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Greenhouse gas emissions of school lunches provided for children attending school nurseries: A cross-sectional study

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Abstract

Background: Schools and early years settings provide an opportunity to promote healthy and sustainable food, but standards and guidance in England focus predominantly on nutritional quality. The present study estimated greenhouse gas emissions (GHGE) of school lunches provided for children attending school nurseries, including comparison between meal options.

Methods: Menus, recipes and portion weights for lunches provided for 3–4-year-old children attending nine school nurseries were collected daily for one week. GHGE for each food and recipe were calculated using Foodprint functionality of Nutritics software. GHGE were calculated for each menu option (main, vegetarian, jacket potato and sandwich) provided in each school, and for meals with and without meat/fish.

Results: In total, 161 lunches including 273 foods were analysed. Median GHGE across all meals was 0.53 kgCO_2e (i.e. kilograms of carbon dioxide equivalent) per portion, with significantly higher GHGE associated with main meals (0.71 kgCO_2e per portion) compared to all other meal types (0.43–0.50 kgCO_2e per portion; $p < 0.001$) which remained after adjustment for meal size and energy density. Red meat-based meals were highest in GHGE (median 0.98 kgCO_2e per portion and 0.34 kgCO_2e per 100 g) and meals containing any meat/fish were significantly higher in GHGE (median 0.58 kgCO_2e per portion) than vegetarian meals (median 0.49 kgCO_2e per portion) ($p = 0.014$). Meals with higher adherence to the nutrient framework underpinning the early years guidelines had significantly higher GHGE than meals with lower adherence ($p < 0.001$).

Conclusions: The results were comparable to previous estimates of school lunch GHGE and highlight variation by meal option. Consideration of GHGE alongside the nutritional quality of lunches by caterers could support provision of healthy and sustainable lunches.

KEYWORDS
children, early years, greenhouse gas emissions, school lunch, sustainability

Highlights

- Mean greenhouse gas emissions (GHGE) across all meal types provided for 3–4-year-old children attending school nurseries was 0.61 kgCO_2e (i.e. kilograms of carbon dioxide equivalent) per portion (SD 0.32) (median 0.53 kgCO_2e per portion).

- When GHGE were compared for different meal types, total GHGE were significantly higher for main meals compared to jacket potato meals, vegetarian meals, and sandwich meals, and this was the case whether compared per portion, per 100 g food or per 100 kcal.
- Red meat was the greatest contributor to GHGE per portion.
- There was larger variation in the GHGE of non-vegetarian meals compared to vegetarian meals (depending on the protein included) and meals containing meat or fish had significantly higher GHGE than vegetarian meals.
- Meals with medium or high adherence to the nutrient framework underpinning the early years guidelines had significantly higher GHGE than meals with low adherence.

INTRODUCTION

One-third of global greenhouse gas emissions (GHGE) come from the food system.[1] A substantial dietary shift to a more "plant-forward" diet with increased consumption of whole grains, fruits, vegetables, nuts and legumes, as well as a reduction in animal source protein and dairy, has been proposed to support achievement of the UN Sustainable Development Goals and Paris Agreement on climate change.[2,3] In the UK, school food is the largest contributor to public sector food procurement[4] and 1.6 million (87%) infant pupils in England took up their eligibility for free school lunches in 2023.[5] In addition, one in five registered childcare places (315,000) are provided within a school setting.[6] Schools therefore represent an important opportunity to provide and promote more environmentally sustainable food[7,8] alongside supporting healthy diets.[9]

Lunches provided in schools in England are required to meet food-based standards.[10] These standards were developed to meet children's nutritional requirements, rather than considering environmental sustainability. However, supporting guidance recommends using fresh, sustainable and locally sourced ingredients, and includes advice such as encouraging children to have a meat-free day each week.[11] Voluntary food and drink guidelines for early years settings represent best practice in food provision for early years settings in England, including school nurseries.[12] Similar to the standards for school food, the food and drink guidelines for early years settings are food-based (defining whether, and how often, different foods should be provided within early years settings) developed to support food provision to meet a "nutrient framework" setting out appropriate amounts of energy and 11 different nutrients for children aged 1–4 years.[12] These guidelines also include general advice about reducing the environmental impact of food provision through strategies such as reducing food waste, and by choosing seasonal and locally grown foods, but it is not known how widely these guidelines are used to plan lunches for children attending school nurseries.[13]

Previous research has estimated the environmental impact of school lunch provision, predominantly through quantification of GHGE (expressed as carbon dioxide equivalent [CO_2e]) from the production and consumption of lunch foods, using life cycle analysis (LCA) data from published datasets.[14–19] The results indicate a wide variation in average school lunch GHGE between and within countries, as a result of factors such as level of red meat provision and waste.[7] Estimates of GHGE for primary school lunches in England have included analysis of data collected as part of a nationally representative survey of primary school lunches conducted in 2009 prior to the introduction of the current standards in 2015.[15,16] Mean GHGE for primary school lunches in 2009 were estimated as 0.72 $kgCO_2e$ (i.e. kilograms of carbon dioxide equivalent) per meal[15] and 1.02 $kgCO_2e$ per meal[16] by separate studies. Further modelling conducted by Wickramasinghe et al.[20] estimated that mean GHGE of primary school lunches would increase to 0.79 $kgCO_2e$ following the introduction of the current food-based standards in 2015. However, little research estimating GHGE of school lunches in England following the introduction of these current standards has been identified,[7] with no studies including school nursery lunches. In previous research conducted in Italian primary schools, protein-based dishes had considerably higher GHGE (0.44 gCO_2e per 100 g) than non-protein-based dishes (0.03–0.26 gCO_2e per 100 g).[21] Comparison of vegetarian and non-vegetarian school meals served in primary schools in France and Italy and in menus designed to meet Spanish schools' dietary guidelines has consistently shown vegetarian lunches to have lower GHGE than non-vegetarian lunches.[14,17,19] An increase in vegetarian lunches[22] and/or reduction in red meat provision[18] at the same time as maintaining overall nutritional quality have therefore been proposed as approaches to reduce GHGE of school lunches.

The present study aimed to evaluate the GHGE associated with school lunches, including different meal options, provided for 3–4-year-old children attending school nurseries. An additional aim was to compare the results obtained using the Foodprint functionality of Nutritics nutrient analysis software[23] with those of similar previous studies.[7,14,20] Previous analysis revealed that, on average, school nursery lunches provided excess energy, carbohydrate, fat, free sugars, and sodium in comparison to the nutrient framework underpinning the food and drink guidelines for early years settings, and insufficient iron.[24,25] A final aim was therefore to evaluate whether GHGE differed according to degree of adherence to this framework.

METHODS

Ethical approval was granted by Sheffield Hallam University research ethics review system (ID: ER38429936). A detailed description of school selection, data collection and nutritional analysis was published previously.[24,25] Briefly, 10 infant and primary schools providing lunches to nursery pupils were recruited from Sheffield and the surrounding areas between February and July 2022. Each school was visited on five consecutive days and, on each day, two portions of each meal option as served by kitchen staff for nursery children were collected. These typically included a main meal option (generally containing meat or fish), a vegetarian main meal option, a jacket potato option (a baked potato with fillings such as cheese, baked beans or tuna mayonnaise) and a sandwich option, each served with starchy and/or vegetable accompaniments and a dessert. Each food item was weighed using kitchen scales, and mean portion weights were calculated for each food item provided as part of each meal. Menu and recipe information (detailing the ingredients and quantities used to prepare the collected meals) was provided by nine of the 10 schools or their caterers.

The recipes provided by each school or caterer were entered into Nutritics nutrient analysis software[23] by two researchers, both registered nutritionists with experience in nutritional analysis. Ingredients included in the recipes were entered as raw foods with the cooking method applied to each ingredient to adjust for nutrient losses during cooking. The overall weight change was also calculated for each recipe using standard options in Nutritics.[23,26] Where individual foods were provided as part of meals (e.g., boiled carrots, raw cucumber), recipes were entered for these as either raw or cooked foods, depending how they were served. The exact portion weight was then entered for each recipe, using the portion weight data collected for that meal. Queries regarding missing or unclear information was resolved by consensus and ten percent of recipe analysis was checked to ensure consistency and reliability.

The analysis included 273 individual foods. GHGE (as kilogram [kg] CO_2 equivalents per kg food) were calculated for each food by the Foodprint functionality of Nutritics, based on the best available match from foods listed within published LCA research.[27–31] The GHGE data assigned for each food was manually checked by the researchers to ensure the most appropriate match was selected from the available options from different datasets, based on the description of the food, country of origin of the data and, for consistency between recipes entered by the two researchers. In total, 87 food codes (31.9%) were manually updated to either insert missing data or select a closer match than the default chosen by Nutritics. No available data were found for one food commonly served within the schools (purchased Yorkshire puddings), and the GHGE for this product were calculated based on the ingredients included within a standard Yorkshire pudding recipe.[26]

Weekly menus were created in Nutritics for each meal type (main meal, vegetarian main meal, jacket potato meal and sandwich meal, each including accompaniments and desserts) in each school and the GHGE of an average daily lunch provided for each meal type in each school was calculated (as kg CO_2 equivalents [CO_2e]) per serving). Schools usually offered a choice of dessert options as part of lunch, typically including a dessert listed on the menu (e.g., a cake or biscuit) or a fruit and/or yoghurt alternative. Where this was the case, an average of all available dessert options was included in the analysis for that day.

Data were exported from Nutritics and uploaded to SPSS for analysis.[32] Each meal was coded to state whether it was vegetarian (i.e., containing pulses, meat alternatives, eggs or cheese as the protein source, or included no protein source) or non-vegetarian (i.e., containing meat, poultry or fish) irrespective of the menu option it was included as part of (as not all main meal options contained meat or fish). Meals were also coded for the predominant protein sources contained within the main course (e.g., red meat, pulses and cheese or meat alternatives and pulses). The mean and median GHGE were then calculated for each meal type (per portion, per 100 kcal and per 100 g).

Previous analysis of the energy and nutrient content of the lunches[25] was used to classify each individual lunch as "meeting" or "not meeting" minimum and/or maximum standards for energy and 11 different nutrients included in the nutrient framework underpinning the voluntary food and drink guidelines for early years settings in England.[12] Lunches were then grouped into three categories of adherence with the nutrient framework depending on how many of the 12 standards had been met, to enable evaluation of GHGE by level of adherence with the nutrient framework (a measure of nutritional quality).

GHGE data by meal option showed unequal variances and/or was not normally distributed, so was analysed using non-parametric Mann–Whitney U tests and Kruskal–Wallis tests, aiming to check for significant differences in GHGE between vegetarian/non-vegetarian meals and by meal option and nutrient framework adherence respectively. $p < 0.05$ was considered statistically significant and, where significant differences were seen by meal type, a Dunn's post-hoc test with Bonferroni correction was conducted to check between which meal options and categories of adherence with the nutrient framework significant differences occurred. Although data were non-parametric, means and SDs are also reported to enable comparison with other studies.

RESULTS

In total, 161 lunches (45 main meals, 45 vegetarian meals, 39 jacket potato meals and 32 sandwich meals) including 273 individual food ingredients were analysed. GHGE data originated from systematic reviews and databases published by Scheelbeek et al.[27] (141 foods; 51.6%), The SU-EataBLE LIFE database[29] (53 foods; 19.4%), The AGRIBALYSE 3.0 database®[28] (35 foods; 12.8%), Clune et al.[30] (26 foods; 9.5%) and the Hestia database[31] (17 foods; 6.2%). GHGE for one food was calculated manually.

Mean GHGE across all meal types was 0.61 $kgCO_2e$ per portion (SD 0.32) (median 0.53 $kgCO_2e$ per portion). Total GHGE were significantly higher in main meals (mean 0.85 $kgCO_2e$ per portion), compared to all other meal types (mean 0.55, 0.53 and 0.46 $kgCO_2e$ per portion for jacket potato meals, vegetarian meals, and sandwich meals respectively) (median values 0.71, 0.50, 0.48 and 0.43 $kgCO_2e$ per portion respectively; $p < 0.001$) (Table 1). Because sandwich meals were significantly smaller than all the other meal types ($p < 0.001$) but provided the same amount of energy (non-significant difference, $p = 0.997$), GHGE were also calculated per 100 g and per 100 kcal for each meal type to adjust for size and energy content (Table 1). After adjustment for meal size, main meals remained significantly higher in GHGE (mean 0.28 $kgCO_2e$ per 100 g [SD 0.13], median 0.23 $kgCO_2e$ per 100 g; $p < 0.001$) than the other meal types, which were all 0.20 $kgCO_2e$ per 100 g or below. Adjusting for energy density, main meals also contributed higher GHGE per 100 kcal (mean 0.20 $kgCO_2e$ per 100 kcal [SD 0.11], median 0.15 $kgCO_2e$ per 100 kcal) compared to other meal types which were all 0.13 $kgCO_2$ $kcal^{-1}$ or below ($p < 0.001$).

In terms of the meal's protein type, "red meat" was the greatest contributor to GHGE per portion (1.02 $kgCO_2e$) and per 100 g (0.34 $kgCO_2e$ per 100 g) followed by "cheese and poultry", "cheese", "cheese and

TABLE 1 Meal weight, energy content and greenhouse gas emissions of lunches as served for 3–4-year old children attending nine school nurseries, by meal option.

	All meals	Main meals	Vegetarian meals	Jacket potato meals	Sandwich meals	*p* value
Number of meals	161	45	45	39	32	
Meal weight (g)						
Mean (SD)	298.6 (80.6)	296.2 (71.4)	302.3 (84.8)	352.0 (63.0)	231.8 (54.3)	
Median	295.7	295.7	290.0	352.8	229.0	$p < 0.001$
Energy content (kJ)						
Mean (SD)	1884.6 (48.0)	1874.6 (517.6)	1905.8 (712.3)	1826.6 (443.1)	1939.8 (752.9)	
Median	1821.4	1849	1804.7	1836.9	1784.1	$p = 0.997$
Energy content (kcal)						
Mean (SD)	447.7 (145.4)	445.3 (123.4)	452.8 (170.2)	433.3 (105.9)	461.1 (179.5)	
Median	433.4	439.0	429.9	435.1	424.3	$p = 0.997$
GHGE ($kgCO_2e$)						
Mean (SD)	0.61 (0.32)	0.85 (0.45)	0.53 (0.19)	0.55 (0.15)	0.46 (0.18)	
Median	0.53	0.71	0.50	0.48	0.43	$p < 0.001$
GHGE per 100 kcal						
Mean (SD)	0.14 (0.07)	0.20 (0.11)	0.12 (0.03)	0.13 (0.02)	0.10 (0.02)	
Median	0.12	0.15	0.12	0.13	0.11	$p < 0.001$
GHGE per 100 g						
Mean (SD)	0.21 (0.09)	0.28 (0.13)	0.18 (0.04)	0.16 (0.04)	0.20 (0.04)	
Median	0.19	0.23	0.17	0.15	0.20	$p < 0.001$

Abbreviations: g, grams; GHGE, greenhouse gas emissions; kcal, kilocalorie; $kgCO_2e$, kilograms of carbon dioxide equivalent.

fish" and then "poultry", each producing 0.21 $kgCO_2e$ per 100 g (Table 2). The least contributing proteins were 'pulses, fish and egg' (0.13 $kgCO_2e$ per 100 g) and "cheese, pulses and fish" (0.15 $kgCO_2e$ per 100 g).

Non-vegetarian meals (those including meat, poultry or fish whether included as main, jacket potato or sandwich options on the menu) were higher in GHGE (mean 0.72 $kgCO_2e$ per portion [SD 0.42], median 0.58 $kgCO_2e$ per portion) than vegetarian meals (which included cheese, egg, pulses and/or meat alternatives whether included as main, vegetarian, jacket potato or sandwich options on the menu) (mean 0.53 $kgCO_2e$ per portion [SD 0.17], median 0.49 $kgCO_2e$ per portion) ($p = 0.014$) (data not shown).

The 161 lunches were divided into three groups of approximately equal group size by level of adherence with the standards included in the nutrient framework underpinning the voluntary food and drink guidelines for early years settings ("low adherence", 0–5 of 12 standards met, 58 meals; "medium adherence", six of 12 standards met, 48 meals; "high adherence", seven or more of 12 standards met, 55 meals) (Table 3). The

TABLE 2 Mean greenhouse gas emissions by protein type included within meal, irrespective of meal type.

Protein type	Number of meals	GHGE per portion ($kgCO_2e$) Mean (SD)	Median	GHGE per 100 g ($kgCO_2e$) Mean (SD)	Median	GHGE per 100 kcal ($kgCO_2e$) Mean (SD)	Median
Cheese	35	0.57 (0.17)	0.55	0.21 (0.03)	0.21	0.12 (0.02)	0.11
Red meat[a]	26	1.02 (0.51)	0.98	0.34 (0.14)	0.34	0.24 (0.12)	0.21
Meat alternatives[b]	21	0.50 (0.15)	0.50	0.17 (0.04)	0.16	0.12 (0.03)	0.11
Fish	20	0.54 (0.21)	0.56	0.19 (0.08)	0.18	0.12 (0.03)	0.12
Pulses	15	0.41 (0.10)	0.41	0.13 (0.02)	0.13	0.12 (0.03)	0.12
Poultry	14	0.51 (0.15)	0.45	0.17 (0.03)	0.17	0.13 (0.03)	0.13
Cheese and pulses	13	0.63 (0.17)	0.65	0.17 (0.03)	0.16	0.13 (0.02)	0.14
Cheese and fish	5	0.66 (0.31)	0.52	0.21 (0.07)	0.20	0.13 (0.03)	0.14
No protein	4	0.55 (0.21)	0.56	0.16 (0.04)	0.16	0.13 (0.02)	0.12
Egg	2	0.34 (0.04)	0.34	0.17 (0.03)	0.17	0.10 (0.01)	0.10
Cheese and red meat	2	0.53 (0.06)	0.53	0.21 (0.00)	0.21	0.10 (0.03)	0.10
Meat alternative and pulses	1	0.54	0.54	0.16	0.16	0.16	0.16
Cheese and poultry	1	0.55	0.55	0.21	0.21	0.10	0.10
Fish and egg	1	0.23	0.23	0.13	0.13	0.09	0.09
Cheese, pulses and fish	1	0.57	0.57	0.15	0.15	0.12	0.12

Abbreviations: g, grams; GHGE, greenhouse gas emissions; kcal, kilocalorie; $kgCO_2e$, kilograms of carbon dioxide equivalent; SD, standard deviation.

[a]Red meat included beef, lamb and pork

[b]Meat alternatives included Quorn™ and soya

TABLE 3 Mean and median greenhouse gas emissions of lunches as served for 3–4-year old children attending nine school nurseries, by level of adherence to the nutrient framework underpinning the voluntary food and drink guidelines for early years settings.

Level of adherence to early years nutrient framework	Meals, *n* (%)	Mean GHGE ($kgCo_2e$ per meal) (SD)	Median GHGE ($kgCo_2e$ per meal)	*p* value
Low (standards for 2–5 nutrients met)	58 (36.0)	0.49 (0.19)	0.43*	$p < 0.001$
Medium (standards for six nutrients met)	48 (29.8)	0.71 (0.43)	0.62	
High (standards for 7–9 nutrients met)	55 (34.2)	0.65 (0.27)	0.59	
All	161 (100.0)	0.61 (0.32)	0.53	

Abbreviations: GHGE, greenhouse gas emissions; $kgCO_2e$, kilograms of carbon dioxide equivalent.

*Statistically significant difference in median greenhouse gas emissions between meals with low adherence to the early years nutrient framework and those with medium adherence ($p = 0.003$) and high adherence ($p = 0.001$) using an independent samples Kruskal–Wallis test and post-hoc Dunn's test with Bonferroni correction.

nutrient framework applies across menus cycles, rather than to individual meals provided, but provides a measure of nutritional quality of the meals. Lunches with low adherence to the nutrient framework had significantly lower GHGE (mean 0.49 kgCO_2e per portion [SD 0.19] median 0.43 kgCO_2e per portion) than lunches with either medium adherence (mean 0.71 kgCO_2e per meal [SD 0.43] median 0.62 kgCO_2e per portion; $p = 0.003$) or high adherence (mean 0.65 kgCO_2e per meal [SD 0.27] median 0.59 kgCO_2e per portion; $p = 0.001$). There was no significant difference in GHGE between meals with medium and high levels of adherence ($p = 0.809$).

DISCUSSION

The present study aimed to evaluate GHGE associated with school lunches provided for 3–4-year-old children using Foodprint. Main meals, which were largely meat-based, were higher in GHGE than all other meal types, even after adjusting for meal size and energy density. When considering the different protein sources within meals, those containing red meat contributed the greatest GHGE, followed by poultry and cheese.

Mean GHGE were comparable to Wickramasinghe et al.[15] who reported a mean of 0.72 kgCO_2e, in over 6000 meals provided for primary-aged children. Slightly lower emissions would be expected amongst the smaller meals in the present study, which were portioned for younger children. Although no other studies have compared sandwich or jacket potato-type meals, our data are comparable to previous studies that show vegetarian lunches had lower GHGE than non-vegetarian lunches.[14,17,19]

Modelling conducted by Wickramasinghe et al.[20] estimated that following the introduction of the current food-based standards for school food in 2015, assuming lunches met more than half of the food-based standards, mean GHGE would be 0.84 kgCO_2e for a 530 kcal primary school lunch. Because the current research focused on lunches provided for nursery pupils, energy content (448 kcal) was lower than 530 kcal, but, when adjusted for energy, our results (0.14 kgCO_2e per 100 kcal) were comparable to these values (equivalent to 0.16 kgCO_2e per 100 kcal). Earlier analysis of menus included in the present study confirmed that more than half of the food-based standards were met in line with this scenario.[25] Our results were also similar to calculations of school lunch GHGE in two areas of the UK, published by Tregear et al.[7] These equated to 0.24 and 0.26 kgCO_2e per 100 g of food procured (rather than served as in our research; energy content not reported) for school lunches, compared with our findings of 0.21 kgCO_2e per 100 g of food served.

Our results were less comparable with those of Dahmani et al.,[14] who calculated the mean GHGE of 249 primary school meals provided in one area of France as 1.8 kgCO_2e. This equates to 0.27 kgCO_2e per 100 kcal, which almost double the value in the present study. The GHGE data used by Dahmani et al. (Agribalyse v3.0[28]) was one of the datasets used in the present study and a similar approach was taken to the analysis. Although the balance of meal types differs between the two studies (with more red meat and poultry meals, and fewer egg, cheese and vegan meals in the French analysis), the results by meal protein type also differ and are therefore not a result of the balance of different protein sources within the menu, but may potentially reflect the quantity of ingredients used (e.g., the quantity of beef per serving in a bolognaise dish) or the number of components within the meals provided.

The results from the present study are consistent with previous research in finding that vegetarian school lunches were significantly lower in GHGE than non-vegetarian lunches, and that lunches containing red meat as a protein source were higher in GHGE than lunches containing other protein sources.[14,17,19] Recommendations for promoting sustainable lunches in schools have included reducing red meat and/or increasing vegetarian options.[14,22] This is not required under the current school food standards, where advice is given to encourage all children to have a meat-free day each week, but menus are required to provide a portion of meat or poultry on three or more days each week, and provide a portion of milk and dairy every day, to support adequate provision of protein and micronutrients including iron, zinc, calcium and vitamin A.[10,11] Previous nutrient analysis of the menus included in the present study revealed that vegetarian lunches did not contain less of these nutrients than main meal options,[25] but because neither meal type provided sufficient zinc, any reductions in use of foods providing good sources of micronutrients to promote sustainability should ensure suitable alternative sources of these nutrients are included within meals.

GHGE of lunches were significantly higher where adherence with the nutrient framework underpinning the food and drink guidelines for early years settings was medium or high, indicating that more nutrients within these lunches were in line with dietary reference values. This could be a result of these lunches containing ingredients associated with higher GHGE (e.g., red meat, dairy products) also being good sources of micronutrients such as iron, zinc and/or calcium and supporting sufficient provision of these nutrients. This finding is consistent with the modelling conducted by Poinsot et al.,[22] which concluded that complying with French nutritional guidelines slightly increased GHGE, and Wickramasinghe et al.,[20] who estimated an increase in GHGE would occur with the introduction of the current school food standards in England.

The present study provides an estimate of GHGE associated with lunches provided to children attending school nurseries in one area of England. The analysis used recipes provided by the schools and caterers, as well as portion weights for the meals as served to children, and therefore reflects actual school lunch provision. GHGE data for individual foods were utilised from peer-reviewed research with the ability within the software to review available matches of GHGE data for each code and select the most appropriate match. However, there are some important limitations to bear in mind. First, the analysis was based on lunch provision in nine schools in one area of the country, which may not be representative of other schools and caterers, and focused on meals provided, which may not reflect the total amount of food actually consumed by children, who may have accessed salad bars and other foods outside of the served meal and may not have eaten all their lunch. Although GHGE is a widely used measure, it represents only one aspect of environmental sustainability, and does not consider impacts on factors such as nitrogen and phosphorus pollution, biodiversity loss, and water and land use.[2] Although GHGE data were from peer-reviewed research and published databases, data matched to some foods were for a broader food group rather than the specific food used and, in some cases, used the closest available match as a result of missing data with 31.9% of code choices updated. In addition, the data did not reflect where the food had been sourced by each school (e.g., local grower or national distributor) or the specific cooking method used. Because GHGE data were sourced from a variety of datasets, the exact methodology used in each may also differ impacting on the GHGE figure stated for that food (e.g., GHGE data from some databases was stated as representing "cradle to grave", whereas others represented 'farm to regional distribution centre').

Nevertheless, the present study provides an estimate of current GHGE of actual lunch provision for a group of school nurseries in England, with results comparable to modelled estimates from previous research. The methodology used could be followed by Nutritionists and Dietitians using nutritional analysis software to plan school lunch provision, enabling consideration of the GHGE of school lunch recipes and menus alongside analysis of the energy and nutrient content, and therefore supporting healthy and sustainable food provision.

AUTHOR CONTRIBUTIONS

Claire J. Wall designed the study, collected data, performed analysis and authored the paper. Jo Pearce designed the study, collected data, performed analysis and authored the paper.

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CONFLICTS OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available because of privacy or ethical restrictions.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate and transparent account of the study being reported. The reporting of this work is compliant with STROBE guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

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PEER REVIEW

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