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1 Article

2 **Nutritional Quality of School Meals in France: Impact of**  
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15 **Abstract:** In France, school meals must comply with 15 frequency criteria (FC) expressed as  
16 nutritional requirements (e.g. “starters containing more than 15% fat served no more than 4 times  
17 out of 20”) in a series of 20 consecutive meals. The objective was to assess, for the first time, the  
18 nutritional impact of complying with French school food FC. Based on 40 series of meals actually  
19 served in primary schools (“observed series”), several scenarios (1,600 series per scenario) of  
20 compliance or non-compliance with FC were simulated, and nutritional quality was assessed via  
21 the mean adequacy ratio (MAR/2000 kcal). In the observed series, only 9.7 FC on average (range  
22 4-14) were fulfilled. In the simulated series: i) MAR was positively associated with FC compliance  
23 level, with the highest MAR obtained with complete compliance; ii) MAR decreased when meat or  
24 fish-based dishes were replaced by dishes without meat or fish; and iii) removing the protein dish  
25 without replacement led to the lowest MAR. This study demonstrates that French school food  
26 guidelines ensure good nutritional quality of food services. It also shows that generalizing the  
27 service of meals without meat or fish would deteriorate overall nutritional quality, highlighting the  
28 need to define the composition of vegetarian dishes and their frequency of service to children.

29 **Keywords:** schools; diet; children; France; policy; meat; protein; nutrition, sustainability  
3031 **1. Introduction**

32 The European Union Action Plan on childhood obesity [1] and many other official documents  
33 —listed in a recent report by the European Commission [2]—underscore the fact that schools  
34 provide a privileged framework to promote healthy behaviors, notably in regard to physical activity  
35 and food. This report [2] states that the provision of healthy balanced meals in schools can improve  
36 dietary habits, lessen the incidence of childhood overweight and obesity, increase school attendance  
37 and performance, help reduce health inequalities, and raise children’s and school’s health  
38 awareness. All the member States have made considerable progress in this field with the  
39 establishment of either voluntary or mandatory school food policies [3]. However, the practical  
40 implementation of these policies in terms of food offered in school settings remains complex [2].

1 The World Health Organization (WHO) regional office [4] and the European Parliament [5]  
2 have both emphasized the need to offer children healthier food at school, notably by developing or  
3 improving nutritional guidelines for school meals. School meals often have better nutritional quality  
4 than meals eaten outside the school [6,7]. Most European countries have established specific  
5 recommendations for school meals, but only the United Kingdom, Portugal [8], and more recently  
6 France [9,10] have made them mandatory.

7 In France, the entire public catering sector has been the object of nutritional guidelines since  
8 2001. These guidelines were elaborated and are regularly updated [11-13] by the *Groupe d'Etude*  
9 *des Marchés Restauration Collective et Nutrition* (GEM-RCN [public catering and nutrition market  
10 study group]), a consultation body that includes the main public and private partners involved in  
11 public catering in France, officially brought together under the auspices of the French Ministry of  
12 the Economy. These guidelines pursue a nutritional and public health goal while taking into account  
13 the constraints and practices of professionals in the field, diners' food habits, and the desire to foster  
14 conviviality and educate children about dietary diversity. The GEM-RCN's nutrition guidelines  
15 define the general format of meals, set portion sizes for the dishes and foods most frequently served  
16 in public catering, and recommend service frequencies for fifteen types of dishes in a series of 20  
17 consecutive lunches (or approximately 4 weeks of school). These 15 frequency criteria became  
18 mandatory in all schools in 2011 [9,10]. The studies conducted by the *Agence Nationale de Sécurité*  
19 *Sanitaire de l'Alimentation, de l'Environnement et du Travail* (ANSES [the French agency for food,  
20 environmental and occupational health safety]) before the guidelines became mandatory had shown  
21 that these criteria were not known widely enough, explaining insufficient application by  
22 professionals [14,15]. In addition, quantification of the nutritional impact of these guidelines  
23 remains limited [15], which may weaken application.

24 In addition to nutritional goals, school food is also subject to other expectations such as taste  
25 education, respect for food traditions and habits, support of local agriculture, the fight against waste,  
26 and environmental protection [16]. Protein dishes in particular are the subject of multiple  
27 considerations. The meat/egg/fish food group is a privileged source of many essential nutrients in  
28 the French diet, and the French spend more than one quarter of their food budgets on it [17]. These  
29 nutritional and economic specificities—which prevail in the same manner for protein dishes in  
30 public catering—are complicated by environmental concerns [18,19]. Indeed, according to a report  
31 by the *Agence de l'Environnement et de la Maîtrise de l'Énergie* (ADEME [environment and energy  
32 control agency]), meat and fish make up 21% of food loss and waste in public catering (schools,  
33 healthcare and companies) in France, while accounting for 46% of costs and 77% of greenhouse gas  
34 emissions generated by these losses [20]. It is therefore important to look at replacement protein  
35 sources for sustainability reasons [19]. Protein dishes also raise sociocultural issues because meat  
36 and, to a lesser extent, fish are the subject of specific requests (e.g. exclusion from meals) by  
37 individuals and population groups that emphasize certain religious, ethic, political, psychological  
38 and ideological values, reasons and principles [21].

39 Based on meals actually served in primary schools, the objective of the present study was to  
40 assess, for the first time, the nutritional impact of complying with French school food guidelines,  
41 and of non compliance scenarios, including modifications in protein dishes.

1 **2. Materials and Methods**

2 The GEM-RCN's nutrition guidelines [13] for public catering define the general format of  
3 meals (four or five components: starter, protein dish, side dish, dairy product, and dessert), the  
4 recommended portion sizes for the dishes and foods most frequently served in public catering, and  
5 the recommended service frequencies for fifteen types of dishes in a series of 20 consecutive  
6 lunches (or approximately 4 weeks of school). These 15 types of dishes are themselves defined by  
7 criteria based on one or more characteristic(s) such as the meal component (starter, for example),  
8 and/or the content of some food groups in the dish (for example, proportion of vegetables), and/or  
9 certain nutrients (fat content, for example), or other characteristics of the food served (raw/cooked,  
10 ground/not ground, etc.). The combination of a criterion and an associated frequency forms a  
11 "frequency criterion". For example, dishes meeting the criterion "starter containing more than 15%  
12 fat" must be served no more than four times in a series of 20 consecutive meals. **Table 1** lists the 15  
13 frequency criteria (referred to as "FC" hereafter). Compliance with these 15 FC became mandatory  
14 for all schools in 2011 [9,10], while portion sizes remain indicative. **Figure 1** provides a general  
15 overview of the methodology. Input data were series of meals actually served in primary schools  
16 ("observed series"), the list of the 15 mandatory FC, technical files, recipes and nutrient content of  
17 ingredients. To assess the nutritional impact of French school food guidelines, series of meals were  
18 simulated according to five scenarios of compliance or non-compliance with FC, including  
19 modifications regarding the protein dish.

20 *2.1. Data Collection*

21 For this study, data were collected on 40 series of 20 lunches actually served in primary schools  
22 in France. These series are referred to as "observed series" hereafter. They were provided by two  
23 partners in the study: the *Syndicat National de la Restauration Collective* (SNRC [national public  
24 catering union]) to whom the production and management of school meals has been delegated; and  
25 *Restau'Co*, a network of directly managed public catering professionals. The two partners wrote to  
26 their networks with the operational aim of securing the participation in the study of approximately  
27 ten organizations each, seeking the widest possible diversity in terms of type of operation (meals  
28 produced on site or in a central kitchen), number of employees, geographic location, city size, and  
29 number of meals served. For each organization, participation consisted of providing two series, one  
30 during spring (mainly May and June) and the other during fall (mainly October and November).  
31 Forty observed series were thus collected (2 partners x 10 organizations from each partner x 2 series  
32 from each organization). For each series of 20 meals, the names of the dishes were listed, and a  
33 technical file—i.e. the ingredients and quantities used—was provided for each dish. Technical files  
34 were also provided for simple foods such as a banana or yoghurt. Specifications were sent to each  
35 organization to ensure maximum data homogeneity, quality and precision. Each series was  
36 composed of 20 lunches served over a period of 20 consecutive school days. In addition, the near  
37 totality of meals (94%) consisted of 5 components: starter, protein dish, side dish, dairy product and  
38 dessert.

39 The ingredients making up each dish were recorded by an expert in the field (a dietician) and  
40 the nutrient composition of each dish was estimated using the French food nutrient composition

1 reference table [22]. Each dish was identified according to its meal component (for example, starter)  
2 and the food category of its main ingredient (e.g. vegetables) (**Table A1**). Then, a classification  
3 specific to the 15 FC (Table 1) was applied (for example, the “starter containing more than 15% fat”  
4 criterion).

5 A portion of 50 g of bread was added to each meal as the two partners involved in the study  
6 indicated that this is the portion of bread usually offered to children with lunch at school.

7 For each dish we estimated two weights:

8 - the “observed” weight was determined by adding the weight of each ingredient indicated on  
9 the technical file (taking into account standard cooking loss factors) divided by the number of  
10 diners;

11 - the “recommended” weight was derived from the weights indicated for the various types of  
12 dishes in the GEM-RCN guidelines [13].

13 As explained below, observed weights were applied to the observed series and recommended  
14 weights were used for the simulated series.

## 15 2.2. Nutritional Quality Indicators

16 The nutritional quality of each 20-meal series was estimated through the Mean Adequacy Ratio  
17 (MAR), an indicator that estimates the mean content of essential nutrients expressed as a percentage  
18 of recommended intakes [23]. In the present study, the MAR was calculated taking into account 23  
19 nutrients (proteins, fiber, essential fatty acids, vitamins and minerals) as indicated in equation 1.

(1)

20 where  $content_n$  is the total amount of nutrient<sub>n</sub> in the series of meals considered and  $reco_n$  is the  
21 recommended daily intake of this same nutrient. The recommended daily intake was multiplied by  
22 20 to take into account the number of meals in the series.

23 The recommended daily intakes applied in the present study for each of these nutrients are  
24 given in **Table 2**. These values were obtained by weighting the recommended dietary allowance in  
25 France [24] according to the age and gender representativeness of the population concerned,  
26 specifically children aged 4 to 13 years attending primary school [25]. For example, the calcium  
27 recommendation in the present study (924 mg) was obtained by considering the age-specific  
28 recommendations (i.e. 700 mg for 4- to 6-year-olds, 900 mg for 7- to 9-year-olds and 1200 mg for  
29 10- to 13-year-olds, irrespective of gender) and the representativeness of each age bracket (19.8%,  
30 58.9% and 21.3% respectively). The MAR was calculated for each series of 20 meals since the  
31 series is the relevant unit in the guidelines. The MAR was also expressed for 2000 kcal to have a  
32 view of the nutritional quality of the series assuming it was the sole dietary source for a benchmark  
33 daily energy need of 2000 kcal. In this second version of the MAR, each  $content_n$  was calculated for  
34 2000 kcal and  $reco_n$  was therefore not multiplied by 20, as indicated in equation 2.

(2)

35 where  $content_n$  is the total amount of nutrient  $n$  in the series of meals considered,  $nrj$  is the  
36 energy content of the series, and  $reco_n$  is the recommended daily intake of nutrient  $n$ .

1 In both MAR and MAR/2000kcal, the ratio for each nutrient was truncated at 100 so that a high  
2 content of one nutrient could not compensate for the low intake of others [23]. Thus, the MAR and  
3 MAR per 2000 kcal had a maximum theoretical score of 100. An example of calculation of MAR  
4 and MAR/2000kcal for one given series is provided in **Table A2**.

5 The amounts of fats, saturated fatty acids and free sugars were also calculated. Free sugars are  
6 defined by the WHO as sugar added to foods plus sugars naturally present in honey, syrups and fruit  
7 juices [26].

### 8 *2.3. FC Compliance Scores*

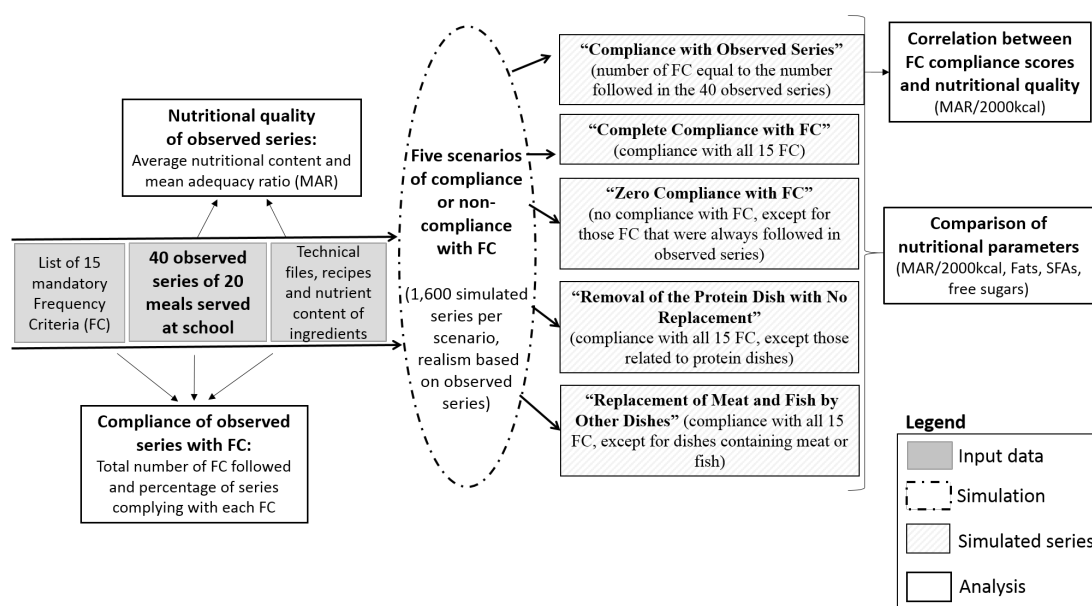
9 Two scores were developed to estimate the level of compliance with FC. The “Number of FC  
10 Followed” score is the sum of 15 sub-scores corresponding to compliance with each of the 15 FC. If  
11 the series complied with one criterion, a sub-score of 1 was assigned; if it did not comply, the sub-  
12 score was 0. Series could therefore obtain a score ranging from 0 to 15. However, when the series  
13 did not comply with a frequency criterion, this score had the inconvenience of not taking into  
14 account distance from expected frequency. For this reason, another score, called the “Relative  
15 Compliance Score” was developed. This score also ranges from 0 to 15 and is the sum of 15 sub-  
16 scores corresponding to compliance with each of the 15 FC. However, when a criterion was not met,  
17 a sub-score of less than 1, but as close to 1 as the observed frequency was close to expected  
18 frequency, was assigned. In this case, the sub-score was equal to  $(1 - \text{relative gap})$ , with the relative gap equaling  $[(\text{observed frequency} - \text{recommended frequency}) / \text{recommended frequency}]$ .

19 For example, for the “starter containing more than 15% fat: 4/20 max” criterion, a series  
20 containing four starters of this type received a sub-score of 1 for each of the two scores; a series that  
21 contained 5 starters of this type received a sub-score of 0 for the first score and a sub-score of 0.75  
22 for the second score; and a series that contained 7 starters of this type obtained a sub-score of 0 for  
23 the first score and a sub-score of 0.25 for the second score.

### 24 *2.4. Generating Simulated Series*

25 Simulations were performed to analyze the relationship between compliance with FC and  
26 nutritional quality. This was done because of the anticipated absence, in the observed sample, of  
27 series complying with all 15 FC and of series not complying at all, as well as of series without meat  
28 or fish. Five different situations were simulated using the five scenarios (Figure 1).  
29  
30  
31





1  
2 Figure 1. Overview of the methodology used to generate simulated series of 20 consecutive meals (based on 40 observed  
3 series), according to five scenarios of compliance and non-compliance with the 15 frequency criteria (FC) in French  
4 school food guidelines.

5 For each scenario, 1,600 series of meals were generated, corresponding to 32,000 meals in each  
6 scenario, or 160,000 meals in all. For all the scenarios, only recommended amounts were applied to  
7 the weight of each dish in the simulations in order to study the nutritional impact of FC specifically  
8 (i.e., without the portion sizes actually served in the observed series interfering with the results).  
9 Methodological details for the simulations are provided in Appendix A.

## 10 2.5. Statistical Analysis

11 The distribution of the number of FC followed in the 40 observed series was calculated, as well  
12 as the percentage of series complying with each criterion. Nutritional values were calculated for  
13 each 20-meal series because the series is the relevant unit in the guidelines. Some results were  
14 presented after being divided by 20, to obtain a “per meal” figure that can be interpreted more  
15 directly.

16 For macronutrients, the values were expressed as a percentage of energy content. For fiber,  
17 vitamins and minerals, the values were expressed as a percentage of recommended daily nutrient  
18 intakes and compared to the percentage of recommended daily energy intake provided by the series,  
19 assuming that good nutritional density would be achieved when the percentage of recommended  
20 daily nutrient intakes was higher than the percentage of recommended daily energy. This was done  
21 by analogy with the concept of nutritious food defined as foods that provide proportionally more  
22 nutrients to favor than calories [27]. In scenario 1 (“Compliance with Observed Series”), the  
23 association between FC compliance scores and nutritional quality (estimated by MAR/2000 kcal)  
24 was analyzed, represented by point clouds and tested by Spearman correlation coefficients. Finally,  
25 the averages for MAR/2000 kcal, fat content, saturated fatty acid content, and free sugar content  
26 were compared across the five scenarios using Bonferroni-adjusted General Linear Model (GLM)  
27 statistical analysis. The variations in these indicators across the different scenarios were also  
28 compared to verify the spread difference of certain distributions.

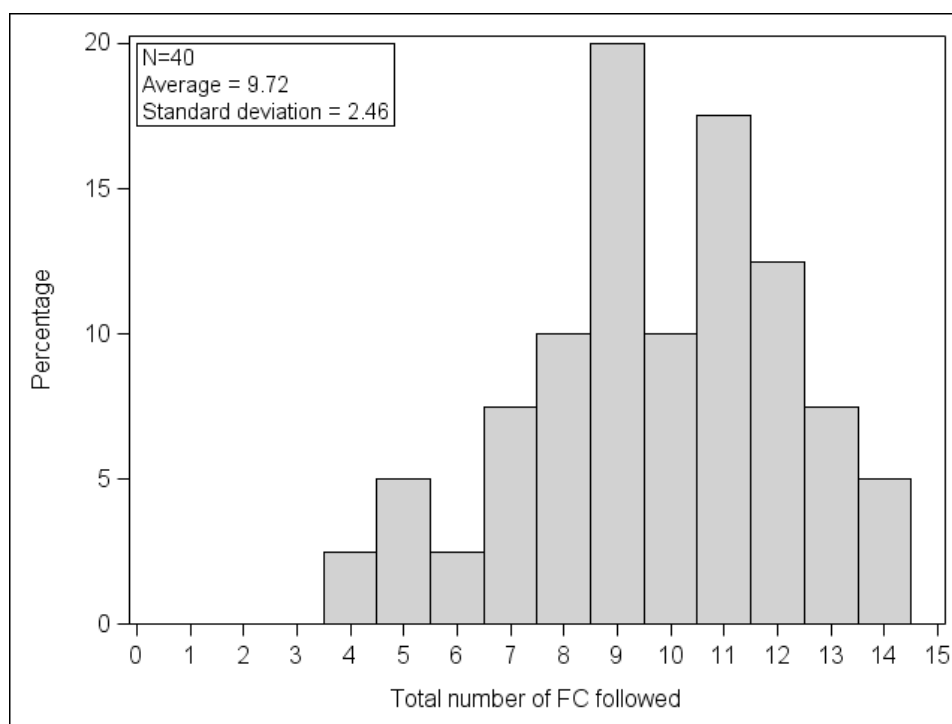
1 **3. Results**

2 *3.1. Distribution of Dishes in the Observed Series*

3 The starters were above all composed of vegetables; protein dishes were composed mainly of  
 4 pork, poultry, beef, veal, lamb or fish; dairy products were mostly cheese; side dishes contained  
 5 starches and vegetables; and desserts were mainly fruit, and less often sugar products and dairy  
 6 desserts (Table A1).

7 *3.2. FC Compliance in Observed Series*

8 On average, 9.7 out of the 15 FC were fulfilled in the sample of 40 observed series, with a  
 9 minimum of 4 and a maximum of 14 (**Figure 2**).



10 **Figure 2.** Distribution of the number of frequency criteria complied with in the observed series of meals (N=40 series).

11 The percentage of series fulfilling the frequency criteria in the 40 observed series varied  
 12 depending on the criterion considered (Table 1).

14



1 **Table 1.** The 15 frequency criteria for school meal service in France [10,13] and the percentage of series fulfilling each  
 2 criterion among the 40 observed series of 20 meals

Criteria	Component(s) Concerned	Expected Frequency	% of observed series fulfilling the criterion <sup>1</sup>
Starters containing more than 15% fat	starter	4/20 max	82.5%
Raw vegetable or fruit dishes containing at least 50% vegetables or fruits	starter, side dish	10/20 min	70%
Dishes to fry or pre-fried dishes containing more than 15% fat	protein dish, side dish	4/20 max	100%
Protein dishes with a ratio of P/F <sup>1</sup> ≤ 1	protein dish	2/20 max	55%
Fish or fish-based dishes containing at least 70% fish and having a ratio of P/F ≥ 2	protein dish	4/20 min	60%
Unground beef, veal or lamb, and offal	protein dish	4/20 min	77.5%
Preparations or ready-to-eat dishes containing less than 70% of the recommended weight for the portion of meat, fish or eggs	protein dish	3/20 max	25%
Vegetables, other than pulses, alone or in a mixture containing at least 50% vegetables	side dish	= 10/20	27.5%
Pulses, starches or grains, alone or in a mixture containing at least 50% pulses, starches or grains	side dish	= 10/20	27.5%
Cheese containing at least 150 mg of calcium per portion	starter, dairy product	8/20 min	77.5%
Cheese with a calcium content of more than 100 mg and less than 150 mg per portion	starter, dairy product	4/20 min	57.5%
Dairy (fresh dairy products, dairy-based desserts) containing more than 100 mg of milk calcium and less than 5 g of fat per portion	dairy product, dessert	6/20 min	40%
Desserts containing more than 15% fat	dessert	3/20 max	95%
Desserts or dairy products containing more than 20 g of total simple sugars per portion and less than 15% fat	dairy product, dessert	4/20 max	100%
Raw fruit dessert 100% raw fruit without added sugars	dessert	8/20 min	77.5%

3 <sup>1</sup> Ratio P/F = protein (g/100g)/fat (g/100g).

4 Only two individual FC were systematically followed in all 40 series: “dishes to fry or pre-fried  
 5 dishes containing more than 15% fat” (4/20 max) and “desserts or dairy products containing more  
 6 than a total of 20 g of simple sugars per portion and less than 15% fat” (4/20 max). The FC on  
 7 “starters containing more than 15% fat” (4/20 max) and “desserts containing more than 15% fat”  
 8 (3/20 max) were also among those with the highest percentage of fulfillment. Criteria expressed by  
 9 strict equality—“cooked vegetables other than pulses, alone or in a mixture containing at least 50%  
 10 vegetables” (=10/20) and “pulses, starches or grains, alone or in a mixture containing at least 50%  
 11 of pulses, starches or grains” (=10/20)—showed low percentage of fulfillment(27.5% each). The  
 12 criterion with the lowest percentage of fulfillment (25%) was the one limiting “protein dishes  
 13 containing less than 70% of recommended weight for the portion of meat, fish or eggs” (3/20 max).  
 14 It should be noted that dishes meeting this criterion are very diverse in terms of ingredients and  
 15 therefore nutrients. For example, they include nuggets, lasagna, stuffed vegetables, quiches, and  
 16 entirely vegetarian dishes such as tomato dumplings, cheese pizzas and Andalusian rice.



1 3.3. Nutritional Quality of the Observed Series

2 The observed series of 20 meals provided on average 14,232 kcal, or 712 kcal per meal, with  
 3 energy from proteins, fats and carbohydrates equal to 18%, 33% and 46% respectively, and that  
 4 from free sugars and SFAs equal to 4.5% and 12.5% respectively (results not shown).

5 The observed series provided 35.6% of recommended daily energy intake on average. The  
 6 MAR, reached 49.3%, therefore clearly above the average threshold of 35.6% of recommended  
 7 energy intake, indicating very good nutritional density in the observed series (Table 2).

8 **Table 2.** Recommended daily intakes of energy and nutrients (proteins, essential fatty acids (FAs), fiber, vitamins and  
 9 minerals) included in the calculation of the Mean Adequacy Ratio (MAR) and percentages of these recommendations in  
 10 the observed series of 20 meals (N=40), expressed per meal<sup>a</sup>

	Recommended daily intake	Average content (% of recommendation, expressed per meal)	Standard Deviation
Energy	1996 kcal <sup>[24,28,29]</sup>	35.6	2.7
Protein	25 g <sup>[28,29]</sup>	129.8	8.5
Linoleic Acid	8.9 g <sup>[30]</sup>	39.3	10.2
$\alpha$ -Linolenic Acid	2.2 g <sup>[30]</sup>	20.4	8.3
DHA	152 mg <sup>[30]</sup>	42.2	18.0
Fiber	13 g <sup>[24]</sup>	59.5	6.2
Vitamin B1	0.8 mg <sup>[24]</sup>	46.3	5.2
Vitamin B2	1.2 mg <sup>[24]</sup>	38.2	3.4
Vitamin B3	9 mg <sup>[24]</sup>	64.9	8.9
Vitamin B6	1 mg <sup>[24]</sup>	56.4	6.0
Vitamin B9	201 $\mu$ g <sup>[24]</sup>	57.6	6.7
Vitamin B12	1.4 $\mu$ g <sup>[24]</sup>	103.4	15.4
Vitamin C	89 mg <sup>[24]</sup>	35.0	6.3
Vitamin D	5 $\mu$ g <sup>[24]</sup>	17.3	4.1
Vitamin E	9.1 mg <sup>[24]</sup>	52.5	15.7
Vitamin A	501 $\mu$ g <sup>[24]</sup>	81.0	14.2
Calcium	924 mg <sup>[24]</sup>	34.2	4.1
Potassium	2892 mg <sup>[31]</sup>	33.6	3.8
Iron	8.2 mg <sup>[24]</sup>	44.0	4.3
Magnesium	203 mg <sup>[24]</sup>	45.6	3.8
Zinc	9.2 mg <sup>[24]</sup>	39.5	4.1
Copper	1.2 mg <sup>[24]</sup>	36.8	3.3
Iodine	120 $\mu$ g <sup>[24]</sup>	42.1	6.7
Selenium	39 $\mu$ g <sup>[24]</sup>	52.0	6.1
MAR (%) <sup>b</sup>		49.3	3.7

11 <sup>a</sup> Here, “meal” is defined as the average value for a complete series of 20 meals divided by 20.

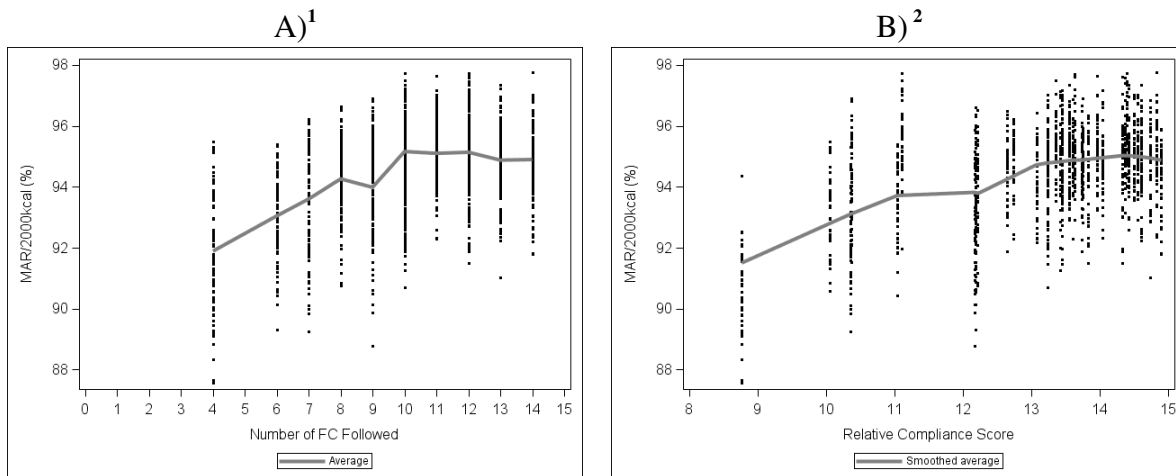
12 <sup>b</sup> Estimated according to equation 1.

13 When the nutrients to favor were examined separately, the observed series provided  
 14 significantly more than the threshold of 35.6% of daily recommended intake for three-quarters of  
 15 them. Vitamin C content (35.0%) was not significantly different from the 35.6% threshold, and

1 calcium (34.2%) and potassium (33.6%) content were slightly but significantly below it. Only  
 2 alpha-linolenic acid (20.4%) and vitamin D (17.3%) content were much lower than the 35.6%  
 3 threshold. The five meal components contributed to coverage of recommended nutrient intakes  
 4 differently depending on the nutrient considered (**Figure A1**). The starters were the main  
 5 contributors of linoleic acid, alpha-linolenic acid, and vitamins A and E. The protein dishes  
 6 provided the bulk of protein, DHA, and vitamins B3, B6, B12 and D, as well as iron, zinc, iodine  
 7 and selenium. The side dishes were the main contributors of fiber, vitamin B9, potassium,  
 8 magnesium and copper. Dairy products and desserts were the main contributors of calcium and  
 9 vitamin C respectively.

10 *3.4. Nutritional Quality of the Simulated Series*

11 For the “Compliance with Observed Series” scenario, the level of compliance with FC,  
 12 regardless of the score used, was positively correlated with MAR/2000 kcal (**Figure 3**).

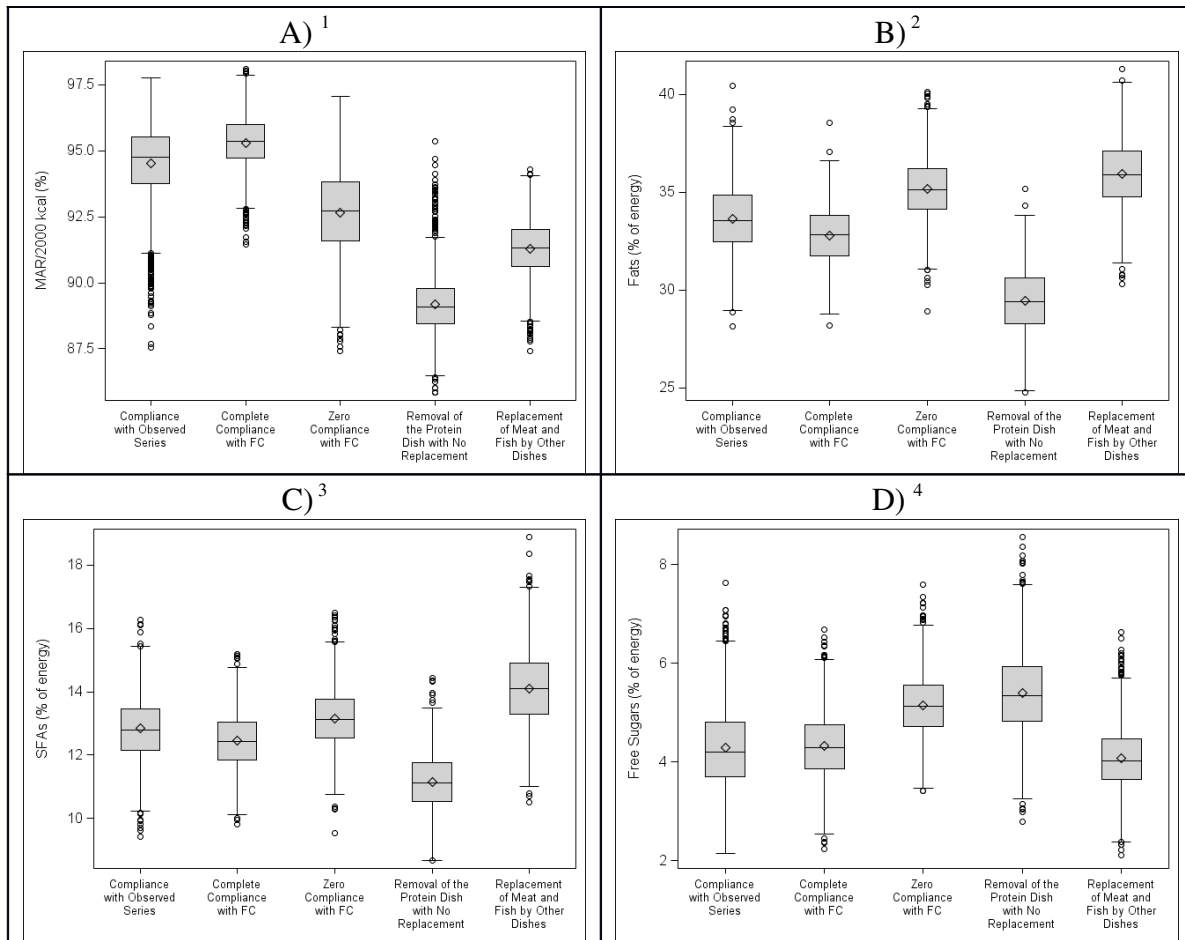


13 **Figure 3.** Mean Adequacy Ratio (MAR, expressed in % of adequacy for 2000 kcal) point clouds according to the level of  
 14 compliance with frequency criteria (FC) estimated by the “Number of FC Followed” (2A) and the “Relative Compliance  
 15 Score” (2B) in the “Compliance with Observed Series” series (n=1600 series simulated by scenario 1, with recommended  
 16 weights).<sup>1</sup> Spearman correlation: 0.36, p<0.0001;<sup>2</sup> Spearman correlation: 0.34, p<0.0001.

17 This correlation reached a plateau—equal to 10 for the “Number of FC Followed” and 13 for  
 18 the “Relative Compliance Score”—above which the correlation was no longer significant.

19 Among the simulated series, the “Complete Compliance with FC” series had the highest  
 20 MAR/2000 kcal on average (**Figure 4**).

21



1 **Figure 4.** Nutritional quality of simulated series according to five scenarios: Box Plots 3A) Mean Adequacy Ratio (MAR,  
2 % of adequacy for 2000 kcal), 3B) Fats (% of energy), 3C) Saturated Fatty Acids (SFAs, in % of energy), 3D) Free  
3 Sugars (% of energy).<sup>1</sup> For MAR/2000 kcal, the averages are statistically different ( $p < 0.05$ ) from one series to another.<sup>2</sup>  
4 For fats (% of energy), the averages are statistically different ( $p < 0.05$ ) from one series to another, except between “Zero  
5 Compliance with FC” and “Replacement of Meat and Fish with Other Dishes.”<sup>3</sup> For SFAs (% of energy), the averages are  
6 statistically different from one series to another ( $p < 0.05$ ).<sup>4</sup> For free sugars (% of energy), the averages are statistically  
7 different ( $p < 0.05$ ) from one series to another except between “Complete Compliance with FC” and “Compliance with  
8 Observed Series,” and between “Complete Compliance with FC” and “Replacement of Meat and Fish with Other  
9 Dishes.”

10 In addition, in the “Complete Compliance with FC” series, the standard deviation of the  
11 MAR/2000 kcal was significantly lower than in the other series, suggesting that compliance with  
12 FC can prevent the occurrence of series with low MAR/2000 kcal values.

13 The “Zero Compliance with FC” series had lower nutritional quality (lower MAR/2000 kcal,  
14 plus high energy contribution from fats, SFAs and free sugars) than in the “Complete Compliance  
15 with FC” and “Compliance with Observed Series” scenario.

16 In the “Removal of the Protein Dish with No Replacement” series, the energy contribution from  
17 fats and SFAs was lower than in the other simulated series, the MAR/2000 kcal was significantly  
18 lower, and the energy contribution from free sugars was higher.

19 The “Replacement of Meat and Fish with Other Dishes” series were those in which the energy  
20 contribution from SFAs was highest, as was the contribution from fats, which was as high as in the  
21 “Zero Compliance with FC” series. The contribution from free sugars was not different from that of

1 the “Complete Compliance with FC” series. The MAR/2000 kcal was higher than that of the  
2 “Removal of the Protein Dish with No Replacement” series, but it was lower than the MAR/2000  
3 kcal of the other three simulated series, including the “Zero Compliance with FC” series.

#### 4 **4. Discussion**

5 This study is the first one to clearly demonstrate the nutritional interest of the French school  
6 food guidelines. In addition, it shows that generalizing the service of meals without meat or fish  
7 would deteriorate the nutritional quality of school food service, advocating for a precise definition  
8 of the place of vegetarian dishes in school meals.

9 The observational part of the study was done on a sample of 40 series of 20 meals served in  
10 primary schools. The nutritional analysis of “observed” series revealed that they had good  
11 nutritional density because they provided proportionately more of the nutrients to favor (49.3% of  
12 recommendations) than calories (35.6% of daily recommendations). When nutrients were estimated  
13 separately, only alpha-linolenic acid and vitamin D were present in low quantities compared to  
14 recommendations. Yet, these nutrients are known for being largely deficient in French diets, for both  
15 children and adults [29], indicating that this is not a deficit specific to school food. In France, one  
16 school child out of three is deficient in vitamin D, advocating for systematic winter supplementation  
17 of this vitamin [32]. When it comes to alpha-linolenic acid, the GEM-RCN document recommends  
18 using mixtures of oils with high alpha-linolenic acid content [11].

19 The analysis of the relationship between FC compliance level and nutritional quality required  
20 recourse to simulations. Indeed, it could not be done with the sample of observed series because of  
21 their relatively small number (n=40) and because of the absence, in this sample, of series complying  
22 with all criteria and series not complying at all. The generation of a very large number of series  
23 close to what was observed (“Compliance with Observed Series”) showed that nutritional quality,  
24 estimated by the MAR/2000 kcal, increased with FC compliance level. In addition, the series  
25 simulated to comply with all 15 FC (“Complete Compliance with FC”) were nutritionally superior  
26 to all other series, notably the series close to what was observed (“Compliance with Observed  
27 Series”). Complete compliance can therefore prevent the occurrence of series of mediocre  
28 nutritional quality. In the present study, observed compliance was also partial, with only 9.7 out of  
29 the 15 frequency criteria followed on average in the sample of observed series. Yet, one can assume  
30 that, compared to all school food in France, compliance with frequency criteria was over-estimated  
31 in this sample because it was collected on a voluntary basis. This result seems to agree with studies  
32 done in other countries such as Australia [33], the United Kingdom [34] and other European  
33 countries [2], which have shown that school food guidelines, whether mandatory or not, are often  
34 difficult to implement and must be associated with measures aiming to facilitate their application.  
35 The aim is notably to help professionals correctly classify dishes in regard to existing  
36 recommendations or mandatory guidelines [2,35,36]. One can also assume that simplifying criteria  
37 could facilitate their application [2]. In this regard, our results suggest that it would be possible to  
38 revise the frequency criteria for school food in France so as to make them more flexible or reduce  
39 their number without losing effectiveness because there was no measurable nutritional benefit  
40 beyond compliance with 10 criteria (and a relative score equal to 13). However, more work would be  
41 needed to explore which kinds of simplification would be beneficial and acceptable.



1 One major advantage of the French school food guidelines is how they are formulated, which  
2 allows for the simultaneous consideration of several different characteristics of the dishes. Thus,  
3 some dishes are to be favored (minimal service frequency) while others are to be limited (maximal  
4 service frequency), but nothing is outlawed. In addition, the criteria apply to both the composition  
5 of dishes in certain ingredients and their nutrient content, and often combine two types of  
6 requirements (e.g. the “fish or fish-based preparations containing at least 70% fish and having a P/F  
7 ratio  $\geq 2$ ” criteria). School food guidelines are very different in the United Kingdom, where a sharp  
8 distinction is drawn between food-based standards (FBS) and nutrient-based standards (NBS) [8].  
9 FBS (13 criteria) were first imposed in 2001, and then deemed insufficient and supplemented by  
10 NBS (14 criteria) [37,38]. However, even with these dual requirements—FBS and NBS—some  
11 nutritional goals, notably regarding iron, zinc and sodium, remain difficult to achieve [38].  
12 Simplified standards (7 criteria on food groups to serve or limit) were introduced in 2014, because  
13 the previous ones were too difficult to understand and implement [34]. However, the new standards  
14 were in turn the subject of debate and criticism, notably regarding insufficient control of fat,  
15 saturated fatty acids, free sugars and sodium content [36]. Our study suggests that an approach such  
16 as the one adopted in French school food guidelines, which combine characteristics linked to the  
17 food, its nutrient composition and its service frequency in the same criteria, allow for good control  
18 of the nutritional quality of meals served to children.

19 Protein dishes are important contributors to greenhouse gas emissions and food waste in school  
20 meals [36], representing new challenges for this food sector [20]. However, the present study  
21 showed that their suppression would deteriorate the nutritional quality of series, as would replacing  
22 protein dishes containing meat or fish with dishes that do not contain meat or fish. The poor  
23 nutritional performance of the “Removal of the Protein Dish with No Replacement” scenario can be  
24 explained by the major contribution of protein dishes to the content of many essential nutrients  
25 (Figure A1). But the poor performance of the “Replacement of Meat and Fish by Other Dishes”  
26 scenario is likely due to the mediocre nutritional quality of the dishes without meat or fish. Indeed,  
27 in the observed series, protein dishes without meat or fish were mostly based on eggs and/or cheese  
28 and grains, and lacked diversity (data not shown). Partners were therefore asked to provide  
29 additional protein dishes without meat or fish, especially plant-based protein dishes. However,  
30 despite this precaution, series modeled with the “no meat no fish” scenario were of lesser  
31 nutritional quality than with the observed scenario. This seems to confirm that it is nutritionally  
32 relevant to limit “protein dishes containing less than 70% of recommended weight for the portion of  
33 meat, fish or eggs” to 3/20 max. However, the large majority (75%) of the observed series did not  
34 fulfill this criterion, suggesting that it could be useful to modify it. The present results suggest that  
35 it could be interesting to include in the guidelines a positive definition of the expected nutritional  
36 characteristics of vegetarian dishes, and to determine how often they could be served to children.  
37 For instance, a new frequency criterion could be developed for dishes combining pulses and whole  
38 grains, considering that they are good sources of fibers, micronutrients and proteins, but also taking  
39 into account that they contain anti-nutritional factors that adversely influence the bioavailability of  
40 nutrients (i.e. the amount of ingested nutrient effectively available for the organism [39,40]). More  
41 generally, the present results show that meeting nutritional requirements is not necessarily  
42 compatible with reducing consumption of animal products, although the latter is recommended to

1 lower the carbon footprint of our diet [36,41,42]. In a recent study, total replacement of animal  
2 products with products of plant origin improved some nutritional aspects (less sodium and SFAs,  
3 and more fiber) but decreased the content and/or the bioavailability of many essential nutrients  
4 (zinc, thiamine, vitamin A, vitamin B12, calcium and iron) [43].

5 The present study has its limitations. First, the data used in the descriptive portion were  
6 collected voluntarily and are therefore not representative of school food service in France. However,  
7 non-representativeness is not a major limitation because our goal was not to evaluate the nutritional  
8 quality of school meals in France but rather to assess the nutritional impact of complying with  
9 French school food guidelines and test some modifications in practices. Another limitation lies in  
10 the fact that the nutritional analysis was done on dishes as prepared in kitchens and served to  
11 children but not the portions actually eaten by children. We know, however, that offering healthier  
12 food at school encourages healthy eating among children [44,45]. For some dishes, the estimated  
13 nutrient content may have been inaccurate. Thus, for dishes with sauce, the quantity of sauce taken  
14 into account in the analysis was higher than the amount actually served to children because a non-  
15 negligible amount of the sauce remains in the serving dish. A final limit is that, in the scenarios of  
16 elimination of the protein dish or replacement of meat or fish dishes, it would be interesting to  
17 consider the bioavailability of nutrients when estimating the nutritional quality of the series. This  
18 consideration would likely have confirmed or even strengthened the observation of a nutritional  
19 worsening of the series in these scenarios because many key nutrients, such as iron, zinc and  
20 vitamin A, have greater bioavailability when they are of animal origin rather than plant origin  
21 [39,40], even though satisfactory bioavailability may be achieved in diets containing moderate  
22 quantities of animal products [46].

23 This study also presents strengths. First, precise data on meals and dishes actually served in  
24 schools were specifically collected for this study, making the database unique and rare. Indeed, it  
25 was produced based on real technical files and recipe cards—that is to say taking into account the  
26 nature and quantity of each ingredient in the dishes served by professionals—and not standard  
27 recipes or generic products systematically affiliated with a reading of dish names, as is habitually  
28 the case in other studies on school food [36,47,48]. With the exception of sodium and, to a lesser  
29 extent, sugars, whose quantities are often still difficult for professionals themselves to estimate, we  
30 can therefore consider that the estimated nutrient content was very precise. It was crucial to attain  
31 this level of precision to reliably estimate not only the nutritional quality of the series but also their  
32 level of compliance with frequency criteria because these criteria include the nutritional  
33 characteristics of dishes that depend directly on how the dishes are prepared. Another strength is the  
34 innovative and powerful approach that we elaborated to test the nutritional impact of the French  
35 school food guidelines. This approach allowed for realistic testing of the simultaneous compliance  
36 with the 15 frequency criteria, which had until now only been explored separately and partially,  
37 notably because of the lack of series complying fully with them [47].

## 38 **5. Conclusions**

39 In conclusion, this study revealed the good nutritional quality of a sample of series of meals  
40 served at primary schools in France and the nutritional relevance of French school food guidelines.  
41 The results suggest that there may be room for intelligently increasing the flexibility of these

1 guidelines because no nutritional benefit was observed above a relative score of 13 (out of 15  
2 frequency criteria). However, in the event of a wide gap from frequency criteria guidelines, whether  
3 for all criteria or those addressing protein dish service, a risk of worsening nutritional quality was  
4 shown. Thus, in the absence of a precise definition of the nutritional characteristics of protein  
5 dishes without meat or fish, the generalization of their service in schools could harm the nutritional  
6 balance of meals served to children.

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12 study, reviewed and revised the manuscript, and approved the final manuscript as submitted. Dr. Nicole Darmon conceived and  
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## 20 Appendix A

21 In the first scenario—“Compliance with Observed Series”—series of meals were generated to  
22 produce series that were close to what was observed while gaining high statistical strength. Each of  
23 the 40 observed series was repeated 40 times by keeping the same service frequency of the meals  
24 while including different dishes. For example, if an observed series contained five “starters  
25 containing more than 15% fat”, all the 40 series simulated based on this series also contained five  
26 “starters containing more than 15% fat” but each dish introduced in each simulated series was  
27 selected using a weighted random sampling (for example, if a grated celery salad containing more  
28 than 15% fat was served ten times more often than a cheese puff pastry containing more than 15%  
29 fat in the observed series, then grated celery salad was 10 times more likely to be selected than  
30 cheese puff pastry in simulated series). In all, 1,600 (40 x 40) series were simulated in this scenario.

31 In the second scenario—“Complete Compliance with FC”—series of meals in which all 15 FC  
32 were followed exactly were generated. All of the structures compatible with compliance with FC  
33 while remaining within realistic frequency ranges were first counted. These realistically complying  
34 ranges were identified from 40 observed series as follows: For example, if all the observed series  
35 respecting the frequency criterion “starters containing more than 15% fat: 4/20 max” always  
36 contained at least 2 (and never 0 or 1) “starters with more than 15% fat”, then the frequency range  
37 realistically complying with the criterion would be 2-4 (even though the authorized range was 0-4).  
38 In all, 3,024,000 structures of series realistically complying with all 15 FC were enumerated, within  
39 which 1,600 structures were derived so as to obtain the same representativeness of compliance with  
40 each criterion (e.g. if, among the observed series complying with the criterion “starters containing  
41 more than 15% fat: 4/20 max”, we observed 25% of them contained two starters containing more  
42 than 15% fat, 25% containing 3 starters containing more than 15% fat, and 50% containing 4

1 starters containing more than 15% fat, then these proportions were maintained in the simulation).  
 2 Then, as previously, dishes were allocated to each of the 1,600 structures, taking into account the  
 3 classification of each dish in regard to the 15 FC and its degree of appearance in the observed  
 4 series.

5 In the third scenario—“Zero Compliance with FC”—series that complied with none of the  
 6 regulatory frequency criteria while remaining within realistic and representative frequency ranges  
 7 were generated. For example, if no observed series contained 10 “starters containing more than 15%  
 8 fat”, then this was also the case for the “Zero Compliance with FC” series. In addition, if, among  
 9 the observed series that did not comply with the “starter containing more than 15% fat: 4/20 max”,  
 10 75% had five and 25% had six, then these proportions were repeated in the simulation. This concern  
 11 for realism also led us to decide that if a frequency criterion was followed in all observed series, it  
 12 would also be followed in the “Zero Compliance with FC” series.

13 In the fourth scenario—“Removal of the Protein Dish with No Replacement”—series of meals  
 14 were generated by removing all protein dishes from the “Complete Compliance with FC” series  
 15 (generated in the second scenario).

16 In the fifth and last scenario—“Replacement of Meat and Fish by Other Dishes”—series of  
 17 meals were generated by randomly replacing the protein dishes and starters containing meat or fish  
 18 in the “Complete Compliance with FC” series (generated in the second scenario) with protein  
 19 dishes and starters that did not contain meat or fish. It should be noted that dishes “without meat or  
 20 fish” are defined as “vegetarian” under the GEM-RCN’s Nutrition Recommendations [13]. In order  
 21 to have sufficient diversity in the simulated series for this scenario, 32 dishes served as protein  
 22 dishes without meat or fish and not included in the dishes present in the 40 series of 20 meals were  
 23 specifically collected from the partners. These additional technical files corresponded to dishes  
 24 actually served in schools as alternatives to meat or fish dishes.

## 25 Appendix B

26 **Table A1.** Categorization and distribution of dishes per meal component in the 40 observed series

Component	Category	Number
Starter	Vegetables	521
	Starches	160
	Deli Meats	37
	Cheese	29
	Fruits	23
	Eggs	10
	Fish	9
Protein Dish	Pork, Poultry	305
	Beef, Veal, Lamb	243
	Fish	211

	Eggs	34
	Starches	6
	Vegetables	1
Side Dish	Starches	441
	Vegetables	357
Dairy Product	Cheese	556
	Dairy Products	220
	Dairy Desserts	5
	Sweetened Foods	1
Dessert	Fruits	478
	Sweetened Foods	164
	Dairy Desserts	111
	Dairy Products	17
	Starches	16

1

2 **Appendix C**

3

**Table A2.** Example of calculation of MAR and MAR/2000kcal for one series containing 14871 kcal

	MAR estimation	MAR/2000kcal estimation						
Nutritional content of the series	Recommended 20 days intake	ratio	ratio>100 replaced with 100	ratio>100 replaced with 100	content for 2000kcal	Recommended daily intake	ratio	ratio>100 replaced with 100
Protein (g)	683,66	500	136,73	100,00	91,94	25	367,78	100
Linoleic Acid (g)	85,76	178	48,18	48,18	11,53	8,9	129,59	100
$\alpha$ -Linolenic Acid (g)	15,53	44	35,29	35,29	2,09	2,2	94,91	94,91
DHA (mg)	1973,28	3040	64,91	64,91	265,39	152	174,60	100
Fiber (g)	188,41	260	72,46	72,46	25,34	13	194,91	100
Vitamin B1 (mg)	7,20	16	44,99	44,99	0,97	0,8	121,01	100
Vitamin	9,86	24	41,08	41,08	1,33	1,2	110,49	100

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B2 (mg)									
Vitamin									
B3 (mg)	118,20	180	65,67	65,67	15,90	9	176,63	100	
Vitamin									
B6 (mg)	11,18	20	55,92	55,92	1,50	1	150,40	100	
Vitamin									
B9 (µg)	2464,13	4020	61,30	61,30	331,40	201	164,88	100	
Vitamin									
B12 (µg)	24,11	28	86,12	86,12	3,24	1,4	231,64	100	
Vitamin									
C (mg)	616,79	1780	34,65	34,65	82,95	89	93,20	93,20	
Vitamin									
D (µg)	19,79	100	19,79	19,79	2,66	5	53,23	53,23	
Vitamin									
E (mg)	128,37	182	70,53	70,53	17,26	9,1	189,72	100	
Vitamin									
A (µg)	6942,86	10020	69,29	69,29	933,74	501	186,38	100	
Calcium									
(mg)	6067,86	18480	32,83	32,83	816,06	924	88,32	88,32	
Potassium									
(mg)	19425,11	57840	33,58	33,58	2612,48	2892	90,33	90,33	
Iron (mg)	73,00	164	44,51	44,51	9,82	8,2	119,73	100	
Magnesium									
(mg)	1944,72	4060	47,90	47,90	261,54	203	128,84	100	
Zinc (mg)	73,85	184	40,14	40,14	9,93	9,2	107,96	100	
Copper									
(mg)	9,93	24	41,39	41,39	1,34	1,2	111,34	100	
Iodine									
(µg)	956,99	2400	39,87	39,87	128,71	120	107,25	100	
Selenium									
(µg)	516,99	780	66,28	66,28	69,53	39	178,28	100	

MAR= 52,90

MAR/2000kcal= 96,52

1

2

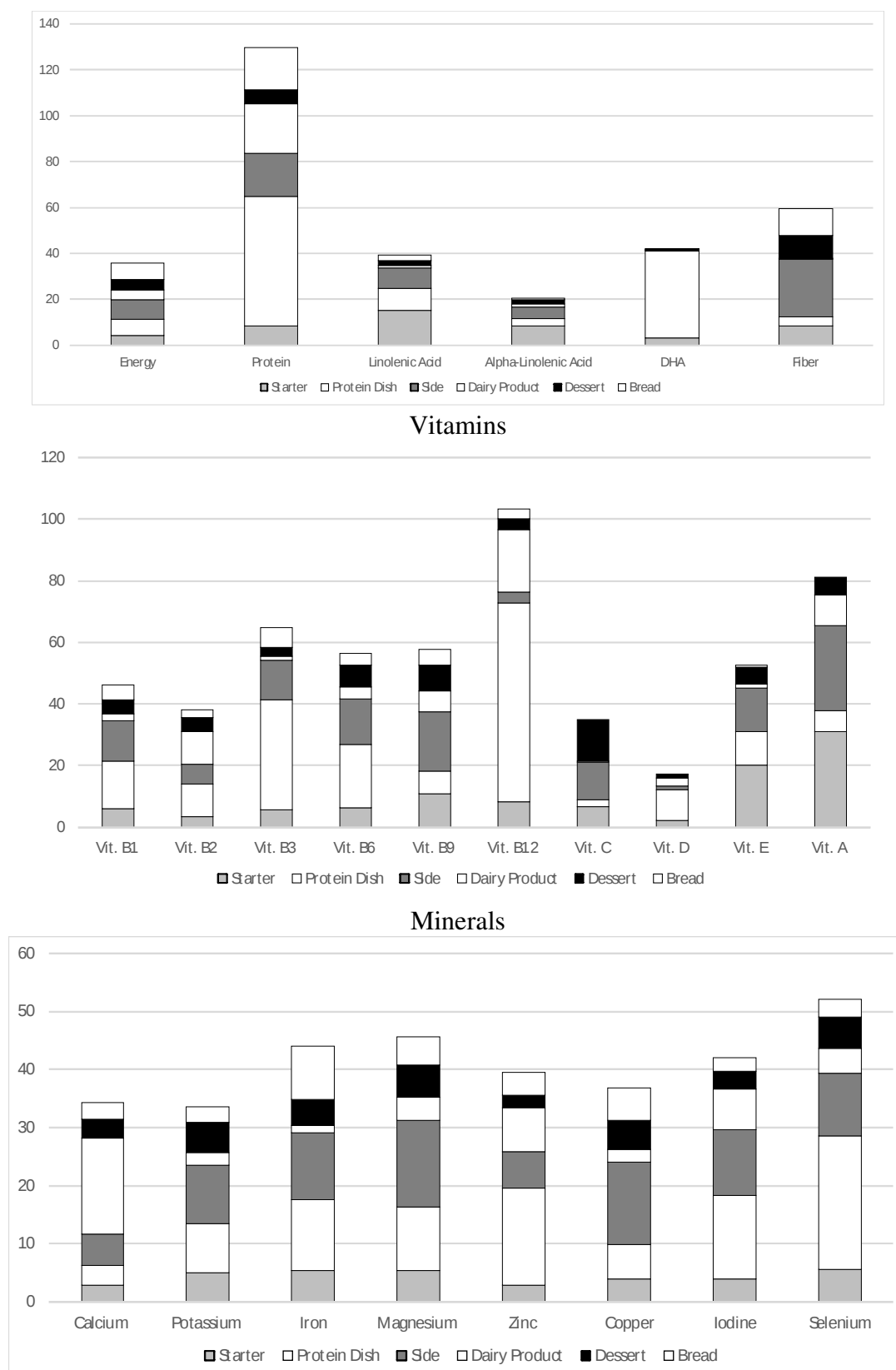
3 **Appendix D**

## Energy, Proteins, Essential Fatty Acids

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1 **Figure A1.** Average contributions of 5 meal components to the nutrient contents of the observed series (n=40 series of 20  
2 meals), expressed in % of daily recommended intakes (multiplied by 20).

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