific request to take part to the study. Out of the 173 schools that answered the questionnaire and agreed to participate in the study across the three regions, a stratified sampling strategy was applied, according to the following criteria:

1. School size, measured as the number of students on roll;
2. School location (urban vs rural area), measured as the degree of urbanization of the municipality, according with the Eurostat definition (Istat, 2016);
3. Kitchen location (internal vs external to school facilities);
4. Catering provider (public service vs private company).

The final sample included 78 primary schools spread across the three Italian regions considered: 35 in Emilia-Romagna, 25 in Lazio e 18 in Friuli-Venezia Giulia (Table 1).

Table 1. Number of schools and participants involved, number of monitored meals and observations collected.

	Emilia-Romagna	Lazio	Friuli-Venezia Giulia	Total
Schools	35	25	18	78
Observations (school days)	327	243	170	740

A formal request of participation was sent to the Municipal School Office of each school of the sample and to the catering providers in case the foodservice was procured by private companies. The monitoring phase covered a period of two weeks (10 school days): one week of the winter menu and one week of the spring menu, to assess as many meal variations as possible.

For the sake of the statistical analysis, data were aggregated by school. The database used for the elaborations consisted of 740 observations: 10 observations for each school of the sample, with the exception of 4 schools that provided complete data only for one week (5 observations each).

2.2 Methodology design

The methodology applied for measuring food waste in school canteens closely follows a previous study (Boschini et al., 2018). The assessment of food waste was based on a direct measurement conducted in the kitchens and at schools during lunchtime. The process of data collection included the weighing of: (i) prepared food; (ii) plate waste, which is the food rejected by the diners after they got their servings, and left on their plates; (iii) intact food, which included the non-served food (i.e. surplus servings not served to diners) and other food items entirely rejected by diners (i.e. portions of bread and fruit not collected by students from the serving trays).

The food served in the Italian school foodservice consists of three main courses (i.e. a first course composed of a carbohydrate-rich component, a second course mainly based on a protein-rich component and a side dish of vegetables), a portion of bread and a portion of fruit, occasionally replaced by a dessert (e.g. cake, yoghurt or ice-cream), and the foodservice staff are instructed to provide children with a different amount of food depending on their age.

The quantities of prepared food, plate waste and intact food were weighed with an electronic scale and measured separately for each meal course. The data gathered referred to all the students dining at each school, with no distinction among students of different age and gender. This quantification allowed to calculate, for each meal course and for each school involved in the study, the amount of a) served food, given by the difference between prepared food and intact food; b) non-consumed food, which is the sum of plate waste and intact food (i.e. the share of prepared food that is not eaten by diners at lunch); c) consumed food, given by the difference between the quantity of food prepared for lunch and the non-consumed food fraction.

2.3 Procedure of data collection and materials

The data collection involved foodservice staff, teachers and students, along a three-steps process (Boschini et al., 2018):

1. the foodservice staff weighed the prepared food and data were daily recorded in a "kitchen diary";
2. after the diners had completed their meal, the food left in their plates was collected in five separated bins, one for each course (as explained below), by the students themselves;
3. at the end of lunchtime, the plate waste contained in the bins as well as the intact food were weighed by a class of students with their teacher and the related data was recorded in a "school diary".

At the end of the quantification procedure, the non-consumed food was disposed of as usual, either through separate organic waste collection or as unsorted waste, with the only exception of the intact portions of bread and fruit, which were frequently taken into classrooms and consumed by the pupils during the afternoon break.

The schools were provided with all the materials required, including plastic bins for the separate food waste collection, drawings to be attached on the bins to help students in the proper separation of the plate waste of different courses, trash bags, an electronic scale and two weekly diaries where the data recorded could be noted (a "kitchen diary", to be compiled by the kitchen staff, and a "school diary" to be filled in by students and teachers in the dining rooms). Teachers and foodservice staff were briefed on the quantification procedures before the study period, and they were provided with paper handbooks with detailed instructions.

In order to avoid bias linked to possible changes in students' food consumption during the period of data collection, only teachers and foodservice staff were fully informed of the real reasons of the experiment. They were instructed to answer in general terms to students inquiring about the procedures of waste separation and weighting.

2.4 Statistical analysis

The factors affecting the quantity of food remaining uneaten at the end of the lunch were analyzed with reference to two different variables:

- diners' leftovers (model A), which represent all the food that is rejected by diners;

- non-served food (model B), that refers to the surplus food not served to diners.

In this study, the variable "non-served food" refers to the surplus portions of the three main courses only, as it was not possible to distinguish surplus food from food rejected by diners for the portions of bread and fruit (see Figure 1). This is due to the fact that in the Italian school foodservice, the serving trays for bread and fruit are directly placed on the dining tables and the diners are free to decide whether to take them or not. As a consequence, the amount of bread and fruit rejected by diners (i.e. diners' leftovers) can either be thrown in the trash bins (portions partially eaten) or remain in the serving trays (portions entirely uneaten), making it impossible to distinguish whether the portions remaining in the serving trays are surplus servings or portions rejected by the diners. The amount of bread and fruit remaining unconsumed (i.e. intact food) was entirely computed among the diners' leftovers, as it can be reasonably assumed that the main part of these food quantities are portions rejected by diners, whereas only a limited fraction could be attributed to overproduction. To this respect, it should be noted that the intact portions of bread and fruit are frequently taken into classrooms by teachers, to be redistributed to the pupils during the afternoon break. Although these food quantities cannot by definition be considered as waste, they were equally included in the diners' leftovers, as the aim of this study was to investigate the reasons why part of the food prepared for lunch was not consumed, regardless its final destination.

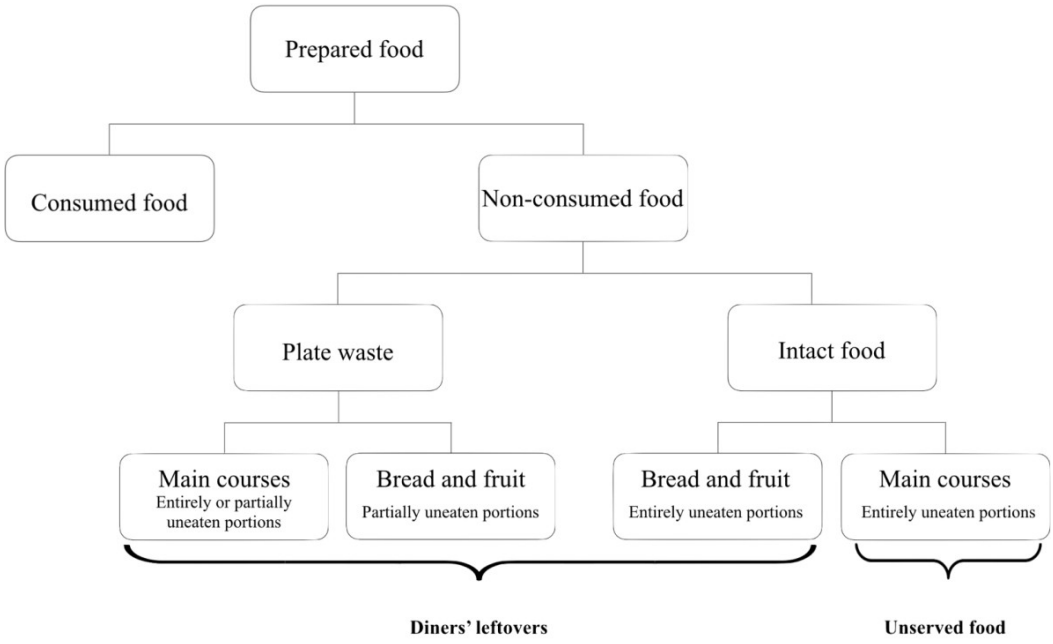

Fig. 1. Overview of the food stream. In bold, the dependent variables selected for the statistical analyses.

The aim of the present study was to analyse the main causes of food remaining uneaten at the end of the lunch. Before performing the statistical analysis, the unavoidable food fractions were subtracted from the total amount of non-consumed food, as the presence of non-edible parts (e.g. chicken bones) clearly does not depend on the attitude of the diners. The extended explanation of the process performed for subtracting the non-edible parts from the total weight of non-consumed food was deeply described in a previous study focusing on the methodology adopted for the data gathering (Boschini et al., 2018).

The causes of diners' leftovers and non-served food were analysed separately against a set of factors which were first selected according to the existent literature on the causes of food waste in foodservice and then integrated according to further hypothesis formulated by the authors. In case of variables whose measure was not available, proxy variables were used. The full list of the variables and corresponding assumptions considered on the possible relationship with the amount of non-consumed food are reported in Table 2.

Table 2. List of selected variables and corresponding hypotheses for model A and B.

Factor	Description of the variable	Possible relation with diners' leftovers (model A)	Possible relation with non-served food (model B)
Geographical area	Qualitative variable: Emilia-Romagna, Lazio and Friuli-Venezia Giulia.	Regional school meal policies and dietary guidelines or other behavioural differences across the regions may influence the diners' food consumption.	Regional school meal policies and dietary guidelines may affect the amount of food remaining in the serving trays.
School location	Qualitative variable: rural or urban.	Diners of schools located in rural and urban contexts may show different food consumption patterns.	-
Kitchen location	Qualitative variable: internal or external to school facilities.	The kitchen location might influence the time occurring between food preparation and lunchtime.	The location of the kitchen may affect the amount of food remaining in the serving trays because of a different capacity in foreseeing the right amount of food to be prepared.
Foodservice providers	Qualitative variable with 19 possible values corresponding to the different food catering companies involved (A, B, C, D, etc.).	Quality of ingredients, recipes, food presentation and organization of the catering service may influence diners' food consumption.	Different food catering providers may apply different policies regarding overproduction, influencing the amount of food remaining in the serving trays.
Mid-morning snack provider	Qualitative variable with 2 possible values: foodservice provider or families.	The amount of food consumed during the mid-morning recess may affect the level of hunger and the quantity of food consumed by diners at lunchtime. In general, foodservice providers have to provide snacks with a limited amount of caloric content, whereas families are free to provide their children the food they want.	-
Prepared food	Quantitative variable: total amount of prepared food (g).	-	The amount of food prepared by the kitchen staff may affect the amount of food remaining in the serving trays.
School size	Quantitative variable: number of students on roll.	-	The size of the schools may influence the amount of food remaining in the serving trays, due to possible scale effects.
Serving size	Quantitative variable: quantity of food served per diner (g), calculated as follows: for the three main courses, quantity of food prepared minus quantity of intact food; for bread and fruit portions, the quantity of served food corresponded to the quantity of prepared food, as previously described in this section.	The amount of food served to each diner may influence the amount of food rejected.	-
Crowdedness	Quantitative variable: number of students dining together in the same room, calculated as follows: number of students on roll divided by the number of dining rooms, divided again by the number of lunch shifts.	The crowdedness of the dining environment might influence the quantity of food consumed by diners. As it was not possible to directly measure the level of noise in each school, the number of diners eating at the same time was used as a proxy.	-
Seasonal menus	Qualitative variable: summer or winter.	The seasonal variation of menus may affect the diners' meal	The seasonal variation of menus may affect the food remaining in the

		acceptance.	serving trays.
Type of first course	Qualitative variable with 12 possible values: first course with tomato sauce, meat, fish, cheese, vegetables, legumes, pesto sauce, oil, meat stock, pizza, soup with vegetables or dish not-served.	The type of first course may affect the diners' meal acceptance.	The type of first course may affect the amount of food sent in excess by the kitchen staff.
Type of second course	Qualitative variable with 9 possible values: white meat, red meat, fish, egg cheese, legumes, charcuterie, pizza*, dish not-served.	The type of second course may affect the diners' meal acceptance.	The type of second course may affect the amount of food sent in excess by the kitchen staff.
Type of side dish	Qualitative variable with 14 possible values: chard, carrot, cucumber, green bean, fennel, lettuce, potato, peas, tomato, spinach, courgettes, mixed vegetables, vegetables with vinaigrette, dish not-served.	The type of vegetables may affect the diners' meal acceptance.	The type vegetables may affect the amount of food sent in excess by the kitchen staff.
Type of fruit	Qualitative variable with 9 possible values: orange, banana, mixed fruits (e.g. apple and banana), kiwi, apple, pear, other fruit rarely served (e.g. pineapple, melon, strawberries), dessert, dish not-served.	The type of fruit may affect the diners' meal acceptance.	-

* Although pizza is generally considered as a first course, in the school foodservice it is occasionally served as second course, following a soup with vegetables provided as first course.

The relation between the amount of food wasted at school canteens (diners' leftovers - model A and non-served food - model B) and its potential determinants was tested through bivariate and multivariate models.

The analyses of the effect of the variables on diners' leftovers and on non-served food were performed through the Spearman's rank correlation, whereas non-parametric tests (Kruskal-Wallis test and Mann-Whitney test) were adopted for qualitative variables, as the dependent variables (leftovers' diners and non-served food) were not distributed normally. These tests allow checking whether a relation exists between the two variables under analysis and each of the factors selected, and they show the type of relation possibly occurring among them.

For the multivariate analyses, random forest models were used to test the relative importance of the set of factors in determining the quantity of diners' leftovers and non-served food. Random forest models were chosen because they are suitable for managing non-linear correlations, and allow considering a high number of qualitative variables among the independent variables (Breiman, 2011). The random forest models were applied with an explorative purpose (Jones and Linder, 2015), by setting two different models (one to analyse the factors affecting the quantity of diners' leftovers - model A - and one for the non-served food - model B) where the dependent variables were analysed against all the factors together. The algorithm used was the *conditional inference forest*, that is based on regression trees, which do not require a simplification process to avoid overfitting issues and enable to provide an undistorted estimation of the importance assumed by each variable analysed (Hothorn et al., 2006, Strobl et al., 2007). The statistical analyses were performed by R software (The R Foundation, 2017).

3. Results

The present study involved 11,518 participants (93.2% students and 6.8% school staff and foodservice personnel), corresponding to 109,656 monitored meals. In total, 60.8 tons of prepared

food was monitored and an average of almost 160 g/day per capita remained unconsumed at the end of the lunch.

3.1 Results from the bivariate statistical analysis

The model A analysed the variables potentially related to the diners' leftovers. The results showed a high statistical significance for the geographical area, the kitchen location, the type of food provider, the seasonal variation of menus and the type of first course, second course and fruit served (see Table 3). The test showed a weak significance for the school location and the type of side dish served, whereas the crowdedness of the dining environment did not show a significant effect on the quantity of diners' leftovers.

Tab. 3. Statistical tests for relationships between diners' leftovers and variables selected in model A.

Variable	Test	Statistics	df	p-value	Significance
Geographical area	Kruskal-Wallis	70.40	2	<0.0001	***
School location	Mann-Whitney	68785.00	-	0.0135	*
Kitchen location	Mann-Whitney[a]	87497.00	-	<0.0001	***
Foodservice providers	Kruskal-Wallis	268.19	15	<0.0001	***
Mid-morning snack provider	Mann-Whitney[a]	32371	-	<0.0001	***
Serving size	Spearman$_a$	0.42	-	<0.0001	***
Crowdedness	Spearman[a]	0.01	-	0.4145	
Seasonal menus	Mann-Whitney	45853.00	-	<0.0001	***
Type of first course	Kruskal-Wallis	38.19	10	<0.0001	***
Type of second course	Kruskal-Wallis	27.57	7	<0.0001	***
Type of side dish	Kruskal-Wallis	24.71	12	0.0163	*
Type of fruit	Kruskal-Wallis	175.20	8	<0.0001	***

[a] One tailed test. *significant for $\alpha<0.05$; **significant for $\alpha<0.01$; ***significant for $\alpha<0.0001$

Higher amounts of diners' leftovers were found in Emilia-Romagna (Mdn = 163 g) and Lazio (Mdn = 130 g) than in Friuli-Venezia Giulia (Mdn = 91 g), in schools located in rural areas (Mdn = 149 g) than in urban schools (Mdn = 131 g) and in schools served by external kitchens (Mdn = 161 g) than in schools with internal kitchens (Mdn = 103 g). The food provider was highly correlated with the amount of diners' leftovers: the maximum amount was reported in the school served by company I (Mdn = 38 g) and the minimum amount in the school served by the company K (Mdn = 204 g). Higher quantities of diners' leftovers were also found in schools where the mid-morning snack was provided by the families (Mdn = 170 g) rather than by the food providers (Mdn = 99 g) and when the winter menus were served to diners (Mdn = 153 g), whilst lower quantities were reported for the summer menus (Mdn = 128 g). The Spearman's correlation between food served and diners' leftovers food was positive, showing that the amount of leftovers increased as the number of students did. With respect to the type of meal course, the results showed that the less appreciated dishes were first course with legumes (Mdn = 185 g) and soup with vegetables (Mdn = 165 g) for the first courses, pizza (Mdn = 187 g) and legumes (Mdn = 178 g) for the second courses and green beans (Mdn = 167 g) and peas (Mdn = 161 g) for the side dishes. Lowest amounts of diners' leftovers were reported for first course with meat (Mdn = 117 g) and first course with pesto sauce (Mdn = 119 g), processed meat (Mdn = g) and red meat (Mdn = g) for the second courses and cucumbers (Mdn = 72 g) and zucchini (Mdn = 115 g) for the side dishes. Lastly, the less appreciated fruits were pear (Mdn = 185 g) and orange (Mdn = 172 g), whereas the most consumed ones were kiwi (Mdn = 145 g) and bananas (Mdn = 148 g), exception made for desserts (Mdn = 108 g).

The model B analysed the variables potentially related to the generation of non-served food for the three main courses (see Table 4). The results showed a high statistical significance for the

geographical area, the kitchen location, the foodservice providers, the amount of food prepared, the school size and the type of side dish served, while no relation emerged with respect to the type of first and second course

Table 4. Statistical tests for relationships between non-served food and variables selected in model B.

Variable	Test	Statistics	df	p-value	Significance
Geographical area	Kruskal-Wallis	165.29	2	<0.0001	***
Kitchen location[a]	Mann-Whitney[a]	87107.00	-	<0.0001	***
Foodservice providers	Kruskal-Wallis	179.57	15	<0.0001	***
Prepared food[a]	Spearman[a]	0.11	-	0.0024	**
School size	Spearman	-0.23	-	<0.0001	***
Type of first course	Kruskal-Wallis	13.73	10	0.1857	
Type of second course	Kruskal-Wallis	7.68	7	0.3617	
Type of side dish	Kruskal-Wallis	29.26	12	0.0036	**

[a] One tailed test.

Higher quantities of non-served food were found in Emilia-Romagna (Mdn = 16,3 g) and in Friuli-Venezia Giulia (Mdn = 4 g) than in Lazio (Mdn = 0 g) and in schools served by external kitchens (Mdn = 12 g) rather than schools with internal kitchens (Mdn = 0 g). The maximum amount of non-served food was generated by the food provider G (Mdn = 29 g), whereas the minimum quantities were registered for the food providers D, E, J, L, N (Mdn = 0 g). The Spearman's correlation between food prepared and non-served food was positive, whereas it resulted to be negative between non-served food and school size, showing that the amount of surplus food decreased as the number of students increased. Among the meal courses, only the side dishes showed a significant relation with the quantity of non-served food: higher amounts of non-served food were produced by vegetables with vinaigrette (Mdn = 27 g) and cucumbers (Mdn = 21 g), whereas lower amounts were produced by fennels and zucchini (Mdn = 0 g).

3.2 Results from the multivariate statistical analysis

The first model analysed the diners' leftovers against a set of potential causes, showing a good fit in explaining the statistical variance observed (R-squared = 0.7455). The most relevant factor influencing the amount of food rejected by the diners was the foodservice providers (see Figure 2). Other relevant determinants were the serving size, the type of fruit, the mid-morning snack provider, the kitchen location and the school location.

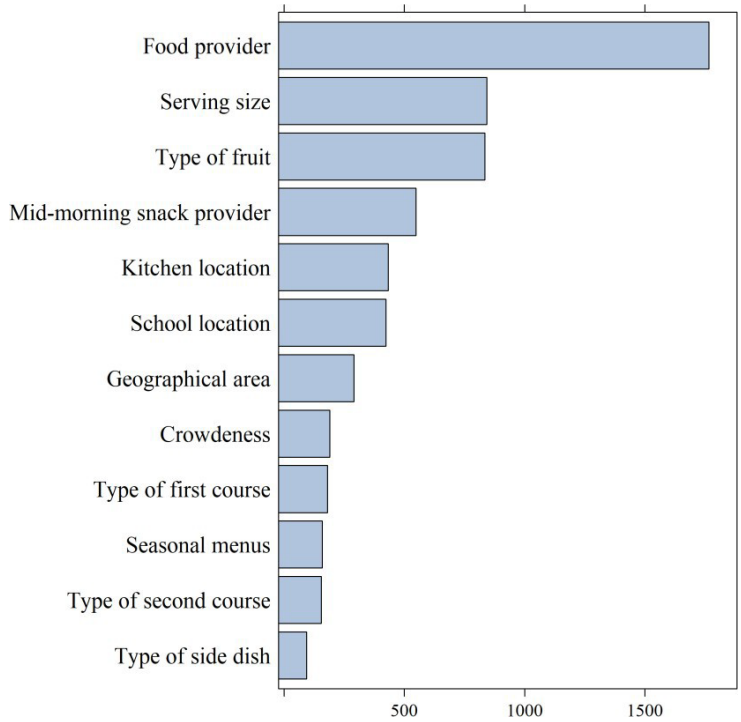

Fig. 2. Random forest variable importance plot for model A.

Considering the foodservice providers, relevant differences emerged across the various catering companies, characterized by higher amounts of diners' leftovers for the foodservice providers B, K, O, G, and quantities significantly below the average for the foodservice providers M, D, I and L (see Figure 3).

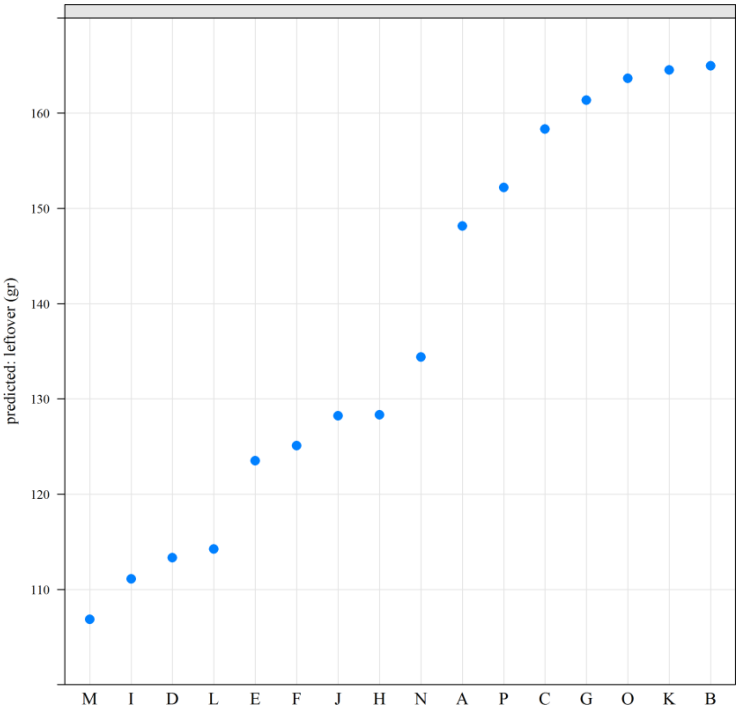

Fig. 3. Partial dependence of diners' leftovers on foodservice providers

The results showed as the relationship between the serving size and the diners' leftovers was not linear, but characterized by a logistic growth and by the presence of a "step" for quantities of prepared food exceeding 370 g/day per capita (see Figure 4).

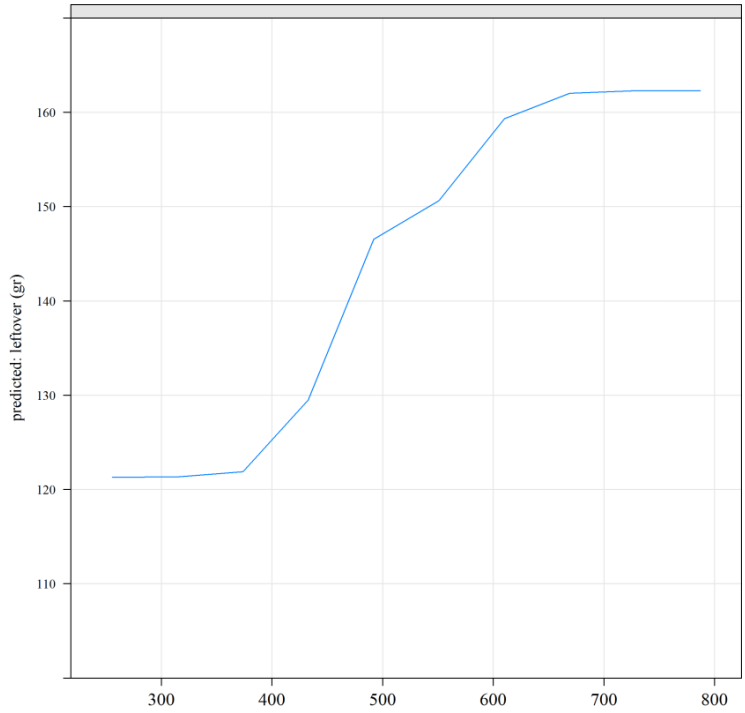

Fig. 4. Partial dependence of diners' leftovers on serving size.

Except for the cases in which a fruit was not served at lunchtime, significant lower levels of diners' leftovers were found when a dessert replaced a fruit (see Figure 6). Moreover, diners rejected less food when banana, fruits served only occasionally or a combination of two fruits were proposed.

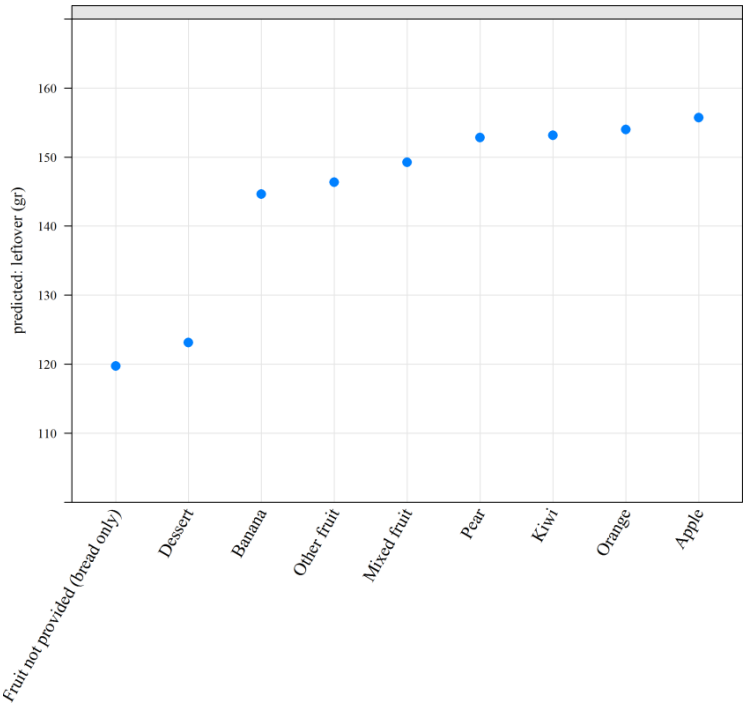

Fig. 5. Partial dependence of diners' leftovers on type of fruit.

The second model analysed the amount of non-served food for the three main courses and showed a reasonable good fit in explaining the statistical variance observed (R-squared = 0.5480). In this case, the factors with the greatest influence on the dependent variable was the geographical area, followed by the amount of prepared food, the foodservice providers, the school size, the type of first course and the kitchen location (see Figure 6).

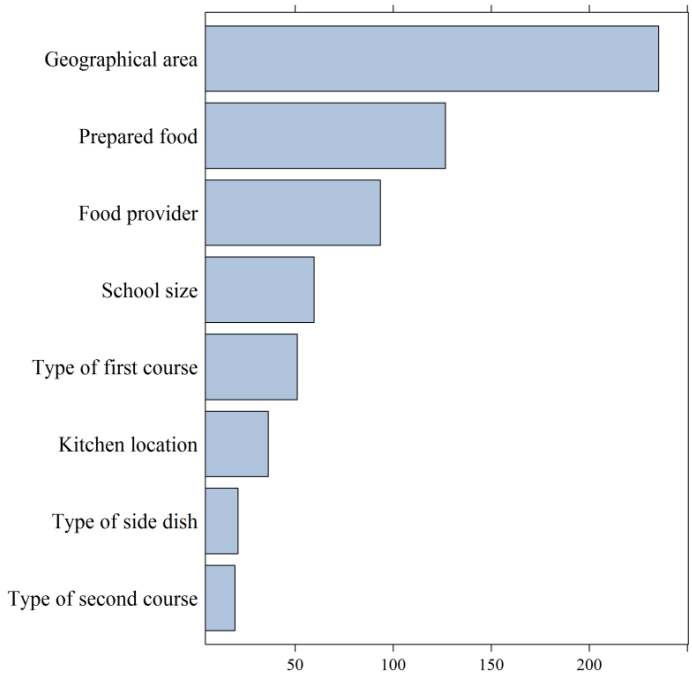

Fig. 6. Random forest variable importance plot for model B.

The generation of non-served food, for equal quantities of prepared food, was substantially different among the three regions. In particular, the results showed higher amounts of non-served food in Emilia-Romagna than in the other two regions (see Figure 7).

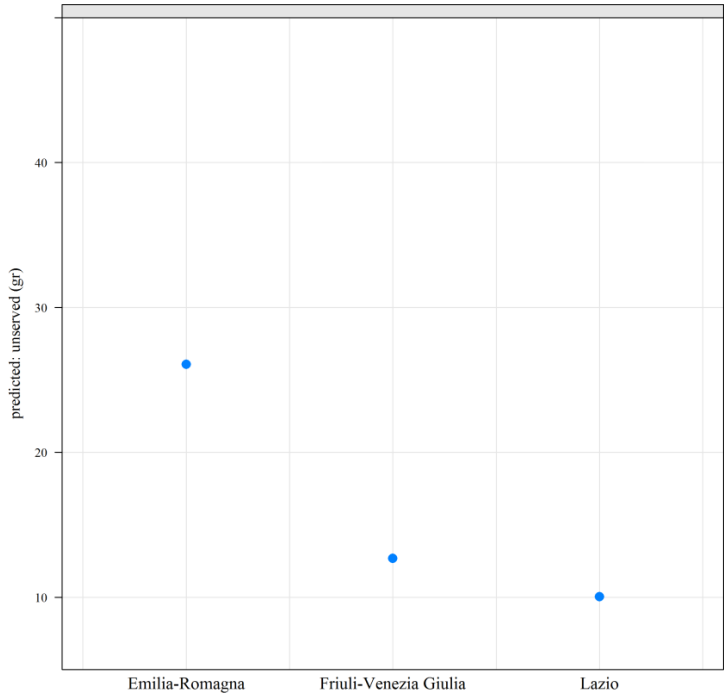

Fig. 7. Partial dependence of non-served food on Region.

The results showed also that when the amount of food prepared exceeded 300 g/day per capita, the quantity of non-served food increased more in Emilia-Romagna than in Friuli-Venezia Giulia and Lazio (see Figure 8).

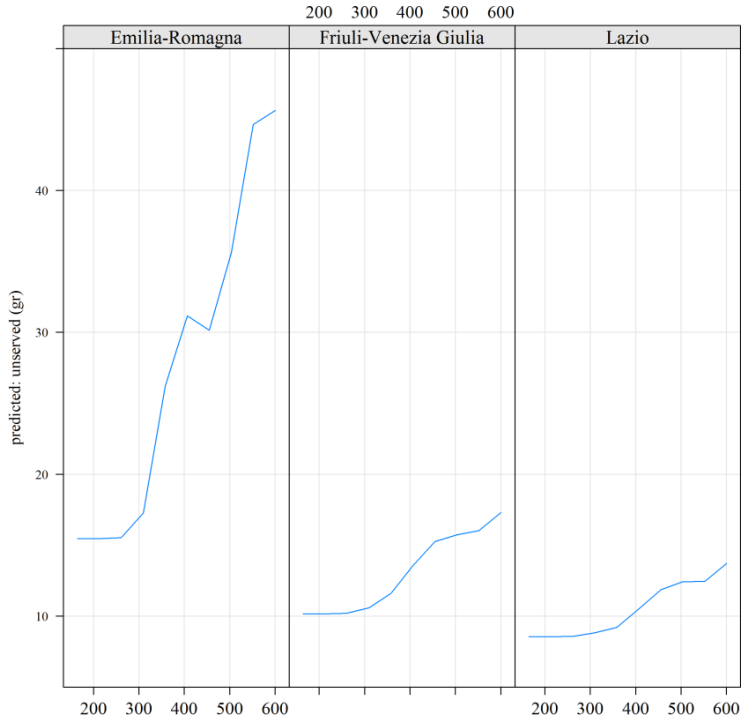

Fig. 8. Partial dependence of non-served food on Region and prepared food.

4. Discussion

The large-scale sample and the method used for the data collection process based on a direct measurement of food waste ensured a high accuracy and reliability of data for the variables considered. The assumed influence of the factors on the dependent variables (see Table 2) was confirmed in most cases, showing that many of the selected factors had a role in influencing the amount of both diners' leftovers and non-served food generated in primary school canteens.

The bivariate analyses performed for the diners' leftovers showed a statistical significance for almost all the variables considered. The role of serving sizes and the location of kitchens confirmed the findings of previous studies, where higher serving sizes and external kitchens were correlated to higher levels of food waste in school canteens (Byker et al., 2014; Painter et al., 2016, Eriksson et al, 2017; Steen et al., 2018). The increase of diners' leftovers in those schools where the provision of the mid-morning snack was in charge of the families supported the evidence found by Marlette et al. (2005), and pushes the debate over the need to extend the nutritional standards required for meals to the rest of food consumed by children at school. Other variables that showed a high statistical significance in reference to the amount of diners' leftovers were the geographical area, the foodservice provider and the seasonal variation of menus. A possible explanation of the higher amounts of diners' leftovers during the winter menus could be that, in that season, soup with vegetables are more frequently served rather than pasta or rice as first courses. Another possible explanation for the higher appreciation of summer menus could be that, being them served for a limited period of time, children get less tired of the meals.

Indeed, the type of meal courses also emerged as significant factors in influencing the amount of diners' leftovers, as they are related to the quality of the meal offered (ingredients, recipes and food presentation) and children's preferences. The weak statistical significance between the amount of

diners' leftovers and the type of vegetables served could be due to an "a priori" lower level of appreciation of this food category by the children, whose consumption seems to be less influenced by the single food item served. A weak but significant relation was also found between diners' leftovers and school location, with an increased amount of non-consumed food in schools located in rural areas, as previously found by Turner and Chaloupka (2014). The crowdedness resulted the only variable that didn't show any statistical significance, despite several studies suggested that a calm ambiance in the dining hall reduces food waste (Byker et al., 2014; Kinasz et al., 2015; Painter et al., 2016; Steen et al., 2018). A possible explanation is that the number of students on roll at school may not be a good proxy for the level of crowdedness. This can be considered a limitation of the study, as the level of noise or crowdedness of the dining rooms was not directly measured.

The analyses on the non-served food, whose potential causes were much less explored in the existing literature, showed a statistical significance for the majority of the variables considered.

Among these variables, the kitchen location has proved to impact the amount of non-served food. A possible explanation of the higher amount of surplus servings produced by the external providers could be that they produce more food in order to be able to compensate any accidental losses which might occur during the transportation phase. The meal courses provided in the menus were partially significant, as only the type of side dish emerged as a factor correlated to the quantity of non-served food. This is somehow difficult to explain, as it was expected that the type of food provided to diners may affect the amount of food produced in excess by the kitchen, regardless the course. It may be the case that, while for the first and second courses the preferences of the diners vary individually, so as about the same quantity is refused in each school every day, for side dishes the preferences are much more prevalent among the children, making some side dishes very well accepted by the diners (e.g. potatoes or carrots) and others frequently refused by the majority (e.g. chards or spinaches).

The multivariate analysis performed for the model A showed the predominant role of the foodservice providers, the serving size and the type of fruit in determining the amount of leftovers. Considering the different variables related to menu composition, the type of fruit was the factor more significantly related to the generation of diners' leftovers. A possible explanation of this result could be that the fruit is consumed at the end of the lunch, when the level of hunger is lower and the type of fruit proposed might become more important in determining its level of appreciation by the diners. This is confirmed by Figure 3, which showed how the amount of diners' leftovers is lower when the fruit is replaced by a dessert.

The second model aimed at analysing the potential effects of different factors in determining the amount of non-served food for three main courses and showed a statistical significance for almost all the variables considered. The multivariate analyses performed for the second model showed the predominant role of the geographical area in determining the quantity of non-served food. This may be due to the local policies in terms of amount of surplus servings provided to schools by the catering providers, that is likely to be influenced by the contracts they have with municipalities. As already emerged from the bivariate analysis, the amount of food prepared seemed to have a wider effect in determining the amount of non-served food rather than the menu composition, confirming that tailoring portions on the real needs of the diners is crucial to avoid the generation of food waste in school catering (Byker et al., 2014; Painter et al., 2016). The relationship between school size and the amount of non-served food confirmed the findings of Cordingley et al. (2011), where more waste was detected in large schools with respect to schools with less students enrolled. Kitchen location was also significant in determining the amount of non-served food, suggesting that promoting internal kitchens may have a positive effect not only on the quantity of plate waste (Eriksson et al., 2017), but also in reducing overproduction. However, other factors such as school size seemed to have a greater effect on the quantity of non-served food than the location of the kitchen.

The study presents also some limitations. The food distribution system for bread and fruit within the Italian school foodservice did not permit to analyze separately the intact portions remaining on the

serving trays both in terms of diners' leftovers and non-served food. Some of the factors potentially related to food waste (i.e. lunch duration, timing of recess, diners' awareness of food waste as an issue and children's age and gender) could not be considered as potential factors affecting food waste, due to methodological constraints that did not allow the collection of information to this regard. Moreover, as in Italian schools' foodservice pupils cannot choose what to eat, it was not possible to study how competitive food items could affect the amount of food waste. Although plate waste could be reduced when different food options are offered to pupils (Buzby and Guthrie, 2002), it is likely that more non-served food is generated, as the availability of a second option may increase the level of overproduction. At the same time, the opportunity for the children to choose daily the same favorite foods (e.g. the same vegetables) may discourage them from tasting new food items, reducing their diet diversity and the educational purpose of school meals. The role of competitive foods in influencing the level of plate waste was analyzed with reference to the provider of the snack for the mid-morning break, as in Italian primary schools students have not access to vending machines.

5. Conclusions

Food losses and waste are a main challenge for the sustainability of food systems and entail significant negative consequences on the environment and the socio-economic system. The present article was focused on school canteens, with the aim to analyse the main causes of food rejected by the children or prepared in excess by the school foodservice. Results from over 100,00 monitored meals identified several factors significantly related to the generation of diners' leftovers and non- served food. The use of random forest models in the multivariate analyses, which allowed to highlight the relative importance of different variables in determining the quantity of non-consumed food at school canteens, showed that the foodservice provider was the most significant factor in influencing the amount of diners' leftovers, confirming that more effort should be put by municipalities to recall the companies in charge of the service on a greater attention on the quality of the meals offered. Other factors that significantly affected the amount of diner's leftovers were the serving size, especially when the amount of food served exceeded 370 g/die per capita, and the composition of the menus, highlighting the importance to reduce the gap between nutritional requirements and children preferences. The results showed also that diners' leftovers increased when children were free to consume snacks without a limited amount of caloric content during mid- morning break, as in the case when food is provided by their families. Moreover, the diners refused higher amounts of food when the kitchens were external to the school premises. This seems in contrast with the current commitment for economic efficiency in public catering services in Italy, which is leading to an increased externalization of the service. Moreover, the phenomenon of food waste in school canteens seemed also to have seasonal and geographical traits, as the level of food consumption was lower during the spring menu and varied across regions. The amount of non- served food showed clear geographical traits, whose underpinning causes have to be explored further.

The present study showed different causes of food waste in school canteens, which call for multiple potential interventions to reduce it. The simplest measures could be regulating the supply of mid-morning snacks, which might be included in the food catering provision; forbidding to throw out the intact portions of bread and fruit, which might be redistributed to the pupils before leaving the school; and introducing an ordering system for school meals, which might contribute to avoid the risk of overproduction by leading the food providers to know the exact number of students eating at school every day. The most complex measures could include the provision of meals in accordance with children's preferences, thus proposing menu elaborated in a more palatable way; monitoring on a regular basis the quantity of food waste generated at school canteens, and promoting the meal preparation from kitchens located within the schools. When developing environmental policies to reduce food waste in the school catering sector, it should be also considered that having lunch at

school has also an educative purpose and it provides a unique opportunity to promote the achievement of healthy and sustainable eating patterns.

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

Clara Cicatiello participated in conception and design and revised the manuscript.

Silvio Franco supported the conception and design of the study and revised the manuscript.

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

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