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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

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

52 The food waste generated in the school foodservice sector is attracting increasing attention both from
53 the academic literature and the public opinion. Studies tackling food waste generation in the
54 foodservice are increasing in number, but more research based on reliable data is required to better
55 understand the potential determinants of food waste in school canteens (Byker et al., 2014; Kinasz et
56 al., 2015). One of the first studies that analysed the causes of food waste at school canteens was
57 conducted by WRAP (Cordingley et al., 2011). Interviews with school and kitchen staff highlighted
58 three main categories of causes. First, operational issues related to catering provider policies and
59 organization of the foodservice at school, such as the absence of an ordering system for school meals,
60 lack of flexibility to adapt centrally planned menus to meet student’s preferences and excessive size
61 of portions with respect to children’s nutritional needs. Second, situational reasons not directly
62 connected to food, such as an unpleasant environment in the dining room, the short time available to
63 pupils to eat their lunch and practical difficulties with eating food that need be peeled, such as fruit.
64 Third, some behavioural reasons emerged, in connection with individual choices, e.g. lack of hungry
65 or limited appreciation of meal options. In another study that investigated stakeholders’ perceptions
66 on school food waste, the phenomenon was attributed to three explanatory factors (Blondin et al.,
67 2014) related to (i) food (palatability and accessibility), (ii) children (taste preferences and satiation)
68 and (iii) organization of the service (lunch duration, foodservice policies and coordination). Another
69 potential factor related to the foodservice management is overproduction, as excessive serving sizes
70 might cause an increase of food waste (Byker et al., 2014; Painter et al., 2016; Steen et al., 2018).
71 The potential reasons for plate waste identified by Martins et al. (2015) were related to children’s
72 preferences and dissatisfaction with the sensory characteristics of the meal and to a high level of noise
73 at the canteen, with potential impact on the students’ dietary intake. Many authors highlighted also
74 the importance of the ambience of the dining hall, namely the lack of time to eat and the pressure on
75 children to finish their meals (Engstrom and Carlsson-Kanyama, 2004; Betz et al., 2015; Silvennoinen
76 et al., 2015; Wilkie et al., 2015). Cohen et al. (2016) found an association between lunch duration
77 and plate waste and suggested that policies enabling students to have at least 25 minutes of seated
78 time might lead to improvements in children’s dietary intakes. Another relevant aspect is the timing
79 of lunch recess: some studies noted that when recess is scheduled before lunch, students consume
80 significantly more food (Getlinger et al., 1996; Bergman et al., 2004). A possible explanation is that
81 scheduling the recess after lunch might increase the risk for children to eat quickly their meals for the
82 desire to go out and socialize. However, early studies yielded conflicting results and the research on
83 this topic remains limited (Hunsberger et al., 2014). In a study conducted by Marlette et al. (2005),
84 higher levels of food waste were found among the participants buying food from the vending
85 machines, suggesting that competitive food items might affect the level of hunger during lunchtime.
86 In recent years, two studies conducted in the Swedish foodservice sector also analysed the role of
87 kitchens in determining food waste quantities and found that schools receiving food from satellite
88 kitchens produced higher levels of food waste compared to those preparing all food by themselves
89 (Eriksson et al., 2017; Steen et al., 2018). Another parameter that might have an influence on the
90 amount of food waste generated in educational establishments is children’s age. According to
91 Cordingley et al. (2011), children attending primary school produced higher amounts of plate waste
92 than children in secondary school, whereas Niaki et al., (2017) found that students attending pre-
93 school had significantly higher food waste than children in subsequent school years. The lack of
94 awareness on the environmental and socio-economic implications of food waste among students has
95 also been suggested as a potential cause (Whitehair et al., 2013; Painter et al., 2016). The location
96 of the

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

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

109 Within this framework, the aim of the present study is to analyse the causes of all the food remaining
110 uneaten at the end of the lunch (plate waste and non-served food). The set of quantitative data was
111 collected from 78 Italian primary schools monitored for a period of two weeks, for a total of almost
112 110,000 monitored meals.

113

114 **2. Materials and methods**

115 *2.1 Study design*

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

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

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

133

134 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

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

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

143

144 *2.2 Methodology design*

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

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

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

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166 *2.3 Procedure of data collection and materials*

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

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

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

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

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

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192 *2.4 Statistical analysis*

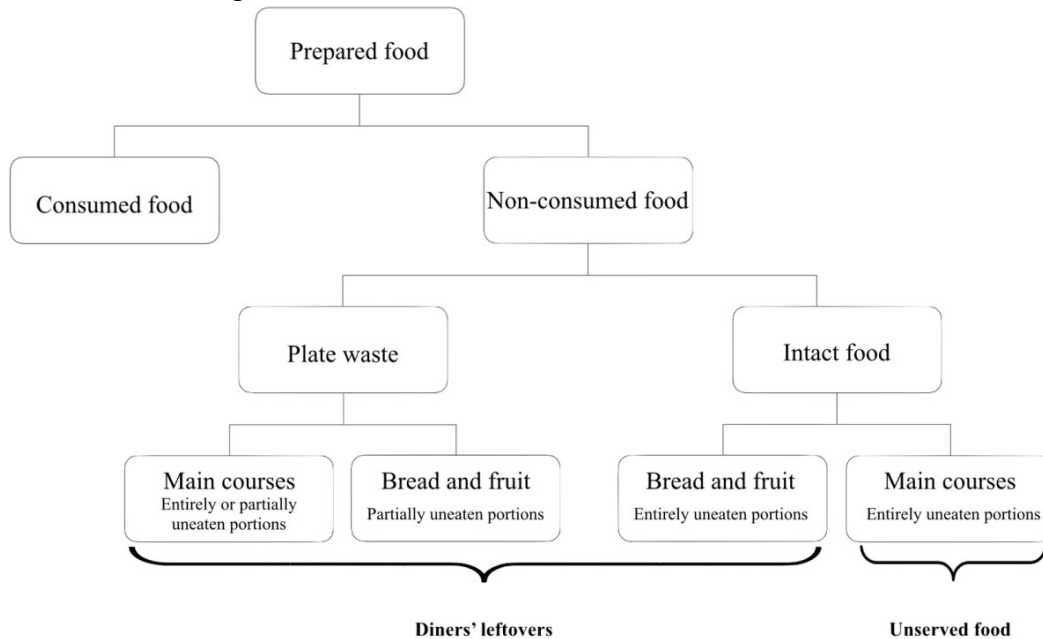
193 The factors affecting the quantity of food remaining uneaten at the end of the lunch were analyzed
194 with reference to two different variables:

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

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- 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.



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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.

229 Table 2. List of selected variables and corresponding hypotheses for model A and B.
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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 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 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 provider	Qualitative variable with possible values corresponding to the different food catering companies involved (A, B, C, D, etc.).	Quality of ingredients, recipes, 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 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.	
325	Type of first course	Qualitative variable with possible values: first course	360	The type of first course may affect the diners' meal acceptance.	375	The type of first course may affect the amount of food sent in excess by the kitchen staff.
326	341	tomato sauce, meat,	361		376	
327	342	cheese, vegetables, legumes,	362		377	
328	343	pesto sauce, oil, meat	363		378	
329	344	pizza, soup with vegetables or	364		379	
330	345	dish not-served.	365		380	
331	346		366		381	
332	Type of second course	Qualitative variable with possible values: white meat, fish, egg cheese, legumes, charcuterie, pizza*, dish not-served.	367	The type of second course may affect the diners' meal acceptance.	382	The type of second course may affect the amount of food sent in excess by the kitchen staff.
333	347		368		383	
334	348		369		384	
335	349		370		385	
336	350		371		386	
337	351		372		387	
338	Type of dish	Qualitative variable with possible values: chard, cucumber, green bean, lettuce, potato, peas, tomato, spinach, courgettes, mixed vegetables, vegetables with vinaigrette, dish not-served.	373	The type of vegetables may affect the diners' meal acceptance.	388	The type vegetables may affect the amount of food sent in excess by the kitchen staff.
339	352		374		389	
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392	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.	401	The type of fruit may affect the diners' meal acceptance.	-	
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* 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

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

434

435 *3.1 Results from the bivariate statistical analysis*

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

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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	***

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

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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

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

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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.

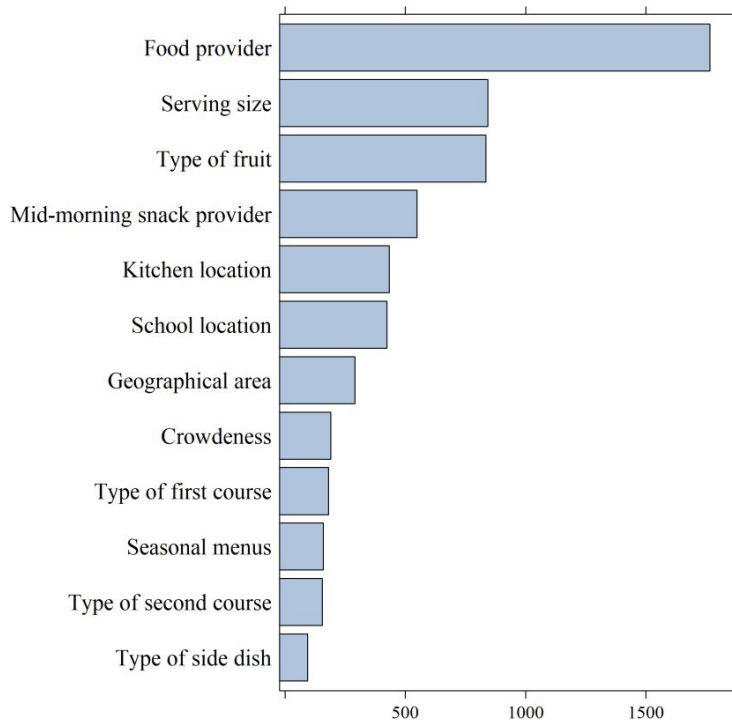
473

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

485

486 3.2 Results from the multivariate statistical analysis

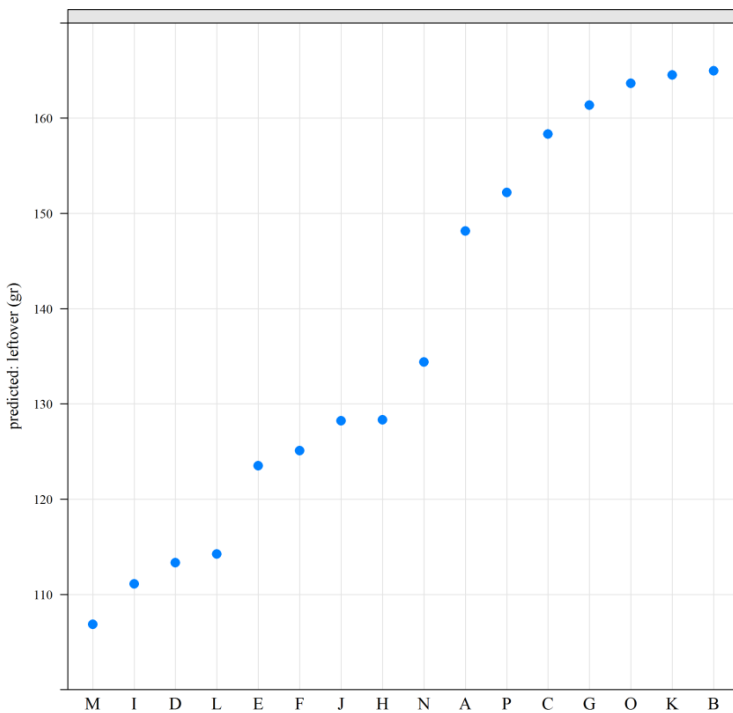
487 The first model analysed the diners' leftovers against a set of potential causes, showing a good fit in
 488 explaining the statistical variance observed (R-squared = 0.7455). The most relevant factor
 489 influencing the amount of food rejected by the diners was the foodservice providers (see Figure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



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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).

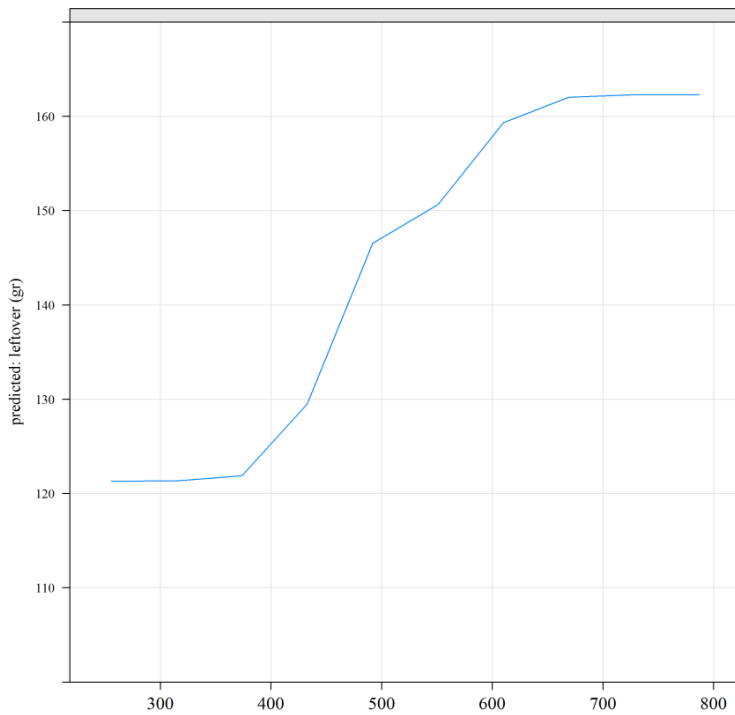


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Fig. 3. Partial dependence of diners' leftovers on foodservice providers

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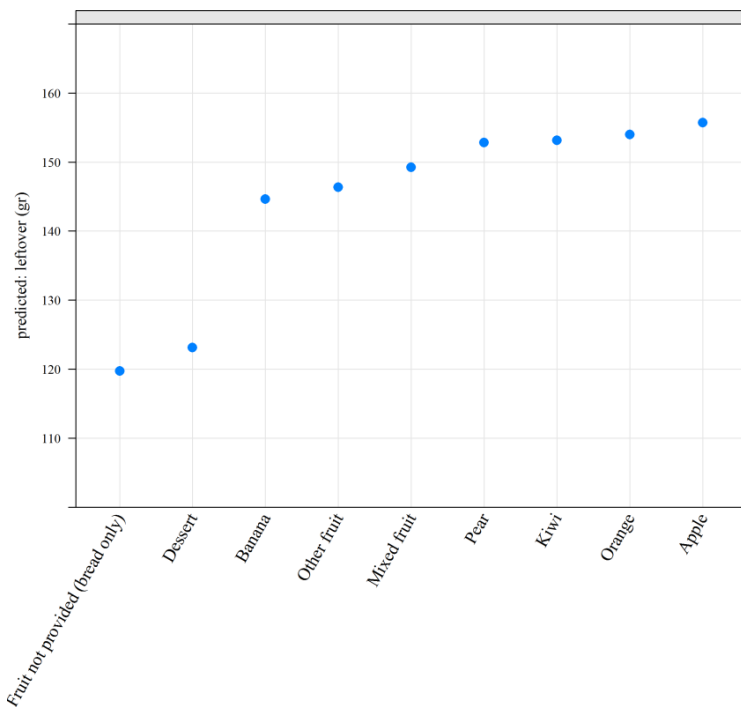
The results showed as the relationship between the serving size and the diners' leftovers was not linear, but characterized by a logistic growth and by the presence of a "step" for quantities of prepared food exceeding 370 g/day per capita (see Figure 4).



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

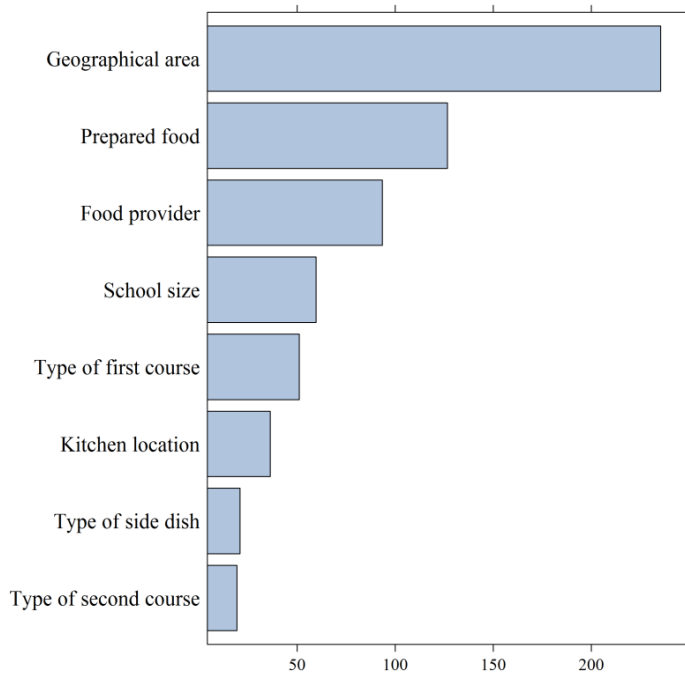
Except for the cases in which a fruit was not served at lunchtime, significant lower levels of diners' leftovers were found when a dessert replaced a fruit (see Figure 6). Moreover, diners rejected less food when banana, fruits served only occasionally or a combination of two fruits were proposed.



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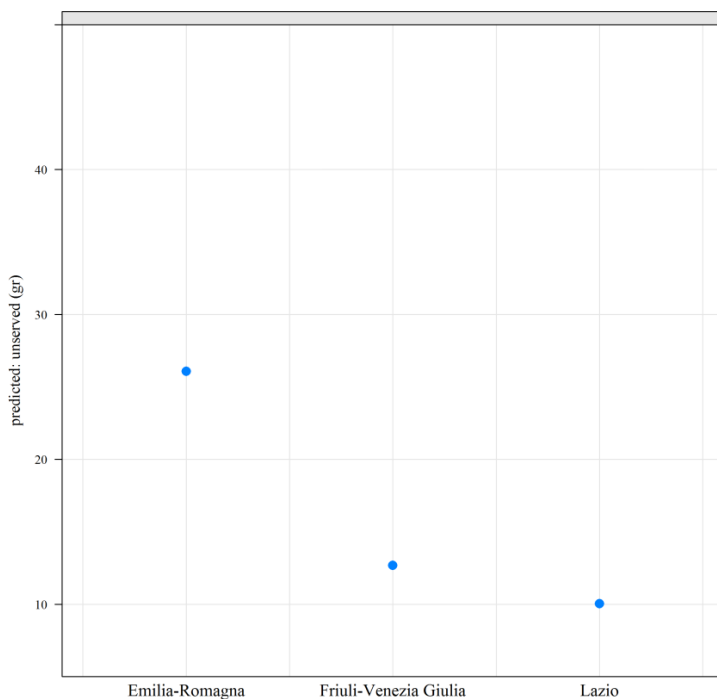
Fig. 5. Partial dependence of diners' leftovers on type of fruit.

513 The second model analysed the amount of non-served food for the three main courses and showed a
 514 reasonable good fit in explaining the statistical variance observed ($R\text{-squared} = 0.5480$). In this case,
 515 the factors with the greatest influence on the dependent variable was the geographical area, followed
 516 by the amount of prepared food, the foodservice providers, the school size, the type of first course
 517 and the kitchen location (see Figure 6).
 518



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

520
 521 The generation of non-served food, for equal quantities of prepared food, was substantially different
 522 among the three regions. In particular, the results showed higher amounts of non-served food in
 523 Emilia-Romagna than in the other two regions (see Figure 7).
 524

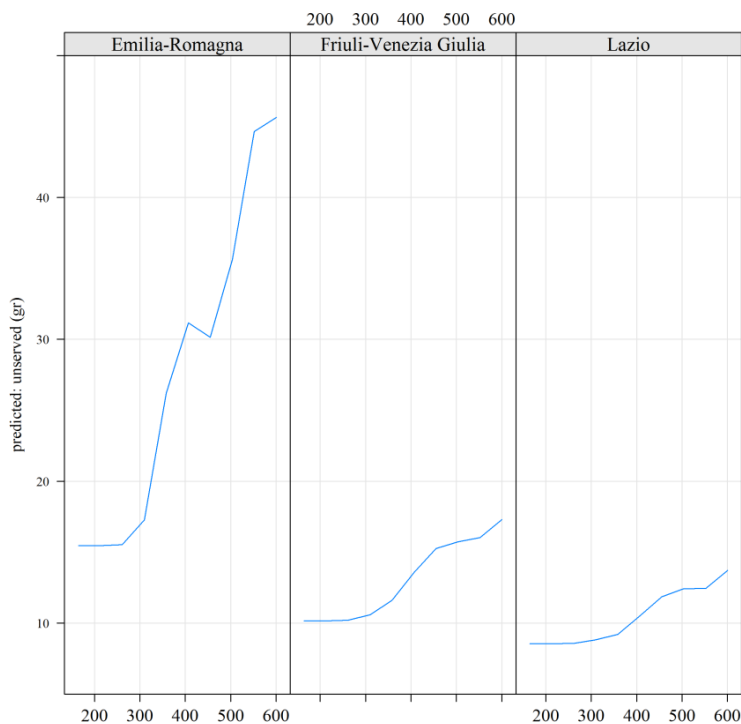


525 Fig. 7. Partial dependence of non-served food on Region.

526

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

530



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

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533

4. Discussion

534

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

540

541 The bivariate analyses performed for the diners' leftovers showed a statistical significance for almost
542 all the variables considered. The role of serving sizes and the location of kitchens confirmed the
543 findings of previous studies, where higher serving sizes and external kitchens were correlated to
544 higher levels of food waste in school canteens (Byker et al., 2014; Painter et al., 2016, Eriksson et al,
545 2017; Steen et al., 2018). The increase of diners' leftovers in those schools where the provision of the
546 mid-morning snack was in charge of the families supported the evidence found by Marlette et al.
547 (2005), and pushes the debate over the need to extend the nutritional standards required for meals to
548 the rest of food consumed by children at school. Other variables that showed a high statistical
549 significance in reference to the amount of diners' leftovers were the geographical area, the
550 foodservice provider and the seasonal variation of menus. A possible explanation of the higher
551 amounts of diners' leftovers during the winter menus could be that, in that season, soup with
552 vegetables are more frequently served rather than pasta or rice as first courses. Another possible
553 explanation for the higher appreciation of summer menus could be that, being them served for a
554 limited period of time, children get less tired of the meals.

555

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

606 serving trays both in terms of diners' leftovers and non-served food. Some of the factors potentially
607 related to food waste (i.e. lunch duration, timing of recess, diners' awareness of food waste as an
608 issue and children's age and gender) could not be considered as potential factors affecting food waste,
609 due to methodological constraints that did not allow the collection of information to this regard.
610 Moreover, as in Italian schools' foodservice pupils cannot choose what to eat, it was not possible to
611 study how competitive food items could affect the amount of food waste. Although plate waste could
612 be reduced when different food options are offered to pupils (Buzby and Guthrie, 2002), it is likely
613 that more non-served food is generated, as the availability of a second option may increase the level
614 of overproduction. At the same time, the opportunity for the children to choose daily the same favorite
615 foods (e.g. the same vegetables) may discourage them from tasting new food items, reducing their
616 diet diversity and the educational purpose of school meals. The role of competitive foods in
617 influencing the level of plate waste was analyzed with reference to the provider of the snack for the
618 mid-morning break, as in Italian primary schools students have not access to vending machines.
619

620 **5. Conclusions**

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

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

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

656

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661

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663

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

666

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

668

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

670

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

673

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