Food Policy 130 (2025) 102784

Contents lists available at ScienceDirect

Food Policy

journal homepage: www.elsevier.com/locate/foodpol

Can changing the meal sequence in school canteens reduce vegetable food waste? A cluster randomized control trial

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ARTICLE INFO

Keywords:
Intervention
Food waste
Mediterranean diet
School meal
SDG 2
Sustainability transition

ABSTRACT

School canteens are crucial drivers for stimulating sustainable eating habits of children in line with global sustainability objectives. Using a participatory approach, we co-design a choice-architecture intervention to assess whether inverting the sequence of Mediterranean lunch dishes served in school canteens is effective in reducing food waste. We implement a randomized control trial using 26 Italian schools, creating one of the largest and the most diverse samples achieved so far for such an experiment. Hence, our analysis yields evidence of internal and external validity far beyond existing interventions which consider only a few education institutions without random selection. A food mass flow analysis of the weighed prepared food, serving waste and plate waste per meal course suggests that in primary school canteens 29% of the lunch prepared gets wasted, i.e., 22,000 tons per year in Italy. Big catering providers are found to produce 23% more food waste. Prioritizing the vegetable side dish as first course has heterogeneous effects across school clusters changing the share of plate waste in total vegetable servings between −26 pp to + 32 pp. Also, the side dish plate waste depends on the type of vegetables served. Differences in lunch implementation and food and eating environments across schools appear to dominate the effectiveness of the intervention, hence, no treatment effect is found for the full sample. Upscaling of the dish reordering as a binding policy strategy for the entire regional territory is therefore not recommended. We conclude that policymakers and researchers should more often use citizen science to maximize benefits for society.

1. Introduction

Schools are recognized as key intervention options for developing pupils' healthy eating behaviors in line with the Sustainable Development Goals of the United Nations Agenda 2030 (WFP, 2017). They specifically can contribute to achieving food security and improved nutrition (SDG2) and reduce food losses and waste (SDG12), but considering schoolchildren are essential agents of change in the advancement of society towards global sustainability, the connected cascade effects have returns on multiple dimensions (Pastorino et al., 2023). In fact, healthy food consumption patterns at school lower the risk of diseases connected to dietary inadequacies (Bonomo & Schanzenbach, 2024) and address diet inequalities of children (Bryant et al., 2023) that also persist into adolescence and adulthood. Also, the consolidation of eating habits and the promotion of education activities on food can serve to grow up better educated and more conscious children able to shape their future more sustainably (Piras et al., 2023; Black et al., 2015).

Recent research has underlined two prominent challenges to be addressed by food policies in school environments, namely the large amount of food wasted and the insufficient consumption of vegetables. Boschini et al. (2018) reports that around 41% of the food which is prepared for school consumption is wasted. This does not only undermine an adequate nutritional intake of children (Chen et al., 2020) but has also proven to create adverse environmental (Zhu et al., 2023) and economic impacts of school catering (García-Herrero et al., 2019). For example, in Italy only 9 % of children consume adequate amounts of fruits and vegetables (Nardone et al., 2019). Most of the food thrown away belongs to these two categories (Boschini et al., 2018). In this context, the government of Emilia-Romagna, a region in the northeast of Italy accounting for about 8% of the country's population, planned to design school food policies to reduce food waste of vegetables and increase their consumption. Thus, the government aimed to obtain evidence-based insights on the effectiveness of interventions tackling

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https://doi.org/10.1016/j.foodpol.2024.102784
Received 29 March 2024; Received in revised form 3 December 2024; Accepted 5 December 2024
Available online 19 December 2024

vegetable food waste in primary schools (Emilia-Romagna region, 2023). To this scope a living lab was activated by involving stakeholders from the school food sector of Emilia-Romagna with a citizen science approach (Emilia-Romagna region, 2023).

Kovacs et al. (2020) point out that many researchers and policy-makers are working to design strategies for boosting sustainable consumption patterns in schools. Several information-based interventions such as educational programs (Boulet et al., 2022; Mariam et al., 2022; Piras et al., 2023), cooking shows (Neyens & Smits, 2017) or cartoon exposition (Binder et al., 2019) have been studied.

In parallel, choice-architecture interventions have been increasingly set up as they are often low-cost and easy to implement (Szaszi et al., 2018). The choice-architecture indicates the physical or social setting in which decisions are made at the status quo. This can include the characteristics of the default setting, the number of options, the attributes, or the description of these options (Thaler & Sunstein, 2008). Considering that individuals make nonoptimal decisions due to bounded rationality and uncomplete information, the approach is based on the principle that a change in the status quo of a situation can lead to change in individual choices fostering a more favorable outcome (Thaler & Sunstein, 2008). When identifying a specific behavioral problem, choice-architecture interventions can target that behavior by changing the way options and decision-making formats are arranged, e.g., in the eating environment (Münscher et al., 2016).

Not surprisingly, a set of interventions modifying the choice-architecture (i.e., the status-quo setting) of school meals have been found effective to incentivize vegetable intake and reduce food waste (Appleton et al., 2016; Cohen et al., 2021; Graça et al., 2023). Strategies include rewards for eating vegetables (Mazzeo et al., 2017), role modelling from adults (Machado et al., 2020), introduction of motivational stickers (Gwozdz et al., 2020; Thapa & Lyford, 2018) and plate size change (Qi et al., 2022; Spill et al., 2010). It has been reported that effects of these interventions are reinforced in public canteens since children are exposed to greater peer pressure towards desired behaviors (Landwehr & Hartmann, 2024; Zhang et al., 2023). On top of that, various analyses modified the placement order of vegetables and fruits in the meal order as a strategy to raise acceptance and intake (see Table 1).

Despite the popularity of this latter type of choice-architecture interventions, their scalability into policy recommendations remains limited. Interventions that assess how changes in the placement of vegetables impacts food waste amounts are rare and often limited to few schools or kindergartens (see Table 1). Although the randomization of samples is considered the gold standard for evaluating the effectiveness of behavioral interventions (Szaszi et al., 2018), all existing studies on dish reordering interventions selected participant schools via convenience sampling. Only one among the eight most recent publications on the change of the dish sequence (Adams et al., 2015) used limited randomization, but only for selecting participants within schools. Only Cohen et al. (2015) implemented a randomized control trial (RCT) in which randomization regarded only the assignment to the treatment and control group.

Such methodological choices not considering experimental approaches not only weaken the internal validity of the analyses conducted, but also limit their potential to deduce policy conclusions at regional or national level as the external validity of the results obtained is not robust (Roe & Just, 2009). Two out of the eight most recent articles listed in Table 1 implement several choice-architectures simultaneously which limit the internal validity of the experiments as effects of each single intervention can hardly be isolated. While five of the existing studies target more than 300 children, these pupil numbers are spread across no more than 8 schools (Cohen et al., 2015) which reduces the potential to capture heterogeneities across school canteen eating environments and providers. The often-small sample sizes of schools considered so far, hence, limit the potential of extracting generalizable patterns which could serve for inferring robust policy conclusions (Peters et al., 2017).

Although direct measurement via weighting is the most common method to assess food waste quantities, three out of eight studies rely partially or exclusively on the counting of food items. Cohen et al. (2015), and Spill et al. (2010; 2011) provide results either in cups or portions of vegetables which are hardly comparable internationally, since these measurements have differing metric equivalents depending on their geographical context. The measurements used and treatment effects of the interventions reported are quite diverse, but – except for Chawner et al. (2024) – results are always supported by significance tests. The study of Chawner et al. (2024) is the only one developed in Europe. As other existing studies focus on North America their international generalizability is limited as the country has fairly specific eating culture so that the practical implementation of school meal catering, and the associated eating environments differ from most other countries and diet patterns.

Given this background, we have been commissioned from the regional government of Emilia-Romagna to assess whether prioritizing the vegetables side dish as first course does avoid food waste and raise vegetable consumption and, hence, can represent a scalable policy strategy. For three consecutive weeks (i.e., 15 consecutive school days) pupils in the schools randomly assigned to the treatment group have been served a lunch menu in which the side dish made of vegetables was served as first course before the rest of the meal. As public authorities should design effective policy strategies ideally based on context-based and robust scientific evidence (Filippini et al., 2018), our contribution extends the present literature by adding an impact evaluation of a choice-architecture intervention on vegetable food waste. We, hence, provide the first analysis which extends the evaluation of school lunch dish order interventions beyond Anglo-Saxon food consumption habits, namely to the Mediterranean region with its distinct dietary pattern (Alexandratos, 2006; González Turmo, 2012; Romagnolo & Selmin, 2017). We transparently compare the school lunch choice environments of the analyzed context with the ones of other countries by developing the first comprehensive synthesis of the typical national lunch serving setups of ten countries across four main food cultures. To the best of our knowledge such comparison is the first of this kind since none of the existing studies which implemented such an intervention (included in Table 1) critically compare their school meals choice environments with the ones of other countries.

Secondly, we adopt a participatory approach for the co-design of the intervention which guarantees direct access to personnel involved in school canteens with up-to-date information providing an accurate applicability of the intervention to the local context through a tailored implementation strategy. Our intervention is not a replication of any of the interventions in Table 1 but is the consensus choice co-created with school food practitioners via a bottom-up approach. Third, we conduct a cluster Randomized Control Trial (cluster RCT) of so far unequaled comprehensiveness which randomly selects schools and randomizes them across control and treatment groups. This approach enables us to establish robust internal and external validity of our results allowing for robust causality and generalizability claims. The cluster setup is necessary as the intervention of interest to the involved authorities was to be implemented at school level while the statistical analysis needed to be conducted at individual class level. By opting for a stratified random selection of schools to control for unobservable factors of pupils' food choices (Custodio et al., 2021) related to different characteristics of school canteen services in the different strata we guarantee internal validity. This results in the second largest sample of pupils (760) and covers the by far largest heterogeneity across schools achieved so far (26 schools). Data on food waste are objectively collected through weighting expressed in kilograms to minimize errors and maximize international comparability (Reynolds et al., 2019) providing a chomprensive and accurate measurement of food consumed and wasted.

Table 1
Existing articles on choice-architecture interventions focused on the placement of dishes in schools to improve children's vegetable consumption.

Article	Intervention	Experimental design	Random selection of the sample	Random assignment to treatment	Sample size	Several interventions combined	Food waste measure methods	Measures	Result	Country
Adams et al. (2015)	Differing salad placement: inside or outside of the serving line	Cross-sectional study	No for schools, yes for children	No	533 students attending 6 middle schools	No	Weighting	Amount of fresh F/V taken, consumed and wasted	Students with salad bar outside the line wasted significantly less F/V than those with salad bars inside the line (30 % vs. 48 %)	USA (Arizona)
Chawner et al. (2024)	Vegetables are served first, as a starter	Crossover design	No for schools, no for children	No	38 nursery school children from 2 schools	No	Weighting	Amount of food served and eaten	The vegetables-served-first, compared with serving all foods together, increased vegetable intake by ~ 12 g per children.	EU (Great Britain)
Cohen et al. (2015)	Strategies include offering vegetables at the beginning of the lunch line	Randomized clinical trial	Schools are recruited from selected districts and, only then, randomly assigned to treatment or control group	Yes	2638 students in 8 elementary and middle schools	Yes	Weighting	Weight of plate waste	Vegetable consumption significantly increased on average of max 0.16 (95 % CI, 0.09–0.22) cups per week	USA (Massachusetts)
Thompson et al. (2017)	Strategies include placement of fruit and vegetables at the beginning of the lunch line	A pre-post prospective evaluation	No for schools, no for children	No	2 elementary schools, 373 students	Yes	Weighting	Weight of plate waste and number of students consuming a portion	Average vegetable consumption increased by 1.1 g ($p = 0.27$), not significantly	USA (Minnesota)
Elsbernd et al. (2016)	Serving raw vegetables while children wait to receive the rest of their lunch meal	Within-subjects experimental design	No for schools, no for children	No	1 kindergarten, 532 students*	No	Weighting and counting food items	Number of pieces left in a given cup from the starting number of pieces in a full portion	The total vegetable intake significantly increased from 4.0 to 5.4 g per child and meal	USA (Minnesota)
Redden et al. (2015)	Vegetables provided as a first item of the menu in isolation	Observational field study	No for schools, no for children	No	800 students in 1 elementary school	No	Weighting and counting food items	Number of uneaten vegetable and number of students taking vegetables	Significant increase in carrots consumption of more than 430 %	USA (Minnesota)
Spill et al. (2010)	Serving different portion size of vegetables at the start of a meal	Within-subject crossover design	No for schools, no for children	No	51 children aged 3–5 years in one school	No	Weighting	Weight and energy intake of carrots and all other foods as well as total vegetable intake and total food and energy intake at the meal	Carrot intake increased significantly by ca. 50 % per child and meal	USA (Pennsylvania)
Spill et al. (2011)	Serving different portion of tomato soup at the start of the meal	Within subject cross-over design	No for schools, no for children	No	72 children aged 3–5 years in one school	No	Counting food items	Soup intake, vegetable intake, and meal energy intake	Effect on vegetable intake not explicitly specified	USA (Pennsylvania)
Our paper	Serving vegetables as a first dish	Cluster Randomized Controlled Trial	Yes for schools, no for children	Yes	760 third grade students in 39 classes of 26 elementary schools	No	Weighting	Weight of prepared food, plate waste and serving waste	On the full sample no statistically significant reduction of the plate waste share of vegetables is detected, but significant heterogeneous effects are observed across school clusters.	EU (Italy)

Notes: *Since different numbers of participating students are provided, we include the number of students present at the first day of data collection (control). CI means confidence interval.

2. Theoretical background

Choice-architecture interventions start from the premise that people are bound in their ability to make rational decisions (Thaler & Sunstein, 2008). They hypothesize that individuals' choices are not always driven by rationality, but often result from interactions of contextual factors on which it is possible to intervene to change people's behaviors. Using the Motivation-Opportunity-Ability framework, they are often categorized in the literature as motivation factors (i.e., the willingness of individuals to perform actions), opportunity factors (i.e., availability and accessibility of materials and resources required to take actions) or ability factors (i.e., person's proficiency of taking an action) (MacInnis et al., 1991).

In the context of personal choices regarding food consumption, the motivations, opportunities and abilities of individuals relate to consumption norms as well as characteristics of the eating and the food environments (Fig. 1). Hence, people's consumption quantities and the corresponding food waste amounts can be influenced by the atmosphere in which individuals eat (e.g., light, noise), by the effort they need to put into consumption (e.g., easy access to certain foods), by the social context (e.g., peers influence), and by external distractions (e.g., watching TV). Additionally, they make their choices based on how the food is presented in terms of salience, variety, size of portions, stockpiling and size of containers. Fig. 1 shows that also consumption norms such as dietary habits (e.g., food preferences), educational or cultural frames (knowledge and meanings of food), and social and biological needs (e.g., hunger, age, gender) also play a role (Story et al., 2002).

In school canteens, those factors have complex interrelationships, which makes it hard to find univocal consensus on why children eat or discard foods. Steen et al. (2018) report that noisy and stressful school canteens tend to increase the amount of food discarded by children, while the presence of teachers during lunch time increases consumption (Liz Martins et al., 2020) since children are less distracted.

Consumption norms have mostly to do with the quantities children are used to eat which ultimately results in individual hunger levels (Zhao et al., 2019), or the type of food they are most exposed to at home, which often results in disliking certain foods. The awareness of and education about healthy and sustainable diets, for example on adequate fruit and vegetable intakes, are also affecting consumption levels (Haß & Hartmann, 2018; Myers et al., 2018). Moreover, the location of schools in either urban or rural municipalities showed a relation with children's food consumption (Boschini et al., 2020). The menu composition including the order of courses, the meal presentation and plate size are some of the environmental factors more often mentioned to affect school children's consumption quantities (Falasconi et al., 2015; Boschini et al., 2020; Qi et al., 2022). The literature also reports several operative circumstances that are associated with children's food consumption and waste. For instance, the more time children have for consuming their lunch, the less they waste (Cohen et al., 2016). The recess organization (whether the break is pre or post lunch) as well as the catering providers' management have been found to contribute directly to children's food consumption volumes and meals satisfaction (Boschini et al., 2020; Maietta & Gorgitano, 2016; Price & Just, 2015).

2.1. Literature review on dish order and vegetable waste

To target the bottleneck of inadequate vegetable consumption and waste, research agrees that changing the default sequence in which foods are served (i.e., the structure of food assortments) matters since people tend to accept the default option (Münscher et al., 2016; Carlsson et al., 2021). One of the main reasons reported for school children to leave vegetables on their plate is that they are too full to eat (Ilić et al., 2022). Therefore, if those vegetables will be served first, they might require less eating effort to be consumed (i.e., students have easier access to them – see Fig. 1), or children eat larger quantities of them due to their sense of hunger (Wansink, 2004) and to the absence of competing foods (Spill et al., 2011). Both spatial and temporal anticipation have been found to increase vegetable consumption and reduce waste (see Table 1). Spatial anticipation relates to the fact that increased visibility of food leads people to eat more of it (Wansink, 2004). Examples in school cafeterias are the placement of salad bars inside vs. outside the serving line, which resulted in increases of salad consumption of 35 %, but also an additional 18 % of salad waste because students took a lot more fruits and vegetables (Adams et al., 2015).

Temporal anticipation is based on the notion that children will spontaneously eat the first food placed in front of them to fulfil hunger, if no other competitive foods are offered (Chawner et al., 2024; Roe et al., 2012). When vegetables got served 10 min before the remaining component of the meal, children are found to increase their vegetable intake by around 12 g (Chawner et al., 2024). Serving vegetables as a first course implemented in combination with other strategies (like long-term exposure to intervention), has been shown to increase vegetable consumption by one sixth of a cup per week on average (Cohen et al., 2015). Thompson et al. (2017) find that serving vegetables at the beginning of the lunch line together with other choice-architecture strategies increases – although not significantly – average vegetable consumption by 1.1 g per person and day. The supply of raw vegetables to children while they wait for other foods was observed to quadruple the number of children at least trying those vegetables (Elsbernd et al., 2016). Redden et al. (2015) showcased that serving either carrots, broccoli or cauliflower to children at the start of the meal without other more preferred foods always had the effect of increasing intakes both in the short and in the long run. By investigating interactions between plate size and anticipation, Spill et al. (2010, 2011) find that the bigger the portions of vegetables offered as a first course of the school lunch the larger the intake.

2.2. Comparison of school meals choice environments

School lunch implementations show varied choice environments across countries (i.e., menu composition, type of service, children's choice, portion sizes and duration of the lunch break) and also reflect the food culture they are embedded in and national dietary priorities for children (Aliyar et al., 2015). Supplementary Table A summarizes typical national lunch serving implementations in ten Western countries grouped into four food cultures: Mediterranean, Northern-European, Central-European and Anglo-Saxon.

Similarly to the typical Mediterranean lunch structure also found in France or Spain (Aranceta Bartrina et al., 2008), a lunch meal at Italian schools consists of a first dish (FD), a second dish (SeD), a side dish of vegetables (SiD), bread (B) and fruits (F). This structure is culturally embedded in the Mediterranean diet (MD) characterized as a nutrition pattern rich in fruits, vegetables, breads and other non-refined cereals, beans and nuts. Local and seasonal products are predominantly used, while dairy products, fish, milk and meat are only moderately consumed (Alexandratos, 2006; González Turmo, 2012). Olive oil is the primary source of fat (Willett et al., 1995). School lunches in Central and Northern Europe as well as in the US and the UK typically foresee one main dish, accompanied by entrees, starters, fruits and dairy products. In the Anglo-Saxon context, school lunches are often served in a canteen or buffet style, in which children decide what and how much food they would like to eat. In the interventions of Adams et al. (2015), Cohen et al. (2015), Thompson et al. (2017), and Spill (2010; 2011) children are entitled to choose the vegetables and/or the quantity they would like to consume. In Elsbernd et al., (2016) and Redden et al. (2015) the type and quantity of served-first vegetables were fixed, but afterwards children were allowed to pick their preferred foods from the lunch line.

In contrast to these choice environments for which most of the existing studies listed in Table 1 have been conducted, the seated lunch service with fixed course structure and standardized portion sizes which reflect national recommendations or regulations represents the standard setup in Italy, France, Spain and Portugal. Generally, children have no

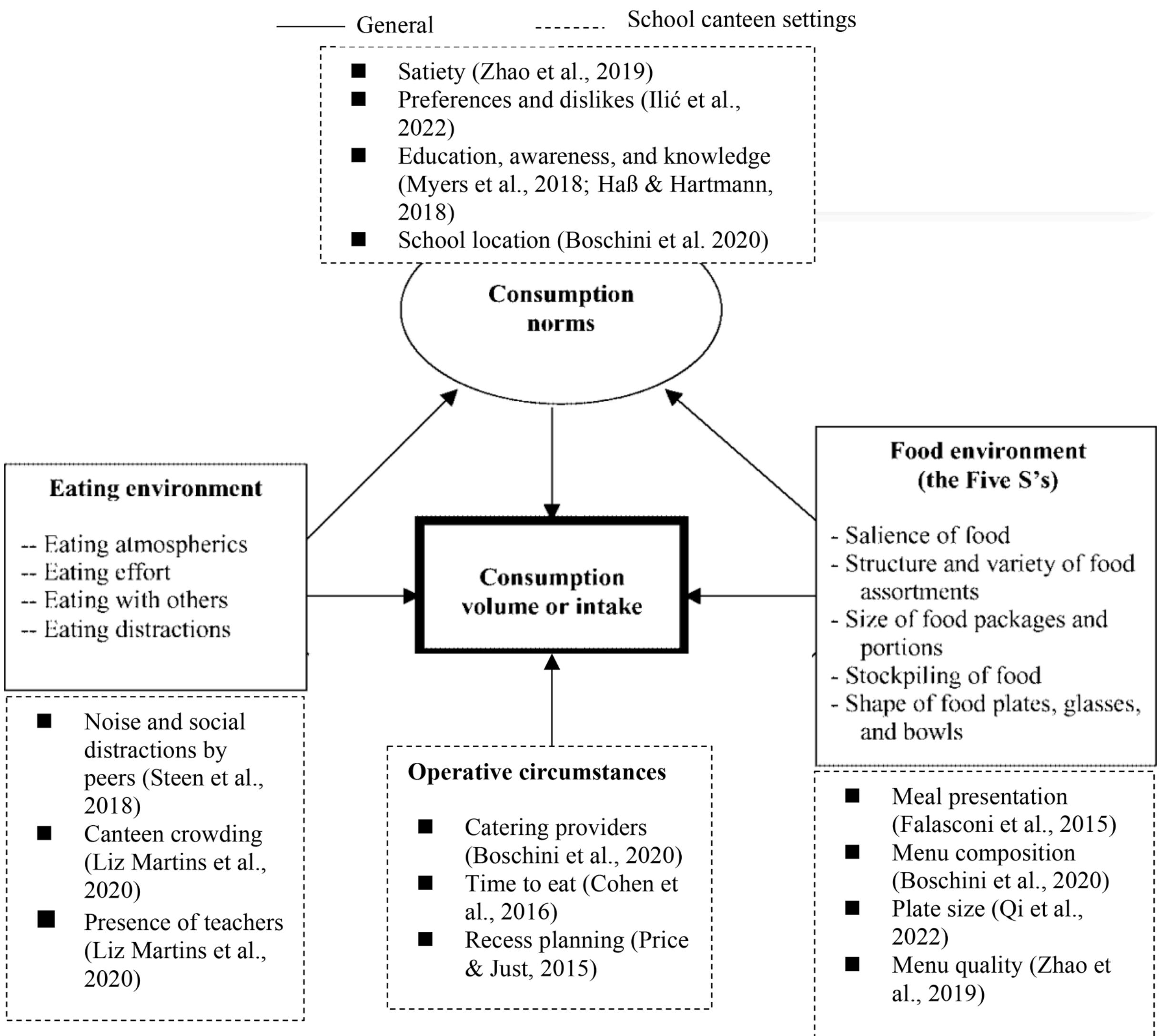

Fig. 1. Overview of the factors influencing food consumption quantities. Source: Authors based on Wansink (2004).

choice on which food and how much of it to put on their plates but are being served the menu of the day for which the caterer and the school have decided which foods to serve in which sequence and amounts.[1] In Italy, accordingly to the menus approved by the sanitary districts,[2] pupils are accustomed to first eating the carb-based FD alone. Then, after a fixed period of time that changes from school to school, they receive the protein-based SeD together with the plant-based SiD. FD, SeD and SiD are served in this order in virtually all schools.[3] Similarly to our intervention, children in the study of Chawner et al. (2024) were exposed to fixed menus and portion sizes with no possibility to choose.

Portion sizes of school lunches are often defined by a set of technical guidelines issued by the responsible ministry or the leading national nutritional institution. Consequently, studies carried out in the USA (Table 1) relied on vegetables portions in line with the Dietary Guidelines for Americans (USDA, 2020). Chawner et al. (2024) design their intervention based on portion sizes recommended by the UK government. In Italy, the dietary pattern, the suggested frequency of the preparation of the core food categories as well as the envisaged nutritional intakes need to follow the guidelines defined by the Italian Ministry of Health (2010) which are based on the Nutritional Recommended Intake Level for the Italian population (Italian Society of Human Nutrition, 2014). Emilia-Romagna, as all Italian regions, translated the national guidelines into a regional operational framework, which is applicable to all its provinces and guarantees the same food procurement practices and sanitary standards across its territory (Regional Sanitary Service ER, 2023). Menus are predetermined and usually rotate on a weekly basis to guarantee a varied diet. Menu rotation can last from 4 up to 8 weeks depending on the catering provider.

The design of our choice-architecture (lunches being served to pupils in seated service, standardized sizes and a predefined course order) reflects the preference consensus of the 25 school lunch sector experts whom we involved to codesign an intervention. The resulting choice architecture in which pupils do not have a buffet-like choice of what and

[1] See for examples Ministry of Health and Consumer Affairs of Spain (2008, chapters 2 and 7) or Ministry of Education of Portugal (2024).

[2] Every region of Italy is split into sanitary districts called Aziende Unità Sanitaria Locale (AUSL), 8 in Emilia-Romagna, which have the role of approving the menu, supervising the menu implementation, monitoring the food quality, and developing educational food activities within their districts. This implies a certain degree of heterogeneity in the way schools deliver their meals across different AUSL. School lunch provision becomes more heterogenous within an AUSL as school canteens are served by different catering companies.

[3] Only in rare situations these lunch components are served at once in a single tray with the recommendation of eating them in that order. On an occasional basis, the guidelines allow schools to serve a single dish that takes the place of FD and SeD together, accompanied by the SiD only.

when to eat, but choose the quantities of the food served to them they eat is not only culturally embedded in the national food culture, but also of relevance to and accepted by practitioners to be feasible and potentially implementable at large scale. It, hence, reflects the cultural consensus how school lunches should be and are typically organized throughout the country.

The school lunch breaks also show some variation (Figure A and Table B in the supplement). In Norway and USA, 20 min are common while in the remaining countries breaks typically take longer with a maximum of 120 min in Portugal. In Italy, school lunch breaks typically take 30 min as in Spain or Finland. The median minimum (maximum) duration of lunch breaks across the ten countries for which information was available amounts to 30 (60) minutes which indicates that most authorities consider such a duration as suitable for primary school children to have a healthy, relaxed and communicative lunch.[4]

Based on this choice environment which represents the typical Mediterranean setup (Supplementary Table A), we expect that if vegetables are served first in Emilia-Romagna school canteens and children have no other foods to choose from, they consume the SiD in higher quantities compared to the normal setting where vegetables arrive as third course only. As we directly measure both served food and food waste of school children (section 3.2), we assess the intervention based on the share of plate waste in the amount of food children have received. This approach provides us not only with a precise measurement of school canteen waste but also with an indirect measurement of pupils' consumption. Hence, we empirically assess the following hypotheses:

H1. Serving the side dish of vegetables (SiD) first leads to a lower share of its served amounts wasted.

Current research also questions whether offering vegetables first has an influence on consumption levels of other meal components (Elsbernd et al., 2016; Redden et al., 2015). Satiety from vegetables can induce reduced consumption of the following courses. Therefore, we also investigate the secondary effect of the intervention investigating on the consumption of FD and SeD[5]:

H2. Serving the SiD first increases plate waste share of the first dish (FD) as well as the second dish (SeD).

Finally, Redden et al. (2015) state that the effectiveness of the serve-first strategy is not dependent on the type of vegetables. Knowing whether this type of choice-architecture interventions work only for specific vegetables is key for real-life settings so that we also test:

H3. The shares of side dish of vegetables not eaten by pupils does not depend on the type of vegetable.

Considering that the studies listed in Table 1 assess intervention impacts for an average sample of 3 schools, and that each stratum of our sample also includes on average 3 schools, we test these three hypotheses first at the strata level (i.e., for all schools belonging to one of the eight AUSLs) and afterwards for the full sample of 26 schools. The results disaggregated by AUSL provide insight on the regional heterogeneity of effects, while the entire sample allows robust conclusions about the external validity and scalability of results.

3. Methods

We implemented a choice-architecture intervention in randomly selected primary schools in the Italian region of Emilia-Romagna between October 2022 and March 2023. The schools have been randomized across control and treatment groups. The intervention consisted in changing the lunch component order from the standard FD – SeD – SiD to SiD – FD – SeD, that is, serving the vegetable side dish first for children in 3rd grade attending the canteen all 5 days of the school week. The intervention has been co-designed with a participatory approach based on Citizen Science and Responsible Research & Innovation principles (Robinson et al., 2018). We follow the internationally recognized spectrum of public participation (IAP2 International, 2018) to define and develop the participation process reflecting the five principles of (1) information, (2) consultation, (3) involvement, (4) collaboration, and (5) empowerment. About 25 stakeholders from the school food sector of Emilia-Romagna (documented in Supplementary Table C) have been involved in three different online workshops between June and July 2022.[6]

3.1. Sampling design

As lunch catering for pupils is organized at school level in Italy, the intervention had to be implemented at school level so that schools are the sampling units. We consider the largest number of schools used achieved so far in comparison to previous studies (Table 1). This helps us to account for institutional heterogeneity due to differences in regulations defined by each AUSL and across practical lunch implementation practices, meaning to capture practice and system level effects on the selected outcome measures. Following the Consolidated Standards of Reporting Trials (CONSORT; Moher et al., 2001), this study uses a cluster RCT with schools being the units of randomization (clusters) and all third-grade classes of a given school the units of analysis. Compared with individual RCTs, cluster RCTs require more participants to obtain equivalent statistical power as individuals in the same cluster tend to be correlated (Campbell et al., 2004), hence, also offer the advantage to obtain robust external validity of the analysis about the generalizability of intervention impacts.

The region of Emilia-Romagna has 555 eligible full-time primary schools. The intervention design excludes those schools which have no canteen or whose third-grade classes are composed of pupils of different ages. Both exclusion criteria were essential to guarantee the applicability of the intervention. The sample size of 26 schools among the eligible ones has been calculated following Ahn et al. (2015) and Campbell & Walters (2014). Based on previous studies we expect the generated food waste per capita between 130 and 150 gr/day and a minimum detectable effect of food waste reduction between 15 to 25 g (Boschini et al., 2018; Antón-Peset et al., 2021). We follow Iaia et al. (2017) and assume an intraclass correlation coefficient between 0.01 and 0.05. The sampled schools were stratified with respect to the eight AUSL districts of Emilia-Romagna as these authorities govern the school food catering at local level. From the 8 strata (each of them having different territory and population) sampling units were selected proportionally to the size of the population in each stratum. In the first round of sampling, 3 schools refused to participate and were resampled to reach the intended sample size. The selected schools were then randomly assigned to the treatment or the control group without masking. To guarantee the applicability of the intervention, for each school only third-grade classes eating at school from Monday to Friday were included. Hence, 10 third-grade classes in the 26 sampled schools were excluded. In the treatment (control) group 20 (19) eligible third-

[4] In the existing literature, the overall lunch break duration as well as the amount of time occurring between the consumption of the meal components is usually not explicitly specified. None of the studies listed in Table 1 except Chawner et al. (2024) detail if a specific time span between the first served vegetables and the rest of the meal was set.

[5] Bread and fruits were excluded from the analysis considering that their serving order is more likely to differs from school to school and the heterogeneity of modalities make these elements not suitable for a standard choice experiment setting. Bread can be served either with the FD, or with the SeD. Fruits are either served as a last menu item or are offered as a mid-morning snack, depending on the AUSL decision. Bread and fruits are sometimes even brought home as afternoon snacks.

[6] Supplementary Table D and Supplementary Figure B detail the full stakeholder participation process. The data gathering protocol was approved by the Ethics Committee on 25 October 2022 (Approval N. 0299280).

grade classes in 13 (13) schools participated in the experiment (see Supplementary Figure C for the locations of the schools within Emilia-Romagna).

Schools of the treatment and control groups are balanced in terms of number of students per school, class size, location of the school (urban vs. rural, costal vs. inland) as well as catering providers (Supplementary Table E). The treatment group experienced the intervention SiD – FD – SeD of serving the SiD as first component of the meal for three consecutive weeks. The control group did not experience any change in the menu serving order FD – SeD – SiD during that period. Each phase of the experimental design is displayed in Fig. 2.

3.2. Intervention co-design and data collection

The co-design process led to several crucial decisions for intervention design. First, the consensus emerged that 3rd graders are the best choice for the target population as they have sufficient autonomous capacities in eating skills with respect to 1st and 2nd graders, while, at the same time, they are not old enough to experience pre-teen transformations and growth. Moreover, the two more years of primary school they attend allow for possible follow-up studies. Second, prioritizing the side dish by serving it first matched best stakeholders' priorities and was perceived as the most feasible intervention option to address vegetable intakes and food waste given the existing practical implementation constraints. Third, the duration of the intervention was chosen for meeting two competing goals, namely allowing children to have sufficient time to adjust to the intervention menu before evaluating its impact on food waste and proposing an approach feasible for school canteen providers. Due to these reasons the consensus among the 25 stakeholders involved in the co-design process was to implement the intervention for 3 weeks.

Measurement of food waste quantities was carried out at baseline (T0) in which the normal menu was served to all 26 schools, and during the third week of the intervention (T1) which only 13 schools received. At T0 as well as T1, measurements lasted for five consecutive school days from Monday to Friday for both the treated and the control group. The stakeholders also indicated that entire classes should be defined as units of analysis in order to make precise weighing feasible as space and time limitations would usually not allow for individual measurements per pupil. Although school staff was informed about the intervention, pupils were not made aware of the background of the experiment to avoid changes in their consumption behavior prior to the menu re-ordering in order to achieve highest possible internal validity.

To minimize biases in food waste measurements prior to and during the intervention due to different palatability of recipes, it was important to have the same menu at T0 and T1. As described in section 2.2, the menu in each school rotates on a weekly basis for a minimum of 4 weeks repeating during the school year. Hence, T0 and T1 were set for the identical weeks of two consecutive rounds of menu rotation in order to have pupils exposed to the same menu in both measurement weeks. Once T0 and T1 were selected for each school, the menu intervention was implemented starting two weeks prior to T1 in the treatment group. Following this structure, the normal menu was served to children in the control and treatment groups in the week following T0. The structure of the intervention design and the measurement steps are shown in Fig. 3 for a standard school with a 4-weeks menu.[7]

Schools were asked to separate the prepared food for each 3rd grade class. Before lunch got served, the schools weighed the entire food prepared to be served to an entire class which we define as the amount of food prepared (*PF*) for consumption (García-Herrero et al., 2021). Hence, the *PF* was separately measured for each of the 39 third grade classes. After lunch, we weighed food waste as the food appropriate for human consumption being discarded (FAO, 2019) separately for the plate waste (*PW*) – defined as the amount of edible food served and left uneaten in the plates (Chapman et al., 2019) – and the serving waste[8] (*SW*) being the amount of food that remains in serving trays as it has not been served (García-Herrero et al., 2021). Children were asked to put the plate waste into a single basket for the class, so that the aggregated plate waste of each third-grade class was obtained per day. Similarly, the serving trays containing the serving waste were separated for each third-grade class so that we weighed the serving waste for each third-grade class in each school.

Following Boschini et al. (2018) *PF*, *PW*, *SW* were separately weighed for the FD, SeD, SiD, using commercial digital scales for treatment and control groups alike. The weights of consumed food $w^{u,d}_{c,CF}$ and served food $w^{u,d}_{c,SF}$ at class level have not been measured but can be derived from *PF*, *PW* and *SW* via Eqs. (1) and (2) and illustrated in Fig. 4:

$$w^{u,d}_{c,PF} = w^{u,d}_{c,SF} + w^{u,d}_{c,SW} \tag{1}$$

$$w^{u,d}_{c,SF} = w^{u,d}_{c,CF} + w^{u,d}_{c,PW} \tag{2}$$

where w denotes the total weight in grams per course $c = \{FD, SeD, SiD\}$ and each measured food waste step $s_m = \{PF, PW, SW\}$ (see Fig. 4). For each of the analysis units (classes) $u = \{1, 2, \cdots, 39\}$ for days $d = \{1, 2, \cdots, 10\}$ – resulting in 373 observations[9] – all 9 measurements (PF, PW, SW) $x(FD, SeD, SiD)$ were repeated. Hence, a total of 3,357 weight measurements $w^{u,d}_{c,s_m}$ – 1,701 for the treatment and 1,656 for the control group – have been gathered.

Fig. 4 also highlights the link between lunch sustainability and nutritious diets because the prepared food $w^{u,d}_{c,PF}$ represents the adequate intake quantities of various food types as recommended by nutritionists. This implies, the higher the amount either lost during serving (*SW*) or not eaten by children and discarded at the end of the meals (*PW*), the less compliant will be the nutritional quality of the lunches from the ideal recommendations. This in turn means that reducing food waste implies more sustainable and healthier diets.

Researchers were appointed in each school to conduct the experiment while catering provider employees and teachers were assigned to supporting roles. Researchers were responsible for the location of food waste bins, for the weighting procedure and data collection. Kitchen employees oversaw the weighting of the *PF*. Teachers supervised the pupils for emptying each course leftovers in a separate basket and guided connected logistical issues providing instructions when needed. Each of these experiment staff received a tailored handbook including all needed instructions.

To account for other factors potentially influencing pupils' food consumption, we selected as many determinants of Fig. 1 as possible which were measurable at class level. Social distraction and canteen crowding, presence of teachers, education and awareness and school location were quantified by five variables at class level by researchers present during classes mealtime (see Supplementary Table F). All weight data were collected using a digital form accessible via QR code as well as on paper being later added to the digital form by researchers.

3.3. Outcome measures

Data has been collected for three complementary groups of variables: food and waste weights following principles established in the literature, a qualitative classification of each of the three dishes as well as qualitative factors potentially influencing consumption volumes as specified

[7] For schools having menu rotations of more than 4 weeks, one or more standard menu weeks were implemented before the 3 weeks of intervention menu to respect the same intervention structure.

[8] In the Italian context, the food that is not served to pupils is thrown away and not reused due to sanitary rules at national and local level.

[9] 17 of the intended 390 observations are missing due to unplanned local strikes of school staff that caused the unanticipated closure of schools.

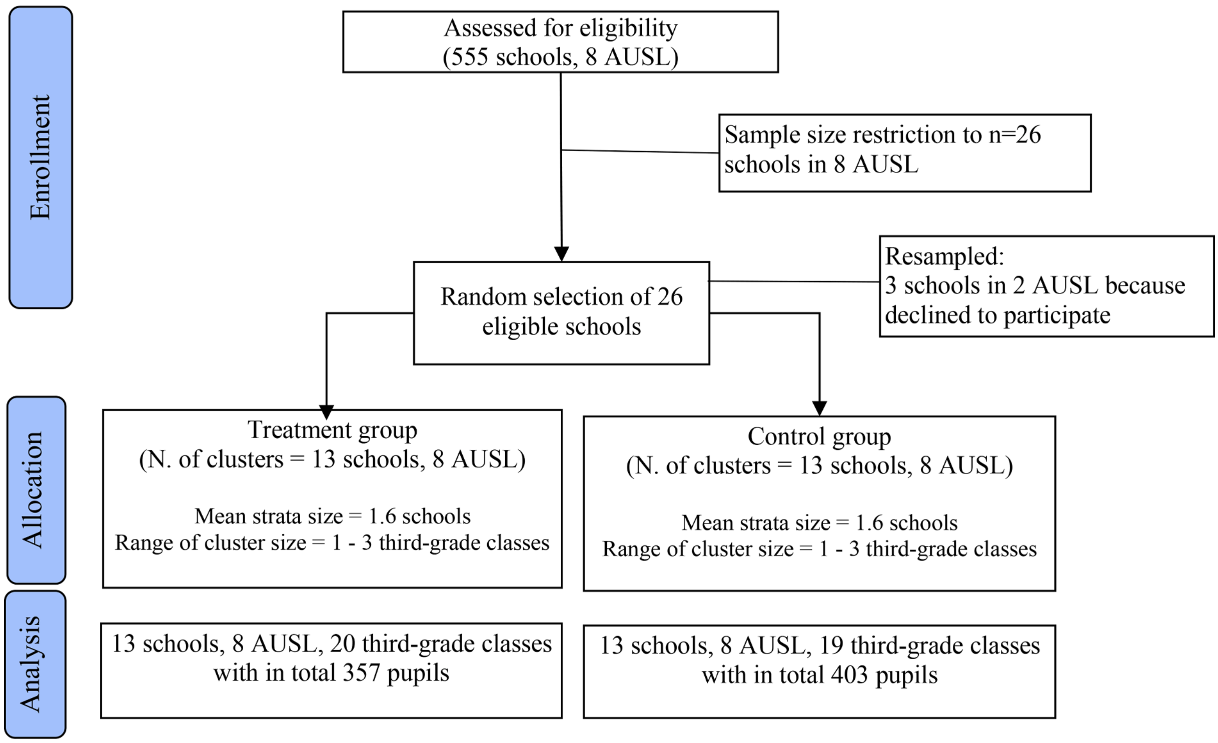

Fig. 2. Sampling design based on the CONSORT guidelines (Moher et al., 2001).

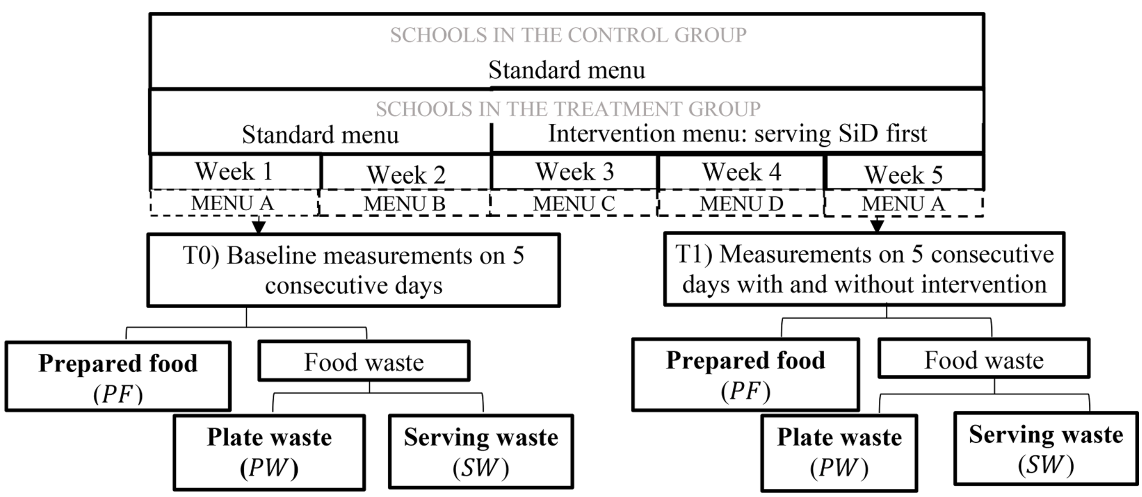

Fig. 3. Overview of the data collection process.

in Fig. 1. For each class the food follows the flow described in Fig. 4 and Eqs. (1) and (2). Hence, the first variable group consists of the 9 weights (*PR*, *PW*, *SW*) x (FD, SeD, SiD) for each of the 39 sampled classes for each of the 10 considered days. These three weights per class and day for each of the three courses are measured at aggregated class level. Knowing the number of children per class, average quantities of *PF, SF, SW, CF, PW* in gr/pupil within a class have been calculated and used for the analysis.

The second group of measurements categorizes all observed FD, SeD and SiD into the food categories defined by the Emilia-Romagna regional government (Regional Sanitary Service ER, 2023). This categorization of dishes is included to control for the qualitative differences in sensory attributes and plate taste from a children's perspective which connects to the literature as Williams et al. (2005) has shown that children tend to be highly selective in this respect. The categorization allows to assess hypothesis H3 stating that SiD waste does not depend on qualitative differences in sensory attributes and plate taste. Hence for each course category Ca, dummy variables $Ca_c^{u,d} = \{1;0\}$ which take the value 1 if the dish served on day d to class u belonged to category Ca or zero otherwise resulting in 373 indicator variables.

Table 2 presents some descriptive analysis of the resulting 10 FD, 15 SeD and 12 SiD categories focusing on their frequencies observed in our sample. Pasta with veggies, the most popular FD, is served almost eight times the least served one (i.e., pizza). White fresh meat is the most frequently served SeD, and together with cakes (i.e., pies and salty cakes) and fresh fish accounts for 45 % of all SeDs served. Raw veggies and salads are by far the SiD most often chosen by schools (see Table 2).

The third group of variables also contains 373 observations of qualitative covariates X^{ud} class u was exposed to on day d that are hypothesized by the literature to influence food consumption of children (see Supplementary Table F for the full list). They are derived from Fig. 1

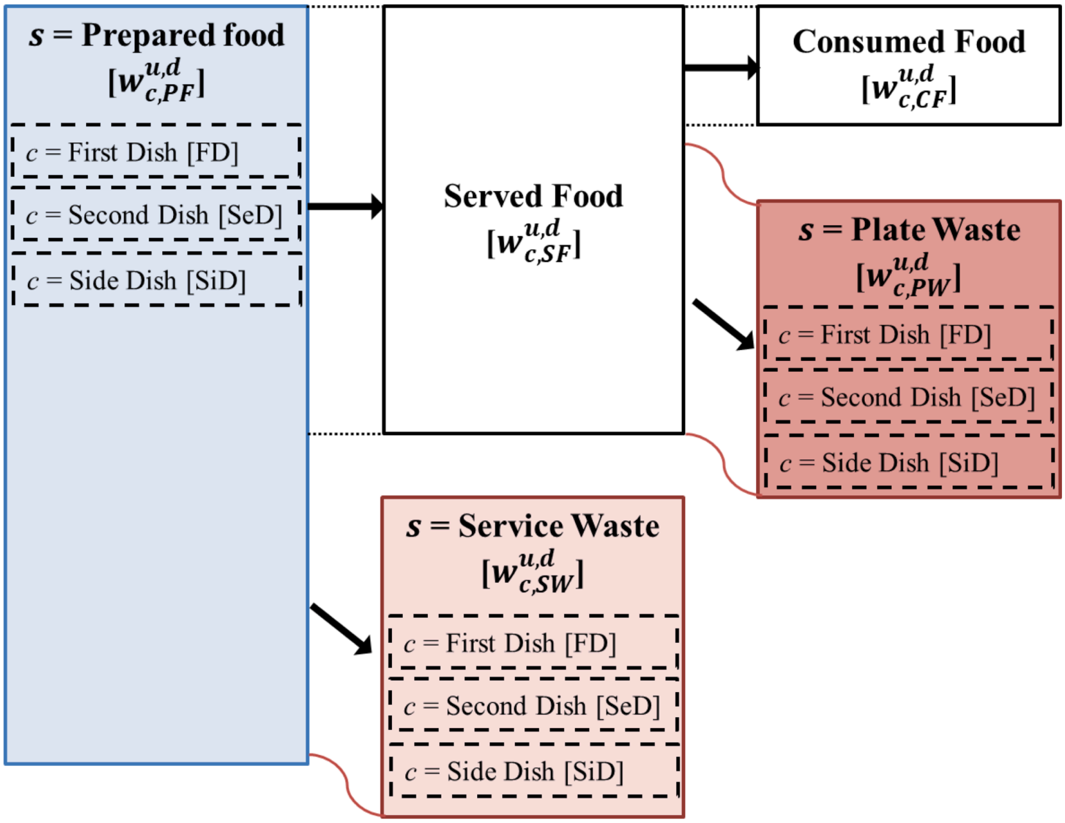

Fig. 4. Food mass flows considered in this study per class and day. Note: The relative sizes of the boxes do not represent food quantities. Colored boxes indicate measured quantities, while white boxes indicate quantities that have not been measured but have been derived from those.

Table 2
Incidences of food categories across courses.

FD category	#	%	SeD category	#	%	SiD category	#	%
Pasta with veggies	92	25 %	Meat (white, fresh)	69	18 %	Raw veggies and salads	112	30 %
Rice	63	17 %	Cakes (pies, salty cakes etc.)	51	14 %	Carrots (cooked)	53	14 %
Soups	61	16 %	Fish (fresh)	50	13 %	Others	38	10 %
Fresh Pasta	52	14 %	Cheese (fresh)	29	8 %	Fennel (cooked)	32	9 %
Pasta with oil	37	10 %	Pulses (processed)	28	8 %	Cabbage (cooked)	30	8 %
Pasta with pulses	21	6 %	Meat (beef, fresh)	27	7 %	Potatoes (cooked)	30	8 %
Pasta with fish	16	4 %	Eggs	25	7 %	Green peas (cooked)	29	8 %
Pasta with meat	13	3 %	Cheese (matured)	22	6 %	Peas (cooked)	17	5 %
Pizza	12	3 %	No SeD*	19	5 %	Spinach (cooked)	12	3 %
Others	6	2 %	Fish (processed)	17	5 %	Cauliflower (cooked)	10	3 %
			Meat (pig, fresh)	12	3 %	Zucchini (cooked)	6	2 %
			Pulses (natural)	12	3 %	No SiD**	4	1 %
			Meat (preserved)	10	3 %			
			Others	2	1 %			
Total	373	100 %	Total	373	100 %	Total	373	100 %

Notes: Categorization for first dishes (FD), second dishes (SeD) and side dishes (SiD), respectively. Incidences measured via observation counts ("number of" #) and frequencies (%).
* In these cases, schools served the single dish (see Section 2.2) which we categorized as FD.
** In these cases, schools did not serve SiD contrarily to what the region's guidelines suggest.

and relate to the eating environment and operative circumstances of the lunches.

To assess our three hypotheses, we define three outcome variables calculated as the share of plate waste in the total amount of food served to children $PW\%_c{}^{u,d}$ for each of the three courses $c = \{FD, SeD, SiD\}$ as:

$$PW\%_c{}^{u,d} = \frac{w^{u,d}_{cPW}}{w^{u,d}_{cPF} - w^{u,d}_{cSW}} \cdot 100 \tag{3}$$

In contrast to most similar studies that adopt absolute weights or frequencies of plate waste as outcome measures (Cohen et al., 2015; Redden et al., 2015; Thompson et al., 2017), $PW\%_c{}^{u,d}$ allows to standardize food waste measurements relatively to the amount of food that a class actually received. This approach is necessary when covering a wide set of schools many of which might slightly differ from each other in the actual institutional implementation of the lunch serving. We cover a sample of schools governed by 8 different sanitary units (i.e., having slightly different practices for menu implementation) and supplied by 6 different catering providers, ultimately resulting in a high degree of heterogeneity. Thus, we are able to control for differing service styles of the canteen providers in different schools as some canteen providers might systematically serve more/less food than specified in guidelines.

The heterogeneity in the served side dish is in fact greater between schools, than between classes within the same school (see Supplementary Table G). Moreover, such outcome measure enables us to compare foods that are very different in mass as wasting 30 g of salad is hardly comparable with wasting 30 g of potatoes, since the recommended portion for Italian schools for potatoes is 150 g/pupil while the one for salads is 50 g/pupil. The choice of using plate waste share rather consumption volumes was taken since directly measuring consumption volumes was not feasible in our intervention setting. Additionally, results expressed in food waste can be straightforwardly used for informing the growing debate on the topic (Bruns et al., 2024; Zhang et al., 2023) and can serve as a basis for the sustainability evaluation of the phenomena similar to what done by García-Herrero, L. et al. (2019, 2021).

Using *PW* in gr/pupil as outcome measure might not be accurate since it does not account for the differing weights resulting from the different menus in schools and it does not control for the amount of food that children of one class receive. Hence, we choose the share of plate waste in the weight of food children have received ($PW\%_c{}^{u,d}$) as this appears to be the most accurate measurement of food waste produced. We observe a significant difference in the SiD quantities served to children in the two groups despite of randomization resulting from a Wilcoxon signed-rank test on median[10] weights of *PF, SF, SW, CF, PW* (g/pupil) at T0 between the control and treatment groups (see Supplementary Table H). Supplementary Figure D depicts the distributions of the deviations of *PF, SF, SW, CF, PW* (gr/pupil) from their median weights for the control and treatment groups at T0 and T1. Their skewed shapes appear plausible due to the fact that food categories are very different in weight (i.e., see previous example confronting salad and potatoes), and register only right-coded outliers since no negative values are possible. At T0 there are 121 different menu combinations of FD, SeD and SiD (see Supplementary Tables I and J).

3.4. Empirical approach

First, to show the internal validity of our study, we describe the core characteristics of our randomized sample at baseline.[11] We investigate the dietary patterns of children in order to provide a general assessment of their relations to the MD and characterize typical menus of FD, SeD and SiD served to the third graders.

Second, we use flow diagrams – following García-Herrero et al. (2021) or Pancino et al. (2021) – to visualize the typical food flow and food waste structures across all sampled school canteens before the intervention based on median weights and their 95 % confidence intervals (CIs) of each of the five preparation steps *PF, SF, SW, CF,* and *PW*.

Third, we investigate whether company sizes of the catering providers *P* cause heterogeneity in food waste structure. For that aim, we consider three types of catering providers: small ones serving one school, medium ones serving two to four schools, and big ones serving between nine to ten schools. We focus the analysis on contrasting the largest vs. the smallest caterers. For that, we aggregate the food waste measurements of the two largest and the two smallest catering companies. With the help of a tree map we visually compare the food waste structures in the classes they serve relative to the weights of their prepared food at T0. Wilcoxon signed-rank tests are conducted on the medians of *PF*, *SF*, *SW*, *PW*, *CF* between the two groups in order to detect significant differences.

Fourth, we characterize the observed patterns in the changes in average plate waste shares per pupil before and during the intervention in order to assess its causal impact. As the existing literature reported in Table 1 assesses intervention impacts for an average sample of 3 schools[12] and each of the eight AUSL strata of our sample of 26 schools also includes on average 3 schools, we first take a disaggregated perspective and re-interpret our experiment as eight simultaneously performed small interventions. Hence, we analyze in a first step the plate waste shares *PW%* disaggregated by AUSL. This perspective guarantees comparability with the typical sample sizes used so far and, most importantly, allows to assess the homogeneity of the effects found across all eight AUSLs which will – in contrast to the existing literature – for the first time provide evidence on the external validity of the results obtained. To describe how *PW%* differs for the FD, SeD and SiD across the AUSLs, we compare the means[13] of *PW%* for the treatment and control groups at T0 and T1 by AUSL. We then present summary statistics of *PW %* for the entire sample and test for statistically significant differences of the changes in *PW%* from T0 to T1 for the treatment and the control group accompanied by boxplots of *PW%* by AUSL.

To assess the treatment effect of the inversion of the dish sequence on plate waste percentages we apply a difference-in-differences regression in the fifth and last step of the analysis.[14] We assume that the average outcome among the treated and non-treated would have followed "parallel trends" in the absence of treatment because without the intervention they would have been exposed to the same menus and stimuli. Since children were not informed about the intervention, we also can plausibly assume that the treatment has no anticipation effect (i.e., a causal impact before its actual implementation). Together these assumptions allow us to identify the average treatment effect on the treated (ATT) defined in Eqs. (4) using a two-way fixed effects (TWFE) regression. To account for the institutional heterogeneity of catering services due to the different AUSL regulations and service implementation, we consider a difference-in-difference specification that allows for multiple groups, one treatment ($i = 1$) and one control ($i = 0$) for each AUSL.

$$PW\%_c{}^{u,d,a} = \alpha_{i,a} + \phi_{t,a} + \sum \delta_{post,a} D_{i,t,a}^{u,d} + \sum \beta_{ca} Ca_c^{u,d} + \sum \beta_X X^{u,d} + \varepsilon_{i,t,a}. \tag{4}$$

The outcome variable $PW\%_c{}^{u,d,a}$ denotes the share of plate waste in the total food served to the average pupil in class *u* on day *d* for meal course $c = \{FD, SeD, SiD\}$ in AUSL $a = \{1, 2, .., 8\}$; $D_{i,t,a}^{u,d}$ is a dummy variable that takes value 1 for the treatment groups in the intervention period for each AUSL. It represents the interaction of a treatment variable that takes value 1 for the treatment group during the intervention with 8 dummies taking value 1 for each AUSL. The parameters $\alpha_{i,a}$ and $\phi_{t,a}$ are the corresponding group and time fixed effects at AUSL level and $\sum \delta_{post,a}$ represent the ATT for each AUSL. $Ca_c^{u,d}$ are dummy variables for the food categories (see Table 2 for the full list) and $X^{u,d}$ is a vector of class-level covariates described in Supplementary Table F; $\varepsilon_{i,t,a}$ is a mean-zero error term. As suggested by Roth et al. (2023) we estimate standard errors clustered at the school level at which treatment is independently assigned.

We then estimate Eqs. (5) for the overall sample, i.e., considering only one treatment and one control group to assess whether the effect of the intervention is homogeneous across the eight AUSLs:

[10] Considering the skewed distribution of *PF, SF, SW, CF, PW* in gr/pupil (see Supplementary Figure D) we use the median as preferred measured of central tendency.

[11] In order to deliver a transparent analysis, we report all weights in gram per average pupil unless differently stated.

[12] We calculated the means of schools sampled in similar previous studies (see Table 1).

[13] Considering the normal distribution of *PW%* (see Supplementary Figure E) we use the mean as the preferred measured of central tendency.

[14] Since we found no statistically significant correlation between the class composition and the *PW%* for FD, SeD and SiD (see Supplementary Table K), we consider each observation as repeated cross-sections in which only two time periods are available (i.e., the treated schools that receive the treatment during the second period, and the schools of the control group that do not receive the treatment in either period).

$$PW\%_c{}^{u,d} = \alpha_i + \phi_t + \delta_{post}D^{u,d}_{i,t} + \sum \beta_{ca}Ca^{u,d}_c + \sum \beta_X X^{u,d} + \varepsilon_{i,t}. \quad (5)$$

In Eqs. (5),$D^{u,d}_{i,t}$ simplifies to a dummy variable that takes value 1 for the treatment group in T1 and α_i and ϕ_t are again group and time fixed effects. δ_{post} is the ATT at the level of the full sample (see Supplementary Table L for the detailed description of the model).

We assess robustness of these estimations in three ways. First, considering the repeated measures over time for each class (5 consecutive school-days for T0 and T1) we test the model whether our results are robust to time correlations between observations. Second, as Boschini et al. (2020) reports that differences in catering providers are the most important food waste driver in Italian schools, we estimate Eqs. (5) also for each of the three caterer company sizes. Third, we estimate Eqs. (5) also for a derivative measure of consumption (specified in Eqs. (1) and Eqs. (2) to check for possible spillover effects on consumption.

4. Results and discussion

4.1. Dietary patterns of school lunches

Table 3 displays the characteristics of the 13 schools randomly assigned to the control group and the 13 of the treatment group. Characteristics are similar across the intervention and control group.

Schools serve a vast range of dishes (10 FD categories, 15 SeD categories and 12 SiD categories across the full sample – see Table 2) and diverse menus. In the control and treatment groups in both periods 127 unique dish combinations of FD, SeD, and SiD are served (Supplementary Materials Tables I and J).[15] The combination across both groups most frequently served is pasta with veggies (FD) followed by fresh fish (SeD) and raw veggies (SiD). Among the ten most served unique combinations, pasta with veggies is the most frequent FD, while meat (both beef and white) is the most frequent SeD. The only reoccurring SiD across the ten most served unique combinations were raw veggies and salads.

Although we do not aim to evaluate school children's adherence to the MD as done by Aresi et al. (2023), Roccaldo et al (2014) and Tognon et al. (2014), our results allow several conclusions. In line with the MD, the most frequently served FD are made of cereals topped with vegetables, or extra virgin olive oil (Table 2). While only rare amounts of red meat and moderate amounts of fish, dairy and poultry are suggested in the MD in favor of larger quantities of plant-based proteins (Benhammou et al., 2016), the investigated lunch menus do not strictly reflect this dietary pattern. The most frequently served SiD are animal-based proteins in the form of meat and fish. A variety of vegetables is served on a daily basis, both raw and cooked indeed reflecting MD patterns (Bach-Faig et al., 2011).

Table 3
Descriptive statistics.

Characteristics	Schools in treatment group (n = 13)	Schools in control group (n = 13)
# AUSL	8	8
# schools	13	13
# classes	20	19
# children	357	403
Min # children/class	8	6
Max # children/class	26	22
# average children/class	20.2	18.8
#catering providers	3	3

Notes: # means "number of".

4.2. Food mass flows in school lunch canteens

Fig. 5 displays the median weights and their 95 % CIs of each step of the food mass flow in the canteens of all 26 schools before the intervention (see Supplementary Table M for the list of variables used in the analysis). In the full sample, the median pupil receives for lunch 361 g of food ($w^{tot}_{c,SF}$) of which 207 g are FD, 79 SeD, and 70 SiD. From those amounts, the median children discard as plate waste 56 g of FD, 26 g of SeD, and 30 g of SiD resulting in a median of 117 g of plate waste generated by each child on every school day. This amount is almost one third lower than the 160 g waste per pupil and meal observed by Pancino et al. (2021) across 76 Italian schools. Nonetheless, Boschini et al. (2020) indicate a fairly high variability of food waste in schools as a consequence of factors such as types of foodservice providers, kitchen locations or existing mid-morning snacks. Similar patterns of very high variations of food waste in schools due to different menus and structural conditions were also found by Eriksson et al. (2017) or Derqui et al. (2018). Our results confirm this heterogeneity, since in our sample of 26 schools located in a single region, the 95 % CIs of plate waste medians tend to be large. This confirms the rather nonuniform structure of this food waste generation presumably due to highly heterogeneous food and eating environments (Fig. 1) which exist across school canteens and affect pupils' food intake.

We confirm findings from previous studies in Italian school canteens (García-Herrero et al., 2019; Falasconi et al., 2015), which unanimously detect the presence of significant waste amounts in the serving of food and the inadequate intake of vegetables by children. Food consumption per pupil amounts typically to 137 g of FD, 49 g of SeD and 27 g of SiD. Compared with the regional recommendation for primary schools (Regional Sanitary Service ER, 2023) we observe a certain deviation. Children typically consume 61 % more of the recommended FD quantity and insufficient amounts of SeD and SiD which fall short the recommended portions by −20 % and −76 %, respectively. The large CIs hint to substantial intake variability across children, classes, and schools.

Based on the data provided in Supplementary Table N, we estimate total food and waste amounts circulating in public primary school canteens at the country level of Italy. Food amounts are estimated by multiplying the number of total meals served in Italian primary schools by the median food mass weights of Fig. 5. The quantity of food prepared for all primary school canteens in Italy amounts to ca. 77,000 tons per year of which 45,000 tons of FD, 17,000 tons of SeD, and 15,000 tons of SiD.[16] Over one school year, the plate waste generated in public primary Italian school canteens amounts to ca. 22,000 tons, of which 11,000 tons of FD, 5,000 tons of SeD and 6,000 tons of SiD. Our estimation enriches the results of Pancino et al. (2021) which provide aggregated quantities for plate waste plus serving waste. They estimate that all Italian primary school generate about 30,000 tons of non-consumed food per school year.

4.3. Food waste structure and caterer size

In order to provide some insight about the relation between

[15] The observed differences in the numbers of unique menus at T0 (121) and T1 (110) was caused by the 17 missing observations due to unplanned strikes (see section 3.2) and the few exceptional cases when catering services implemented small menu changes due to procurement shortages. Menu counts in the control and treatment groups at T0 are similar.

[16] Such evidence supports a better understanding of the relevance of this sector in driving procurement practices. The exact values are 77,097 tons servings per year of which 44,493 tons of FD, 17,662 tons of SeD, and 14,943 tons of SiD of which 22,012 tons is total plate waste consisting of 11,069 tons of FD, 5,076 tons of SeD and 5,867 tons of SiD. When using/referring to these point estimates the large CIs of our results should be considered which suggest some heterogeneity of food mass quantities across school canteen settings.

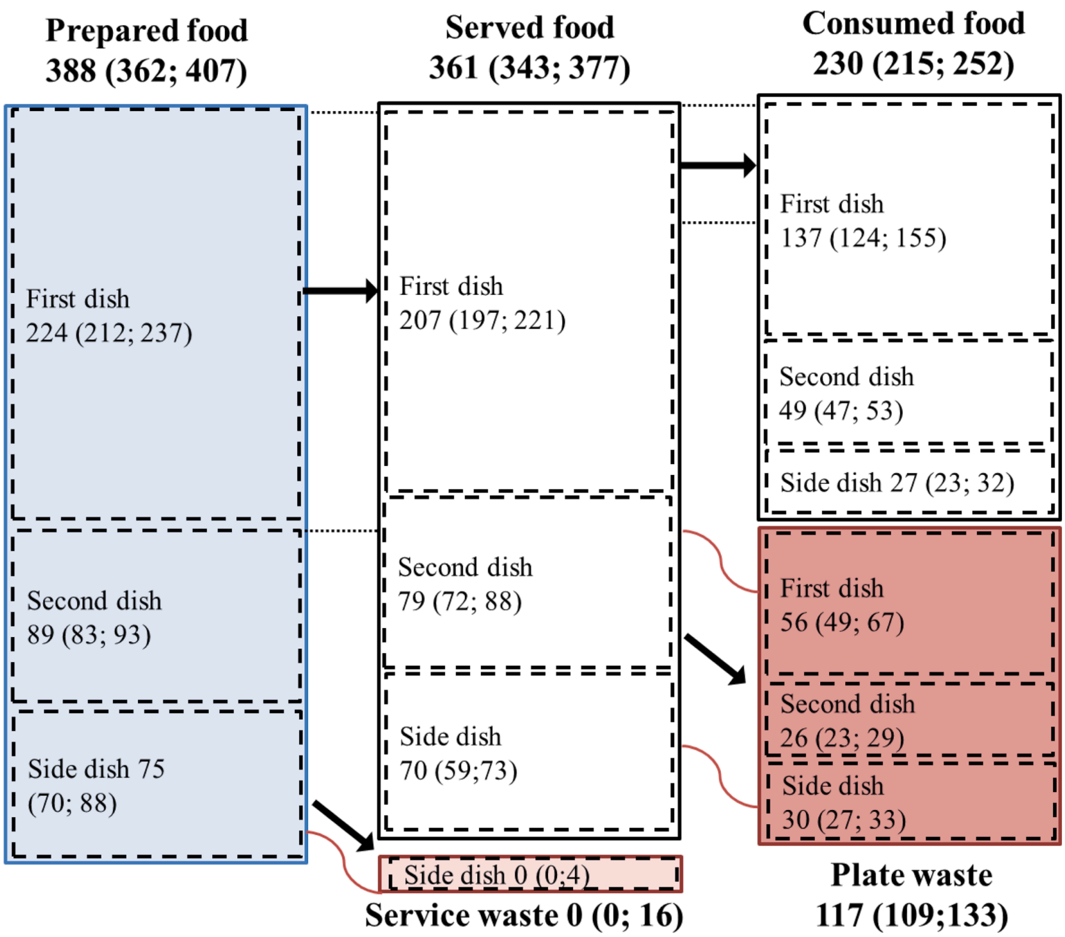

Fig. 5. Median food mass flows (g/pupil) before the intervention. Note: The sizes of the boxes approximately represent the shares of the median food quantities at T0 for all 26 schools in the column total. Note that the weights of FD, SeD and SiD do not exactly add up to the column totals as all values are measured/ calculated medians.

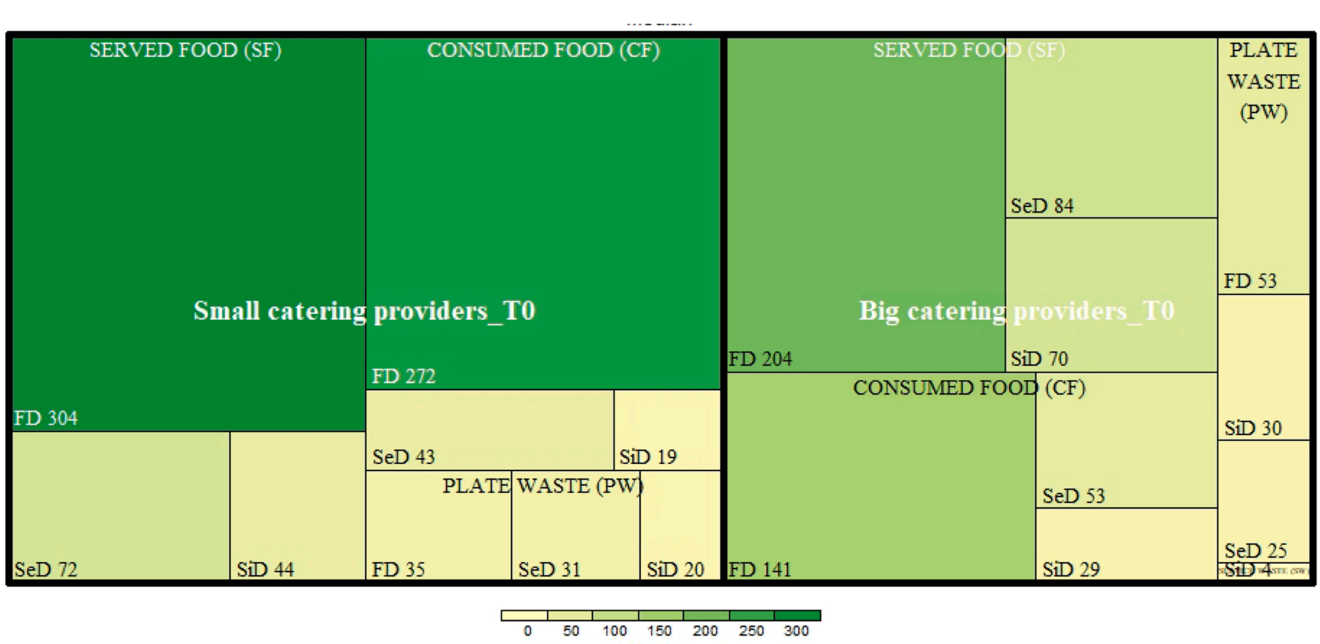

Fig. 6. Median weights (g/pupil) of lunch components for small and big catering providers at T0. Note: SW is shown only for the SiD of big caterers since for small providers it has a median of zero for all three courses.

institutional implementation of school lunches and food waste, we now analyze to what extent the structure of various food waste aspects depend on the size of the catering provider – measured as the number of schools supplied by a certain company – at T0. For that aim, we contrast big to small caterers.

Fig. 6 shows that although served portions of the first three courses of small caterers amount to 420 g, 86 g get typically discarded by pupils without any serving waste, while for large operators 358 g are served of which typically 108 g get wasted and 4 g per pupil are lost in the serving process.[17] SiD portions served by small operators are structurally 38% smaller than those served by large firms and significantly less serving waste is generated. Plate waste and pupil's SiD intakes do not structurally differ by catering company size (Supplementary Table P).

In schools served by small companies, children consume 50% significantly more of the first three courses FD, SeD and SiD so that total *PW* is 20% significantly lower (see Supplementary Table P). Therefore, we observe a significant relationship between the size of catering companies and the total plate waste of children. The sustainability performance of small catering providers is much better than big catering providers. The median pupil wastes 20% (30%) of *SF* in schools supplied by small (big) providers of the total of the three courses served. The largest share of *PW/SF* occurs for SiD (47% for small and 42% for big caterers), while only 11% (26%) of the FD is discarded for small/big caterers.

Significantly larger FD quantities (+49%) are served in schools supplied by small operators, children consume significantly more FD (+93%), and waste less of it (−34%). No significant differences appear between small and big catering providers for SeD intake and plate waste.

4.4. Descriptive analysis of the outcome variable

Fig. 7 shows the distributions of plate waste shares *PW%* for each of the three courses FD, SeD and SiD as well as the total *PW%* for control and treatment at T0 as well as T1 for all eight school clusters (AUSLs) and the entire sample. The heterogeneity both in changes of *PW%* averages and CIs from pre- to during intervention point to a high variability in practical implementation of the school catering services which are governed and defined by each AUSL for all schools located in its area. In particular, average plate waste shares of SiD during the intervention significantly lowered only in AUSL4, significantly increased in AUSL2, but did not significantly change for six of the eight strata (Supplementary Table Q). Plate waste shares of FD during the intervention did not significantly change in any of the treated classes, while plate waste shares of SeD significantly increased in treated classes in AUSL2 and significantly lowered in AUSL3 (Supplementary Table Q). This evidence, hence, stresses the importance to consider a more diverse sample of schools for guaranteeing the external validity of the effects of such interventions in comparison to sample sizes of three schools or less which are predominantly used in the literature.

Statistical characteristics of the plate waste shares for the full sample are presented in Table 4 and illustrated in the bottom right panel of Fig. 7 and in Supplementary Figure F. The plate waste shares of the SiD only are also provided for each of the 10 days of measurements in each school in Supplementary Figure G. Supplementary Table R details the same characteristics for the treatment and control groups separately at T0 and T1. Across the treatment and control groups before and during the intervention 36% of the food served is wasted by the average pupil. Both for the treatment and control, SiD accounts with 53% for the largest shares of the servings not consumed while waste of the second dish (around 36%) and of first dish (around 32%) are on average lower. In both groups, the variability of FD and SeD plate waste indicated by the coefficient of variation (CV) is higher than for SiD. This can be interpreted as a broader convergence of likes and dislikes on the SiD across children, which in turn drives the lower variability of the total plate waste (i.e., they waste similar amounts across different SiD types). Differently, the high variability of FD and SeD suggests that children are more sensitive to the type of FD and SeD served (i.e., they waste very different amounts depending on what is served on that day). However, the CIs for the control and the treatment groups have similar widths (see Fig. 7). For the entire sample no significant changes in plate waste shares of FD, SeD and SiD appear between T0 and T1 (see Supplementary Table Q).

4.5. Average treatment effects of the intervention

Table 5 and Table 6 report estimations for the difference-in-difference regression models providing insights for the hypothesis guiding this study (H1 to H3). Table 5 reports the ATT for each of the 8 AUSLs estimated with eq. (4) on the SiD (H1), FD and SeD (H2) respectively. Concerning hypothesis H1, we find that in all but one AUSL (AUSL8) SiD plate waste shares change significantly due to the intervention. We observe significant decreases in *PW%* of SiD in AUSL 3 (−26 percentage points (pp) change in plate waste share), and AUSL 4 (−13 pp change in plate waste share), while in the other six the intervention led to a significant increase in SiD plate waste shares (+19 pp, +32 pp, +10 pp, +10 pp, +18 pp in AUSL1, AUSL2, AUSL5, AUSL6, and AUSL7, respectively). This pattern at individual school cluster level per AUSL results in no significant ATT for the SiD plate waste share across all 13 treated schools as estimated with eq. (5) (Table 6, first line).

When assessing hypothesis H2, Table 5 shows a significant increase of the intervention on the FD plate waste share in AUSL2 (+13 pp), AUSL4 (+13 pp), and AUSL5 (+6pp). Concerning the induced changes in the shares of served SeD discarded by students, Table 5 reports heterogenous effects: a significant increase of SeD plate waste share is registered in AUSL2 (+39 pp) and AUSL5 (+9pp), while a significant decrease is found for AUSL3 (−16 pp) and AUSL6 (−18 pp). Across all treated schools, serving the SiD first has no significant effect in changing plate waste shares of either FD or SeD (Table 6).

Thus, if we interpret our experiment as eight simultaneously performed small interventions, they exhibit a considerable heterogeneity of effects with respect to H1 and H2. Due to that lack of comparable effect sizes and effect directions, no significant change for any of the three plate waste shares due to the intervention is found across all 13 schools with 357 pupils which have been exposed to the intervention of serving the vegetable side dish first. Our results are robust to time correlations (Supplementary Material Table S presents the robustness check) and to catering service provider company sizes supplying the sampled schools (see Supplementary Table T). Therefore, we infer that differences in the intervention effects across the eight AUSL described in Table 5 are not driven by differences across provider sizes. Finally, our results remain consistent also if the intervention effect is measured on the derived consumption volumes and on the derived consumption volumes over the total amount of food served to children as in the AUSLs where plate waste increased, consumption volumes decreased and vice versa (see Supplementary Table U and Table V).

We also conclude that the heterogeneity in practical lunch implementation described in the literature as food and eating environments (Fig. 1) across schools and classes appears to dominate the effects of the intervention on the shares of the served food for each of the three courses discarded.

This suggests that previous studies assessing intervention impacts from small samples of about 3 schools on average, which were not randomly selected (Table 1) are likely to have mainly picked up school-specific institutional or socio-cultural factors instead of robust and generalizable effects of the intervention. They, therefore, possess not only very limited internal validity – because they are not conducted as RCT, but also very limited external validity so that any generalizations of

[17] Precise median weights for the sum of FD, SeD and SiD are indicated in Supplementary Material Table O. In the text the total median weights are indicated as sums of the median weights for FD, SeD and SiD visible in Fig. 6.

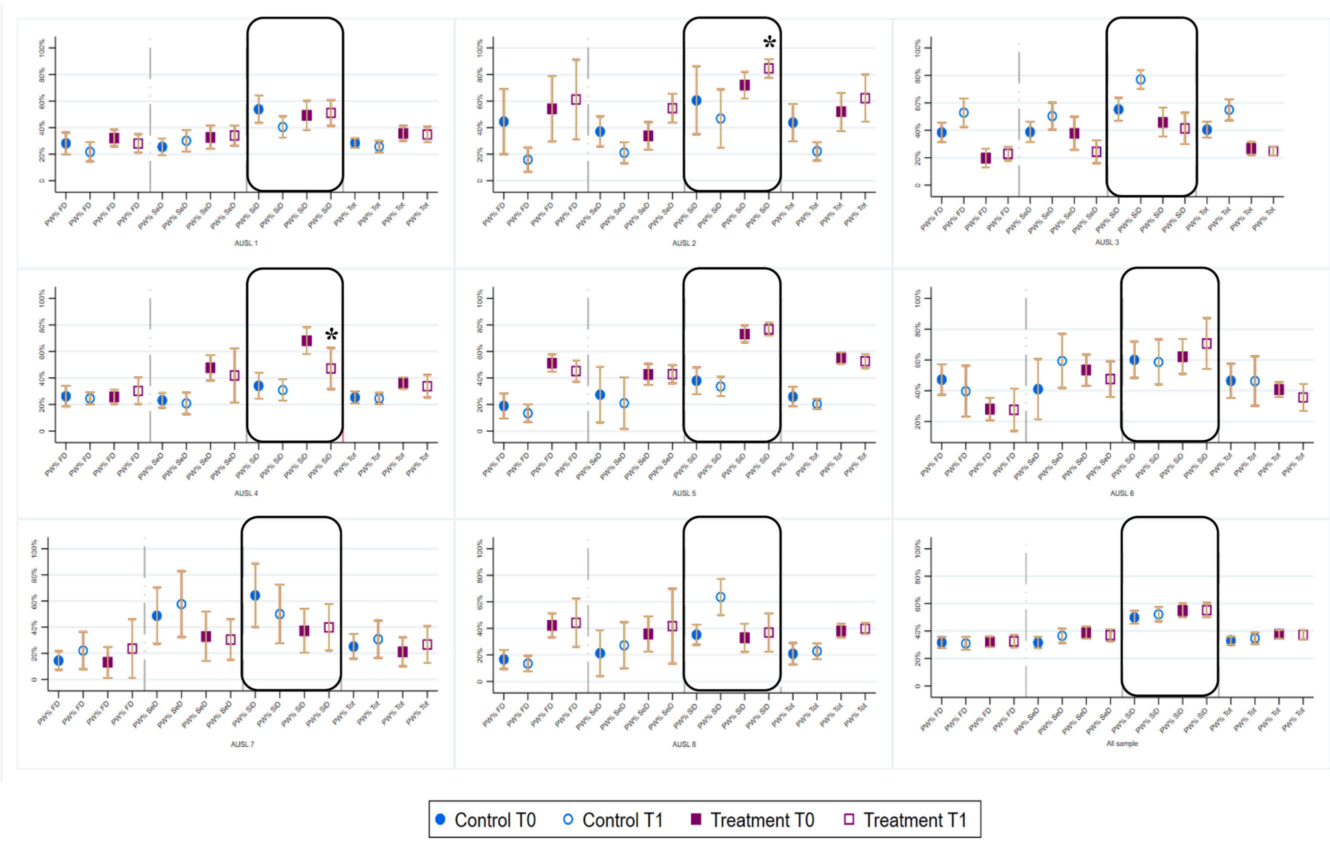

Fig. 7. Means and 95% CIs of plate waste shares *PW%* by course, period and school cluster. Notes: The frame highlights changes in PW% for the vegetable intake via SiD. The asterisk denotes significant changes observed in treatment schools during T1, that is, the third week of the intervention.

Table 4
Descriptive statistics of the full sample of plate waste percentages *PW%*.

Variable	Mean	95 % CI		CV	p50	IQR	IQR/p50
PW% FD	32%	30%	34%	65%	28%	25%	92%
PW% SeD	36%	34%	38%	60%	32%	33%	102%
PW% SiD	53%	51%	56%	47%	54%	42%	78%
*PW%*_tot	36%	34%	37%	47%	33%	23%	69%

Note: FD = first dish, SeD = second dish, SiD = vegetable side dish (target of the intervention), tot = FD + SeD + SiD.

their findings have to be made with great care.

For answering H3, average effects across the eight small-scale subsamples are presented in Table 6. Results suggest that – in contrary to the literature – the shares of the side dish which does not get eaten by pupils indeed depend on the type of vegetables served. Table 6 shows that among the vegetables served as SiD children waste on average significantly more zucchini (+48 pp plate waste share), cauliflower (+11 pp plate waste share), and cabbage (+8pp plate waste share), with respect to the benchmark category 'other vegetables'. Potatoes' plate waste share is significantly lower (−20 pp) than the benchmark. Plate waste shares of carrots, green beans, fennels, raw veggies, peas and spinach do not significantly differ from the benchmark category. Hence, contradicting the conclusion by Redden et al. (2015), some of the vegetables which an experiment might be using in a school lunch setting constitute a relevant influence factor on the intervention effect itself.

4.6. Limitations and future research

In contrast with existing studies outlined in Table 1 our paper substantially extends the internal as well as the external validity of the literature on the topic, moving from a prevalent USA-focused analysis to a RCT in the context of Mediterranean food culture, where the school meal choice environment differs substantially (see Supplementary Table A). The overall results we observe for the entire sample are in line with the heterogeneity of effects found so far, but at local level we have shown the potential reducing vegetable plate waste by 26 pp. Some previous studies suggest that the results of such an intervention have either a very small or no effect on the quantities of vegetables consumed (Table 1). Others indicate an increase in vegetable intakes of a maximum of 430% (Redden et al., 2015). Spill et al. (2011) found that when vegetable soups are served first, the lunch vegetable intake (in particular of broccoli) is reduced by more than 10%. The significant increase of *PW%* of SiD in 5 out of the 8 AUSLs where we implement the intervention is against our expectations, contrasting our *H1*. One of the reasons might be attached to the fact that when – compared to Anglo-Saxon settings where children have the freedom to consume dishes in their preferred order – children are used to typical meal sequences as in the Mediterranean food culture they might reject the consumption of vegetables being served first because does not correspond to the typical dish order they are used to from their families.

The intervention of prioritizing the side dish in the course order has been implemented for only three consecutive weeks. It is possible that exposing children to such a stimulus for longer periods could amplify the effects on vegetable food intake and waste reduction. In addition, to isolate the effect of the intervention, we did not combine the change in dish order with any educational activities for children that could raise acceptance. As our participatory approach for the design of the intervention did not include children although they are the recipients of the experiment, intervention effectiveness might be improved by considering their views. This, however, will require a broad cross-disciplinary approach in order to effectively communicate with them to successfully bring across the main ideas. Finally, we did not evaluate the temporal stability of the intervention effect. For achieving this, it would be

Table 5
Average treatment effects of the intervention by AUSL.

	PW% SiD (percentage points)	*PW%* FD (percentage points)	*PW%* SeD (percentage points)
Treatment AUSL1	19**	−4	−7
	(7)	(9)	(7)
Treatment AUSL2	32**	13*	39***
	(12)	(8)	(4)
Treatment AUSL3	−26***	−10	−16**
	(5)	(8)	(7)
Treatment AUSL4	−13**	13***	−5
	(6)	(4)	(4)
Treatment AUSL5	10**	6***	9***
	(4)	(2)	(2)
Treatment AUSL6	10***	−1	−18***
	(3)	(3)	(3)
Treatment AUSL7	18*	3	−3
	(9)	(7)	(4)
Treatment AUSL8	1	10	−3
	(6)	(10)	(8)
Food categories	Yes	Yes	Yes
Covariates	Yes	Yes	Yes
Observations	369	373	354
R-squared	0.912	0.852	0.862

Notes: Average treatment effects are given in percentage points. Standard errors in brackets. The asterisks mean: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. FD = first dish, SeD = second dish, SiD = vegetable side dish. Covariates are part of the model, but coefficients are omitted.

Table 6
Average treatment effects of the intervention for the full sample.

	PW% SiD (percentage points)	*PW%* FD (percentage points)	*PW%* SeD (percentage points)
Treatment	0.009	0.013	−0.050
	(0.059)	(0.037)	(0.039)
SiD vegetable categories:		Yes (omitted)	Yes (omitted)
Zucchini as SiD	0.479***		
	(0.076)		
Spinach as SiD	0.112		
	(0.070)		
Cauliflower as SiD	0.106*		
	(0.055)		
Cabbage as SiD	0.080**		
	(0.038)		
Fennel as SiD	0.060		
	(0.067)		
Raw veggies as SiD	0.024		
	(0.041)		
Green beans as SiD	0.008		
	(0.065)		
Carrots as SiD	0.003		
	(0.060)		
Peas as SiD	−0.035		
	(0.079)		
Potatoes as SiD	−0.204***		
	(0.047)		
SiD categories	Yes	Yes	Yes
Covariates	Yes	Yes	Yes
Observations	369	373	354
R-squared	0.328	0.322	0.291

Notes: Average treatment effects are given in percentage points. Standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. FD = first dish, SeD = second dish, SiD = vegetable side dish. Covariates are part of the model, but coefficients are omitted.

desirable to replicate the same experimental setup after a couple of months or 1 to 2 years targeting the same classes and schools.

We find that selected aspects of plate as well as serving waste significantly vary between large and small catering companies. Small companies serving only single randomly sampled schools turn out to have superior sustainability and nutritional quality performance as pupils' average vegetable intakes are structurally larger and some plate waste aspects are significantly smaller. Also, for some school clusters we find sizable treatment effects of the intervention while no or unexpected effect directions for others. Therefore, disentangling the role of dish order versus taste and qualitative food and eating environments as well as operative lunch circumstances would help understanding the reasons of such considerable heterogeneity. Such insights would facilitate developing effective incentive designs to support improving the sustainability performance of schools and other public canteens.

Although greater attention in the literature is dedicated to plate waste, complementary analyses on serving waste are needed to pave the way for improving the sustainability of food supply chains. Starting from existing knowledge on country-based drivers of serving waste (Ofei et al., 2015), future research might focus on identifying the most influential causes generating serving waste so that sustainability strategies can be tailored to avoid it.

We also provide a detailed characterization of the food mass flow in school canteens which might serve as the starting point for comparative analyses with food mass flows of other types of canteens. Such a comparison would allow to precisely evaluate the role of school canteens in comparison to, e.g., catering in hospitals, universities, or companies. Thus, similarly solid quantification of the food prepared, served, and wasted in combination with an extended quantification of qualitative food and eating environment characteristics should be provided for other contexts too based on sufficiently large sample sizes which will allow for the generalization of results. Lastly, advanced automatic measurement approaches such as picture-recognition in combination with artificial intelligence analyses might represent interesting options for future real-time food waste quantifications and would allow to assess their methodological strengths and weaknesses in comparison to direct weighting (Mikkelsen, 2019).

To isolate general effect patterns across national and regional nutrition habits and adapt the intervention to school settings in which children are exposed to different choice environments than in Italy, we recommend future research to create replications of this choice-architecture intervention across continents and dietary contexts. Future research might also increase the sample sizes of previously conducted analyses to help understanding if their results will be stable in comparable choice environments or whether there are factors beyond choice environments that lead to null results. Since the time available for eating has been found to be associated to consumption levels (Cohen et al., 2016), we also encourage future analysis to assess the optimal lunch break time – which might be beyond the currently implemented ones – so that pupils have the ideal time to eat the first served vegetables dish as well as the remaining menu to maximize healthy food intake of children and minimize food waste. Additionally, as the choice environment of the school meals may have direct implications on the results of this type of intervention, we suggest developing a comprehensive and systematic comparison of school meal implementations around the globe because this not yet available, but might serve to better contextualize the results of this type of intervention studies.

5. Policy implications and conclusions

Socio-economic research aims at informing evidence-based policy-making. Hence, we analyze to what extent does changing the dish order in school canteens by prioritizing vegetables yield a scalable policy strategy for shifting food intake towards a healthier and more sustainable trajectory. Our study covers the widest institutional heterogeneity of school catering analyses conducted so far. We use not only the largest and most diverse sample of schools so far achieved for this type of choice-architecture intervention, but our analysis is also the first implementing a randomized selection of schools. The design of our experiment substantially extends internal and external validity of similar studies and has, thus, an unprecedented potential for offering policy implications for international, national and local stakeholders.

Firstly, we broaden the existing knowledge on how much food is wasted in each food system segment (Caldeira et al., 2019) which will facilitate the design of effective policies for reducing food waste helping to reach SDG target 12.3 asking *to halve per capita global food waste*. Extrapolating our estimates informs national policymakers that all pupils eating at primary school canteens in Italy waste about 22,000 tons of food per year, which represents 29% of the food prepared for them. Bigger catering providers are found to generate more service waste and 23% more plate waste than smaller ones. This emphasizes the potential for food service companies and authorities to tailor waste reduction strategies. This could be substantially accelerated if policymakers or international institutions like the Milan Urban Food Policy Pact will create inventories of best practices, recommended actions as well as disincentivized actions for supporting the practical design and optimization of canteen food and eating environments which incentivize sustainable consumption patterns. Having provided evidence of the systematic presence of substantial food waste across lunch meal courses in schools, we conclude that actual food intake amounts rather strongly differ from nutritionally desired intakes. Hence, we encourage policymakers and nutritionists to scrutinize whether reducing the portion sizes of FD, SeD and SiD served to children in similar school meals settings would offer an option to cut food waste and resource use without jeopardizing nutritional goals – at least in the short and medium term until effective stimuli for raising vegetable intake have been identified.

Furthermore, our study contributes to the current debate on optimizing school menu structure for speeding up progress towards reaching core global sustainability goals for food systems transition (OECD, 2023). We not only provide a novel comparison of typical school lunch serving setups across ten Western countries but also enlarge the evidence on the effectiveness of a dish reprioritizing intervention in a school canteen environment with the aim of reducing waste to make more food available for children and achieve improved nutrition for reaching SDG2 of *zero hunger*.

From our experimental design and results researchers and international policymakers can understand the role of a sufficiently large sample size and heterogeneity for achieving generalizability of the measured effects. The treatment effects we derive from a sample of 26 randomly selected schools across an entire region of a country, in which around 4.5 million people live, appear to be fairly heterogeneous and not always consistent with each other. Hence, the heterogeneity in practical lunch implementation and food choice environments across schools and classes seems to dominate the effects of the intervention and challenges drawing a single conclusion about the general effectiveness of the intervention. Implementing food policies without considering this heterogeneity may result in undesired effects on food waste amounts generated by children.

Regional and municipal policymakers who took part in the participatory co-design were interested in understanding whether the intervention was effective enough to be translated into a binding policy recommendation to be applied across the entire regional territory. Based on our results, in school clusters where positive effects of the intervention were found (i.e., food waste amounts of vegetable are reduced), shares of plate waste in vegetable servings were reduced from 42% to 16% (i.e., only 12 g of vegetable servings would be discarded per child). Hence, our results also show the potential of the intervention. Put differently, if one assumes that this best-case scenario of reducing vegetable plate waste by 26 pp through prioritizing the vegetable side dish would be feasible in all Italian primary schools, about 1000 kg of vegetable plate waste per year would be avoided.

Comparing results across the school sub-samples show that the intervention significantly reduces food waste for some school clusters but increases it for others and therefore one type of intervention does not fit all. Since different vegetables are found to be associated with different shares of plate waste reduction, sustainability and diet improvements can only be expected for specific vegetable types. As a consequence, authorities of Emilia-Romagna have concluded that they will not upscale the dish reordering as a policy strategy applicable to the entire region. We expect this conclusion holds even more at national and international levels since we hypothesize that interventions covering various dietary patterns and school settings – which are likely to change across regions of one country and even more so across countries – are very likely to face even larger effect variability.

The participatory approach we adopted created positive spillovers in terms of engagement, trust, and sense of belonging. The authorities of Emilia-Romagna benefitted from initiating an exemplary effort for participating in intervention design and data collection in schools as well as from being an active stakeholder in creating robust science-based knowledge for optimizing the use of limited public funds for the best benefit of society. Such a citizen science approach in which stakeholders are involved via a living lab, entitles them to define questions and to find solutions jointly with science. As they are core agents of change, this experience increased their trust in the relevance, usability, and credibility of scientific results which they actively have influenced. As this process was perceived as a very positive and inspiring experience by all participants, we conclude that policymakers should strive to implement those living labs more often in order to involve stakeholders from different fields of knowledge and disciplines. By doing so scientists can in turn optimize the relevance, recognition, and societal impact of their research.

CRediT authorship contribution statement

M. Petruzzelli: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **E. Iori:** Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **R. Ihle:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **M. Vittuari:** Writing – review & editing, Validation, Supervision, Project administration, Investigation, Conceptualization.

Funding

This project was funded under the National Recovery and Resilience Plan (NRRP), Mission 4 820 Component 2 Investment 1.3 – Call for proposals No. 341 of 15 March 2022 of the Italian Ministry 821 of University and Research funded by the European Union – NextGenerationEU; 822 Award Number: Project code PE00000003, Concession Decree No. 1550 of 11 October 2022 823 adopted by the Italian Ministry of University and Research, CUP D93C22000890001, Project title 824 "ON Foods – Research and innovation network on food and nutrition Sustainability, Safety and 825 Security – Working ON Foods".

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors wish to thank Marina Fridel and the technical group of experts of the Servizio Igiene degli Alimenti e della Nutrizione within the Laboratorio di Ristorazione Sostenibile who contributed their knowledge and experience to the intervention design and implementation. The full list of names of contributors is included in the Emilia-Romagna region document n. 13073 of 06/07/2022 (in Italian "*Determinazione dirigenziale della Regione Emilia-Romagna n. 13073 del 06/07/2022*"). Nothing would have been possible without them. We also want to thank the colleagues of the University of Bologna who supported us in the data collection across the 26 schools. We are grateful to all schools that accepted to be part of our sample, and to all catering services providing food to these schools for allowing us to conduct the evaluation of the intervention.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodpol.2024.102784.

References

Adams, M.A., Bruening, M., Ohri-Vachaspati, P., Hurley, J.C., 2015. Location of school lunch salad bars and fruit and vegetable consumption in middle schools: a cross-sectional plate waste study. J. Acad. Nutr. Diet. 116 (3), 407–416. https://doi.org/10.1016/j.jand.2015.10.011.

Ahn, C., Heo, M., Zhang, S., 2015. Sample size calculations for clustered and longitudinal outcomes in clinical research. CRC Press, Boca Raton, FL.

Alexandratos, N., 2006. The Mediterranean diet in a world context. Public Health Nutr. 9 (1a), 111–117. https://doi.org/10.1079/PHN2005932.

Aliyar, R., Gelli, A., Hamdani, S.H., 2015. A review of nutritional guidelines and menu compositions for school feeding programs in 12 countries. Front. Public Health 3, 148. https://doi.org/10.3389/fpubh.2015.00148.

Antón-Peset, A., Fernandez-Zamudio, M.A., Pina, T., 2021. Promoting food waste reduction at primary schools. A case study. Sustainability (Switzerland) 13 (2), 1–19. https://doi.org/10.3390/su13020600.

Appleton, K.M., Hemingway, A., Saulais, L., Dinnella, C., Monteleone, E., Depezay, L., Morizet, D., Armando Perez-Cueto, F.J., Bevan, A., Hartwell, H., 2016. Increasing vegetable intakes: rationale and systematic review of published interventions. Eur. J. Nutr. 55 (3), 869–896. https://doi.org/10.1007/s00394-015-1130-8.

Aranceta Bartrina, J., Pérez Rodrigo, C., Dalmau Serra, J., Gil Hernández, A., Lama More, R., Martín, M.A., 2008. El comedor escolar: situación actual y guía de recomendaciones. Anales De Pediatrría 69 (1), 72–88. https://doi.org/10.1157/13124224.

Aresi, G., Giampaolo, M., Chiavegatti, B., Marta, E., 2023. Process evaluation of food game: a gamified school-based intervention to promote healthier and more sustainable dietary choices. Journal of Prevention 44 (6), 705–727. https://doi.org/10.1007/s10935-023-00741-3.

Bach-Faig, A., Berry, E.M., Lairon, D., Reguant, J., Trichopoulou, A., Dernini, S., Medina, F.X., Battino, M., Belahsen, R., Miranda, G., Serra-Majem, L., 2011. Mediterranean diet pyramid today. Science and cultural updates. Public Health Nutr. 14 (12A), 2274–2284. https://doi.org/10.1017/S1368980011002515.

Benhammou, S., Heras-González, L., Ibáñez-Peinado, D., Barceló, C., Hamdan, M., Rivas, A., Mariscal-Arcas, M., Olea-Serrano, F., Monteagudo, C., 2016. Comparison of Mediterranean diet compliance between European and non-European populations in the Mediterranean basin. Appetite 107, 521–526. https://doi.org/10.1016/j.appet.2016.08.117.

Binder, A., Naderer, B., Matthes, J., 2019. Do children's food choices go with the crowd? Effects of majority and minority peer cues shown within an audiovisual cartoon on children's healthy food choice. Social Sci. Med. 225, 42–50. https://doi.org/10.1016/j.socscimed.2019.01.032.

Black, J.L., Velazquez, C.E., Ahmadi, N., Chapman, G.E., Carten, S., Edward, J., Shulhan, S., Stephens, T., Rojas, A., 2015. Sustainability and public health nutrition at school: assessing the integration of healthy and environmentally sustainable food initiatives in Vancouver schools. Public Health Nutr. 18, 2379–2391. https://doi.org/10.1017/S1368980015000531.

Bonomo, T., Schanzenbach, D.W., 2024. Trends in the school lunch program: changes in selection, nutrition & health. Food Policy 124, 102608. https://doi.org/10.1016/j.foodpol.2024.102608.

Boschini, M., Falasconi, L., Giordano, C., Alboni, F., 2018. Food waste in school canteens: a reference methodology for large-scale studies. J. Clean. Prod. 182, 1024–1032. https://doi.org/10.1016/j.jclepro.2018.02.040.

Boschini, M., Falasconi, L., Cicatiello, C., Franco, S., 2020. Why the waste? A large-scale study on the causes of food waste at school canteens. J. Clean. Prod. 246, 118994. https://doi.org/10.1016/j.jclepro.2019.118994.

Boulet, M., Grant, W., Hoek, A., Raven, R., 2022. Influencing across multiple levels: the positive effect of a school-based intervention on food waste and household behaviours. J. Environ. Manage. 308, 114681. https://doi.org/10.1016/j.jenvman.2022.114681.

Bruns, H., De Laurentiis, V., García, H.L., Listorti, G., 2024. Behavioural insights to reach European Union consumer food waste reduction targets. Food Policy 128, 102725.

Bryant, M., Burton, W., O'Kane, N., Woodside, J.V., Ahern, S., Garnett, P., Spence, S., Sharif, A., Rutter, H., Baker, T., Evans, C.E.L., 2023. Understanding school food systems to support the development and implementation of food based policies and interventions. Int. J. Behav. Nutr. Phys. Act. 20, 29. https://doi.org/10.1186/s12966-023-01432-2.

Caldeira, C., De Laurentiis, V., Corrado, S., van Holsteijn, F., Sala, S., 2019. Quantification of food waste per product group along the food supply chain in the European Union: a mass flow analysis. Resour. Conserv. Recycl. 149, 479–488. https://doi.org/10.1016/j.resconrec.2019.06.011.

Campbell, M. J., & Walters, S. J. (2014). How to Design, Analyse and Report Cluster Randomised Trials in Medicine and Health Related Research. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118763452.

Campbell, M.K., Elbourne, D.R., Altman, D.G., 2004. CONSORT statement: extension to cluster randomised trials. Br. Med. J. 328 (7441), 702–708. https://doi.org/10.1136/bmj.328.7441.702.

Carlsson, F., Gravert, C., Johansson-Stenman, O., Kurz, V., 2021. The use of green nudges as an environmental policy instrument. Rev. Environ. Econ. Policy 15 (2), 216–237. https://doi.org/10.1086/715524.

Chapman, L.E., Richardson, S., McLeod, L., Rimm, E., Cohen, J., 2019. Pilot evaluation of aggregate plate waste as a measure of students' school lunch consumption. J. Acad. Nutr. Diet. 119, 2093–2098. https://doi.org/10.1016/j.jand.2019.04.001.

Chawner, L.R., Birtill, P., Cockroft, J.E., Hetherington, M.M., 2024. Eating vegetables at school lunchtimes: pilot and feasibility studies testing strategies to improve intake. Appetite 201, 107622. https://doi.org/10.1016/j.appet.2024.107622.

Chen, C., Chaudhary, A., Mathys, A., 2020. Nutritional and environmental losses embedded in global food waste. Resour. Conserv. Recycl. 160 (May), 104912. https://doi.org/10.1016/j.resconrec.2020.104912.

Cohen, J.F.W., Hecht, A.A., Hager, E.R., Turner, L., Burkholder, K., Schwartz, M.B., 2021. Strategies to improve school meal consumption: a systematic review. Nutrients 13 (10), 1–51. https://doi.org/10.3390/nu13103520.

Cohen, J., Richardson, S.A., Cluggish, S.A., Parker, E., Catalano, P.J., Rimm, E.B., 2015. Effects of choice architecture and chef-enhanced meals on the selection and consumption of healthier school foods. Diagn. Microbiol. Infect. Dis. 28 (10), 1304–1314. https://doi.org/10.1001/jamapediatrics.2014.3805.Effects.

Cohen, J., Jahn, J.L., Richardson, S., Cluggish, S.A., Parker, E., Rimm, E.B., 2016. Amount of time to eat lunch is associated with children's selection and consumption of school meal entrée, fruits, vegetables, and milk. J. Acad. Nutr. Diet. 116 (1), 123–128. https://doi.org/10.1016/j.jand.2015.07.019.

Custodio, M.C., Ynion, J., Samaddar, A., Cuevas, R.P., Mohanty, S.K., Ray, A., Demont, M., 2021. Unraveling heterogeneity of consumers' food choice: implications for nutrition interventions in eastern India. Glob. Food Sec. 28 (January), 100497. https://doi.org/10.1016/j.gfs.2021.100497.

Derqui, B., Fernandez, V., Fayos, T., 2018. Towards more sustainable food systems. addressing food waste at school canteens. Appetite 129, 1–11. https://doi.org/10.1016/j.appet.2018.06.022.

Elsbernd, S.L., Reicks, M.M., Mann, T.L., Redden, J.P., Mykerezi, E., Vickers, Z.M., 2016. Serving vegetables first: a strategy to increase vegetable consumption in elementary school cafeterias. Appetite 96, 111–115. https://doi.org/10.1016/j.appet.2015.09.001.

Emilia-Romagna region. (2023). *La carta del Laboratorio di Ristorazione Sostenibile*. https://site.unibo.it/laboratorio-ristorazione-sostenibile/it/attivita.

Eriksson, M., Persson Osowski, C., Malefors, C., Björkman, J., Eriksson, E., 2017. Quantification of food waste in public catering services – a case study from a Swedish municipality. Waste Manag. 61, 415–422. https://doi.org/10.1016/j.wasman.2017.01.035.

Falasconi, L., Vittuari, M., Politano, A., Segrè, A., 2015. Food waste in school catering: an Italian case study. Sustainability (Switzerland) 7 (11), 14745–14760. https://doi.org/10.3390/su71114745.

FAO. (2019). *The State of Food and Agriculture 2019*. FAO. https://doi.org/10.4060/CA6030EN.

Filippini, R., De Noni, I., Corsi, S., Spigarolo, R., Bocchi, S., 2018. Sustainable school food procurement: what factors do affect the introduction and the increase of organic food? Food Policy 76, 109–119. https://doi.org/10.1016/j.foodpol.2018.03.011.

García-Herrero, L., De Menna, F., Vittuari, M., 2019. Food waste at school. The environmental and cost impact of a canteen meal. Waste Manag. 100, 249–258. https://doi.org/10.1016/j.wasman.2019.09.027.

García-Herrero, L., Costello, C., De Menna, F., Schreiber, L., Vittuari, M., 2021. Eating away at sustainability. Food consumption and waste patterns in a US school canteen. J. Clean. Prod. 279, 123571. https://doi.org/10.1016/j.jclepro.2020.123571.

González Turmo, I. (2012). Chapter 5. The Mediterranean Diet: consumption, cuisine and food habits. In: MediTERRA 2012 (english) (pp. 115–132). Presses de Sciences Po. https://doi.org/10.3917/scpo.chea.2012.02.0115.

Graça, J., Campos, L., Guedes, D., Roque, L., Brazao, V., Truninger, M., Godinho, C., 2023. How to enable healthier and more sustainable food practices in collective meal contexts: a scoping review. Appetite 187. https://doi.org/10.1016/j.appet.2023.106597.

Gwozdz, W., Reisch, L., Eiben, G., Hunsberger, M., Konstabel, K., Kovács, E., Luszczki, E., Mazur, A., Mendl, E., Saamel, M., Wolters, M., 2020. The effect of smileys as motivational incentives on children's fruit and vegetable choice, consumption and waste: a field experiment in schools in five European countries. Food Policy 96. https://doi.org/10.1016/j.foodpol.2020.101852.

Haß, J., Hartmann, M., 2018. What determines the fruit and vegetables intake of primary school children? - an analysis of personal and social determinants. Appetite 120, 82–91. https://doi.org/10.1016/j.appet.2017.08.017.

Iaia, M., Pasini, M., Burnazzi, A., Vitali, P., Allara, E., Farneti, M., 2017. An educational intervention to promote healthy lifestyles in preschool children: a cluster-RCT. Int. J. Obes. 41, 582–590. https://doi.org/10.1038/ijo.2016.239.

IAP2 International. (2018). IAP2 Public Participation Spectrum. *International Association for Public Participation*, 1. https://cdn.ymaws.com/www.iap2.org/resource/resmgr/foundations_course/IAP2_P2_Spectrum_FINAL.pdf.

Ilić, A., Bituh, M., Brečić, R., Colić Barić, I., 2022. Relationship between plate waste and food preferences among primary school students aged 7–10 years. J. Nutr. Educ. Behav. 54 (9), 844–852. https://doi.org/10.1016/j.jneb.2022.04.003.

Italian Ministry of Health. (2010). *Linee di indirizzo nazionale per la ristorazione scolastica*.

Italian Society of Human Nutrition. (2014). *Dietary reference values of nutrients and energy for the italian population*. https://eng.sinu.it/larn/.

Kovacs, V.A., Messing, S., Sandu, P., Nardone, P., Pizzi, E., Hassapidou, M., Brukalo, K., Tecklenburg, E., Abu-Omar, K., 2020. Improving the food environment in kindergartens and schools: an overview of policies and policy opportunities in Europe. Food Policy 96 (March), 101848. https://doi.org/10.1016/j.foodpol.2020.101848.

Landwehr, S.C., Hartmann, M., 2024. Is it all due to peers? The influence of peers on children's snack purchase decisions. Appetite 192, 107111. https://doi.org/10.1016/j.appet.2023.107111.

Liz Martins, M., Rodrigues, S.S.P., Cunha, L.M., Rocha, A., 2020. Factors influencing food waste during lunch of fourth-grade school children. Waste Manag. 113, 439–446. https://doi.org/10.1016/j.wasman.2020.06.023.

Machado, S.S., Burton, M., Loy, W., Chapman, K.A., 2020. Promoting school lunch fruit and vegetable intake through role modeling: a pilot study. AIMS Public Health 7 (1), 10–19. https://doi.org/10.3934/publichealth.2020002.

MacInnis, D.J., Moorman, C., Jaworski, B.J., 1991. Enhancing and measuring consumers' motivation, opportunity, and ability to process brand information from ads. J. Mark. 55 (4), 32. https://doi.org/10.2307/1251955.

Maietta, O.W., Gorgitano, M.T., 2016. School meals and pupil satisfaction. Evidence from Italian primary schools. Food Policy 62, 41–55. https://doi.org/10.1016/j.foodpol.2016.04.006.

Mariam, N., Nina, L., Fabian, B., Florence, Z., Simone, A., Ulf, S., Daniel, F., 2022. The food waste lab: improving food waste reduction behavior through education. J. Clean. Production 370. https://doi.org/10.1016/j.jclepro.2022.133447.

Mazzeo, S.E., Bean, M.K., Palmberg, A.A., Simpson, C.C., Thacker, L.R., Dunne Stewart, M., Gow, R.W., 2017. A pilot intervention targeting dietary intake in school cafeterias. Health Behav. Policy Rev. 4 (3), 256–264.

Mikkelsen, B.E., 2019. Man or machine? Will the digital transition be able to automatize dietary intake data collection? Public Health Nutr. 22 (7), 1149–1152. https://doi.org/10.1017/S1368980018003993.

Ministry of Education of Portugal (2024). Refeitórios escolares. Direcção-Geral da Educação (DGE). Available at: https://www.dge.mec.pt/refeitorios-escolares. Accessed in August 2024.

Ministry of Health and Consumer Affairs of Spain (2008). Guía de comedores escolares. Ministerio de Sanidad y Consumo y Ministerio de Educación, Política Social y Deporte de Espana Programa Perseo. Available at: https://www.comunidad.madrid/sites/default/files/doc/educacion/p1206_guia_comedores_escolares_programa_perseo.pdf. Accessed in September 2024.

Moher, D., Schulz, K.F., Altman, D.G., 2001. The CONSORT statement: revised recommendations for improving the quality of reports of parallel-group randomized trials. J. Am. Podiatr. Med. Assoc. 91 (8), 437–442. https://doi.org/10.7547/87507315-91-8-437.

Münscher, R., Vetter, M., Scheuerle, T., 2016. A review and taxonomy of choice architecture techniques. J. Behav. Decis. Mak. 29 (5), 511–524. https://doi.org/10.1002/bdm.1897.

Myers, G., Wright, S., Blane, S., Pratt, I.S., Pettigrew, S., 2018. A process and outcome evaluation of an in-class vegetable promotion program. Appetite 125, 182–189. https://doi.org/10.1016/j.appet.2018.01.023.

Nardone, P., Spinelli, A., Ciardullo, S., Salvatore, M. A., Andreozzi, S., & Galeone, D. (2019). Obesità e stili di vita dei bambini: OKkio alla SALUTE 2019. In: Istituto Superiore di Sanità (Vol. 6).

Neyens, E., Smits, T., 2017. Seeing is doing. The implicit effect of TV cooking shows on children's use of ingredients. Appetite 116, 559–567. https://doi.org/10.1016/j.appet.2017.05.048.

OECD. (2023). *Food for thought: School meals for sustainable societies* (Issue 5). https://doi.org/https://doi.org/10.1787/629a2730-en.

Ofei, K.T., Werther, M., Thomsen, J.D., Holst, M., Rasmussen, H.H., Mikkelsen, B.E., 2015. Reducing food waste in large-scale institutions and hospitals: insights from interviews with Danish foodservice professionals. J. Foodserv. Bus. Res. 18 (5), 502–519. https://doi.org/10.1080/15378020.2015.1093457.

Pancino, B., Cicatiello, C., Falasconi, L., Boschini, M., 2021. School canteens and the food waste challenge: which public initiatives can help? Waste Manag. Res. 39 (8), 1090–1100. https://doi.org/10.1177/0734242X21989418.

Pastorino S., Springmann, M., Backlund, U., Kaljonen, M., Singh, S., Hunter, D., Vargas, M., Milani, P., Bellanca, R., Eustachio C. P., Makowicz B. D., Manjella, A., Wasilwa, L., Wasike, V., Bundy D. AP. (2023) School meals and food systems: Rethinking the consequences for climate, environment, biodiversity, and food sovereignty. Discussion Paper. London School of Hygiene & Tropical Medicine, London. doi: https://doi.org/10.17037/PUBS.04671492.

Peters, J., Langbein, J., & Roberts, G. (2017). Generalization in the tropics-development policy, randomized controlled trials, and external validity. In: *World Bank Research Observer* (Vol. 33, Issue 1). https://doi.org/10.1093/wbro/lkx005.

Piras, S., Righi, S., Banchelli, F., Giordano, C., Setti, M., 2023. Food waste between environmental education, peers, and family influence. Insights from primary school students in Northern Italy. J. Clean. Production 383, 135461. https://doi.org/10.1016/j.jclepro.2022.135461.

Price, J., Just, D.R., 2015. Lunch, recess and nutrition: responding to time incentives in the cafeteria. Prev. Med. 71, 27–30. https://doi.org/10.1016/j.ypmed.2014.11.016.

Qi, D., Li, R., Penn, J., Houghtaling, B., Prinyawiwatkul, W., Roe, B.E., 2022. Nudging greater vegetable intake and less food waste: a field experiment. Food Policy 112 (May), 102369. https://doi.org/10.1016/j.foodpol.2022.102369.

Redden, J.P., Mann, T., Vickers, Z., Mykerezi, E., Reicks, M., Elsbernd, S., 2015. Serving first in isolation increases vegetable intake among elementary schoolchildren. PLoS One 10 (4), 1–14. https://doi.org/10.1371/journal.pone.0121283.

Regional Sanitary Service ER. (2023). LINEE GUIDA PER L'OFFERTA DI ALIMENTI E BEVANDE SALUTARI E SOSTENIBILI NELLE SCUOLE E DEGLI STRUMENTI PER LA SUA VALUTAZIONE E CONTROLLO (pp. 1–89).

Reynolds, C., Goucher, L., Quested, T., Bromley, S., Gillick, S., Wells, V.K., Evans, D., Koh, L., Kanyama, A.C., Katzeff, C., Svenfelt, Å., 2019. Consumption-stage food waste reduction interventions–what works and how to design better interventions. Food policy 83, 7–27. https://doi.org/10.1016/j.foodpol.2019.01.009.

Robinson, D., Cawthray, J. L., West, S. E., Bonn, A., & Janice, A. (2018). Innovation in citizen science – setting the scene. In: Citizen Science Innovation in Open Science, Society and Policy (Issue May 2023, pp. 27–40). https://muse.jhu.edu/book/81913.

Roccaldo, R., Censi, L., D'Addezio, L., Toti, E., Martone, D., D'Addesa, D., Cernigliaro, A., Censi, L., D'Addesa, D., D'Amicis, A., Angelini, V., Bevilacqua, N., Catasta, G., Fabbri, I., Galfo, M., Martone, D., Roccaldo, R., Toti, E., Spinelli, A., Cernigliaro, A., 2014. Adherence to the Mediterranean diet in Italian school children (The ZOOM8 Study). Int. J. Food Sci. Nutr. 65 (5), 621–628. https://doi.org/10.3109/09637486.2013.873887.

Roe, B., Just, D., 2009. Internal and external validity in economics research: Tradeoffs between experiments, field experiments, natural experiments, and field data. Am. J. Agric. Econ. 91, 1266–1271. https://doi.org/10.1111/j.1467-8276.2009.01295.x.

Roe, L.S., Meengs, J.S., Rolls, B.J., 2012. Salad and satiety. The effect of timing of salad consumption on meal energy intake. Appetite 58 (1), 242–248. https://doi.org/10.1016/j.appet.2011.10.003.

Romagnolo, D.F., Selmin, O.I., 2017. Mediterranean diet and prevention of chronic diseases. Nutr. Today 52 (5), 208–222. https://doi.org/10.1097/NT.0000000000000228.

Roth, J., Sant'Anna, P.H., Bilinski, A., Poe, J., 2023. What's trending in difference-in-differences? A synthesis of the recent econometrics literature. J. Econom. 235, 2218–2244. https://doi.org/10.1016/j.jeconom.2023.03.008.

Spill, M.K., Birch, L.L., Roe, L.S., Rolls, B.J., 2010. Eating vegetables first: the use of portion size to increase vegetable intake in preschool children. Am. J. Clin. Nutr. 91 (5), 1237–1243. https://doi.org/10.3945/ajcn.2009.29139.

Spill, M.K., Birch, L.L., Roe, L.S., Rolls, B.J., 2011. Serving large portions of vegetable soup at the start of a meal affected children's energy and vegetable intake. Appetite 57 (1), 213–219. https://doi.org/10.1016/j.appet.2011.04.024.

Steen, H., Malefors, C., Röös, E., Eriksson, M., 2018. Identification and modelling of risk factors for food waste generation in school and pre-school catering units. Waste Manag. 77, 172–184. https://doi.org/10.1016/j.wasman.2018.05.024.

Story, M., Neumark-Sztainer, D., French, S., 2002. Individual and environmental influences on adolescent eating behaviors. J. Am. Diet. Assoc. 102 (3), S40–S51. https://doi.org/10.1016/S0002-8223(02)90421-9.

Szaszi, B., Palinkas, A., Palfi, B., Szollosi, A., Aczel, B., 2018. A Systematic scoping review of the choice architecture movement: toward understanding when and why nudges work. J. Behav. Decis. Mak. 31 (3), 355–366. https://doi.org/10.1002/bdm.2035.

Thaler, R., & Sunstein, C. (2008). Nudge: Improving Decisions About Health, Wealth, and Happiness.

Thapa, J.R., Lyford, C.P., 2018. Nudges to increase fruits and vegetables consumption: results from a field experiment. J. Child Nutrition Manag. 42 (1).

Thompson, E., Johnson, D.C., Leite-Bennett, A., Ding, Y., Mehrotra, K., 2017. The impact of multiple strategies to encourage fruit and vegetable consumption during school lunch. J. Sch. Health 87 (8), 616–622. https://doi.org/10.1111/josh.12533.

Tognon, G., Moreno, L.A., Mouratidou, T., Veidebaum, T., Molnár, D., Russo, P., Siani, A., Akhandaf, Y., Krogh, V., Tornaritis, M., Börnhorst, C., Hebestreit, A., Pigeot, I., Lissner, L., 2014. Adherence to a Mediterranean-like dietary pattern in children from eight European countries. The IDEFICS study. Int. J. Obes. (Lond) 38, S108–S114. https://doi.org/10.1038/ijo.2014.141.

USDA, 2020. Dietary Guidelines for Americans, 2020–2025. Work. Heal. Saf. https://doi.org/10.1177/21650799211026980.

Wansink, B., 2004. Environmental factors that increase the food intake and consumption volume of unknowing consumers. Annu. Rev. Nutr. 24 (217), 455–479. https://doi.org/10.1146/annurev.nutr.24.012003.132140.

WFP. (2017). *How School Meals Contribute to the Sustainable Development Goals. February*, 8. https://www.wfp.org/publications/2016-how-school-meals-contribute-sdgs.

Willett, W., Sacks, F., Trichopoulou, A., Drescher, G., Ferro-Luzzi, A., Helsing, E., Trichopoulos, D., 1995. Mediterranean diet pyramid: a cultural model for healthy eating. Am. J. Clin. Nutr. 61 (6), 1402S–S1406. https://doi.org/10.1093/ajcn/61.6.1402S.

Williams, K.E., Gibbons, B.G., Schreck, K.A., 2005. Comparing selective eaters with and without developmental disabilities. J. Dev. Phys. Disabil. 17 (3), 299–309. https://doi.org/10.1007/s10882-005-4387-7.

Zhang, J., Huang, Y., Zhu, J., Zhao, L., 2023. A meta-analysis on the effectiveness of food-waste reducing nudges. Food Policy 120, 102480. https://doi.org/10.1016/j.foodpol.2023.102480.

Zhao, C., Panizza, C., Fox, K., Boushey, C.J., Byker Shanks, C., Ahmed, S., Chen, S., Serrano, E.L., Zee, J., Fialkowski, M.K., Banna, J., 2019. Plate waste in school lunch: barriers, motivators, and perspectives of SNAP-eligible early adolescents in the US. J. Nutr. Educ. Behav. 51 (8), 967–975. https://doi.org/10.1016/j.jneb.2019.05.590.

Zhu, J., Luo, Z., Sun, T., Li, W., Zhou, W., Wang, X., Fei, X., Tong, H., Yin, K., 2023. Cradle-to-grave emissions from food loss and waste represent half of total greenhouse gas emissions from food systems. Nat. Food 4 (3), 247–256. https://doi.org/10.1038/s43016-023-00710-3.