Quantifying the contribution of foods with unfavourable nutrient profiles to nutritionally adequate diets

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1 **TITLE PAGE**

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27

28 **Abstract**

29 That "all foods can fit" into a healthy diet is a long-standing principle of dietetic practice. This

30 study quantified the relative contributions of foods to encourage and foods to limit, using new

31 techniques of individual diet optimization and nutrient profiling. Individual foods from every food

32 group were assigned into 4 nutrient profile classes based on the French SAIN,LIM system. Foods

33 with the most favourable nutrient profiles were in class-1 and foods with the least favourable

34 nutrient profiles were in class-4. An optimized diet, that met the recommendations for 32 nutrients

35 and that respected the existing eating habits, was designed for each adult in the nationally

36 representative INCA1 dietary survey (n=1,171). The relative proportions of the 4 nutrient profiling

37 classes were assessed before and after the optimization process. The contribution of fruits and

38 vegetables, whole grains, milk, and fish was significantly increased, whereas the contribution of

39 refined grains, meats, mixed dishes, sugars and fats was decreased. The optimized diets derived

40 more energy (30% vs 21% in the observed diets) from class-1 foods and less energy (41% vs 56%)

41 from class-4 foods. They also derived a higher amount of class-1 foods (61% vs 51%) and a lower

42 amount of class-4 foods (22% vs 32%). Thus, nutrient adequacy was compatible with the

43 consumption of foods with an unfavourable nutrient profile (one-fifth the basket weight) provided

44 that the diet also contained almost tho-third of foods with the most favourable profile. Translating

45 these results into concrete and quantified advice may have very tangible public health implications.

46

Introduction

It is well established that healthful diets[1,2] ought to contain low-fat dairy products, fish and lean meats, beans and legumes, and plenty of vegetables and fruit[3-5]. However, much of dietary advice is still based on nutrients to avoid. Consumers are advised to limit the intake of saturated fatty acids, sugar, and sodium[6-8] and to eat sparingly foods that contain those nutrients in excess[1,4]. Missing from nutrition education messages are many processed foods[9] and mixed foods belonging to more than one food group[10].

The 2005 Dietary Guidelines for Americans[11] identified nutrient density of foods as a novel strategy for nutrition education and positive dietary guidance. Consumers selecting nutrient dense foods and beverages would be able to satisfy daily nutrient requirements without exceeding their daily energy needs [11]. Supplemental "discretionary" calories, defined as the balance of calories remaining after satisfying nutrient needs, could then be consumed in proportion to energy allowance [11]. Nutrient dense foods were described as those that provided relatively more nutrients than calories, whereas the amount of discretionary calories was set low [12].

The new science of nutrient profiling[13-15] can classify individual foods based on their overall nutritional quality. Nutrient profiling can help distinguish between nutrient-rich foods that provide more nutrients than energy and those foods that are energy-rich but nutrient-poor[16]. Given that lower scoring foods can be more enjoyable and may provide energy at a lower cost [17], calculating their relative proportion in a healthy diet is a question of both public health and consumer importance. Coupling the new techniques of nutrient profiling[14] and individual diet optimization[18], the objective of the present study was to quantify the shift in food intakes from different nutrient profile classes needed to reach nutritional adequacy, while taking into account individual dietary patterns and preferences.

72 **Methods**

73 *Dietary data*

74 The data used in the present study were based on dietary data collected from 1171 adults (age > 18

75 years) in the cross-sectional dietary survey "Enquête Individuelle et Nationale sur les

76 Consommations Alimentaires" (INCA), conducted in 1999 by the French National Agency for Food

77 Safety[19]. Habitual food intakes were estimated using a 7-d food diary recorded by all participants.

78 Energy and nutrient intakes were calculated for each participant using the French food composition

79 database, previously described[20].

80 *The SAIN, LIM nutrient profiling system*

81 The SAIN, LIM scoring system was applied to each food in the food database. After exclusion of

82 drinking water, diet beverages, tea, coffee and fortified foods, the remaining 613 foods were

83 aggregated in 10 food-groups. The French SAIN,LIM system was described in details elsewhere[14].

84 Briefly, it assigned each food to one of 4 classes, based on two independent subscores. The positive

85 SAIN subscore was the mean percent nutrient adequacy for 5 basic nutrients (proteins, fiber,

86 vitamin C, iron calcium), calculated per 100 kcal of food and a variable number of optional

87 nutrients applied to different food groups in the database. Vitamin D, vitamin E, alpha-linolenic

88 acid and monounsaturated fatty acids were used as optional nutrients for nuts and for foods

89 containing more than 97% of their energy as lipids while only vitamin D was used as optional

90 nutrient for all other foods. The negative LIM subscore was calculated as the mean % of maximal

91 recommended values for 3 nutrients to limit: saturated fatty acids (SFA), added sugar and sodium,

92 and was expressed per 100g.

93 Specific thresholds were derived for each subscore so that foods were assigned into 4 broad classes:

94 high SAIN and a low LIM (class-1: most favourable); low SAIN and a low LIM (class-2) high

95 SAIN and a high LIM (class-3); low SAIN and a high LIM (class-4: least favourable).

96 Most fruits and vegetable, eggs, milk, low fat-low dairy products, most fish and shellfish, potatoes,

97 legumes and whole grains were all class-1 foods (Table 1). Most refined cereals, including white

98   bread, together with some cereal-based products containing low amounts of SFA, sugar and salt

99   were class-2 foods. Many cheeses salted and/or smoked fatty fish, meats with an intermediate fat

100   content, and most nuts and vegetable oils were class-3 foods. Virtually all sweets and desserts,

101   animal fats, sweetened beverages, a high proportion of salted snacks, and mixed dishes, most deli

102   meats and fatty meats, full-fat dairy products and sweetened cereals were class-4 foods.

103   *Diet optimization*

104   We designed a set of 1171 individual-specific nutritionally adequate diets using a recently

105   developed individual diet modelling approach[18]. For each individual, a model started from his or

106   her observed diet (i.e. food intakes and nutrient intakes) to design an isocaloric optimized diet

107   respecting his or her food selections and a set of nutrient goals. Nutritional adequacy was ensured

108   by having each diet meet a set of constraints based on the French recommendations for 32 nutrients:

109   proteins, fibers, total carbohydrates, total lipids, essential fatty acids, 11 vitamins (including vitamin

110   D) and 9 minerals, and nutrients to limit. As previously described (18), the minimum levels

111   imposed for nutrients in the optimized diets were: at least the EAR when the observed intake was

112   lower than the EAR; at least the RDA when the observed intake was greater than the RDA; equal to

113   the observed intake level when it was between the EAR and the RDA. This was done to improve

114   the nutrient intakes of each individual in order to reach at least the EAR level for each nutrient,

115   while ensuring that the optimization process did not deteriorate any nutritional component of the

116   observed diets. This is consistent with the current consensus for diet planning of minimizing the

117   percentage of individual's with dietary intakes below the EAR[21].

118   For the energy contribution of macronutrients and for essential fatty acids (including linolenic acid,

119   linoleic acid, DHA and EPA), the constraint levels were identical for all individuals but for fibers

120   and micronutrients, the lower constraint bounds depended on gender, age and the individual's

121   observed intake of these nutrients, as previously described[18]. The nutrients to limit were sodium,

122   free sugars, saturated fatty acids and cholesterol. For cholesterol the maximal constraint bound was

123   either 300 mg per day when the observed intake was below 300mg/d or the observed intake when it

124 was above 300mg/d. Safe upper limits for niacin, folate, ascorbic acid, vitamin A, B-6, E, D, zinc

125 and selenium were also included in each optimization model.

126 Consumption constraints ensured that each optimized diet corresponded as much as possible to the

127 dietary pattern and food preferences of each individual. An upper limit was placed on the quantity

128 of each food, calculating as the 95th percentile amount of the consumer distribution (except when

129 the observed intakes exceeded the 95th percentile).

130 Each optimized diet created by individual modelling came as close as possible to the corresponding

131 observed diet while simultaneously respecting multiple individual-specific constraints. For each

132 person, the optimization algorithm i) preferentially chose foods that the person habitually

133 consumed, ii) maintained quantities consumed as far as possible, and iii) if necessary to reach

134 nutritional adequacy, introduced novel foods but in the lowest amount possible and by preferentially

135 selecting foods with a high percentage of consumers in the French population (i.e. the most popular

136 ones). The energy content of the optimized diets was the same as in the observed diets, and the

137 weight of foods could not exceed 115% of the observed weight. Population-based consumption

138 constraints on foods and food groups were added to ensure social acceptability to the optimized

139 diets.

140 *Statistical analysis*

141 The relative average contributions of each nutrient profiling class to total weight and energy of the

142 optimized diets were calculated for each diet and tested between observed and optimized diets using

143 a paired Student t-test. The relative contributions of the 10 food groups to total weight were

144 similarly assessed and tested. SAS version 9.2 was used for diet modelling and for statistical

145 analysis, using a 5% alpha level for significance.

146

147 **Results**

148 The mean weight of the optimized diets was 1,598g/d as compared to 1,425g/d for the observed

149 diets. The mean energy density of the optimized diets was accordingly reduced from 623 kJ/100g

150 (149 kcal/100g) to 552 kJ/100g (132 kcal/100g). Table 1 shows the average contribution of each

151 food group to the total weight of observed and optimized diets. The total amount of fruits and

152 vegetable increased from 23.1% to 33.6%. Unrefined starches increased from 5.4% to 7.9%, and

153 refined cereals increased from 12.6% to 13.7%. Fresh dairy products such as yogurts and milk rose

154 from 13.2% to 15.6%, whereas the amount of fish rose from 2.5% to 4.1%. The optimization

155 process reduced the amounts of meat, cheese, added fats and sweets, the greatest drop being

156 observed for mixed dishes and salted snacks (from 13.9% to 5.5%). When a given food group was

157 increased, foods which had an augmentation mainly came from the SAIN,LIM class-1 (results not

158 shown). When a given food group was decreased, foods which had a diminution mainly came from

159 the SAIN,LIM classes 3-4 (results not shown).

160 Both the observed diets and the optimized diets were composed of foods from all four SAIN, LIM

161 classes (Figure 1). Following the optimization process, the energy contribution of class-1 foods

162 increased from 21% to 30% and that of class-4 foods decreased from 56% to 41% (Figure 1A).

163 Following the optimization process, the weight contribution of class-1 and class-2 foods increased

164 and that of class-3 and class-4 foods decreased (Figure 1B). The relative weight contribution of

165 class-1 foods increased from 51% to 61% and that of class-4 foods decreased from.32% to 22%.

166

167 **Discussion**

168 Foods from all nutrient profile classes can be part of nutritionally adequate diets. The present

169 results show that foods with the least favourable nutrient profiles can still contribute as much as

170 41% of energy to a nutritionally adequate food pattern, provided that nutrient dense foods with the

171 most favourable nutrient profile account for the majority of food weight (61%). The present data

172 used new techniques to quantify the relative contribution of different type foods to a nutritionally

173 adequate food pattern that, moreover, respected individual food choices. Early fears that nutrient

174 profiling would perpetuate the dichotomy between "good" and "bad" foods are not borne out by our

175 use of profiling methods and diet optimization techniques.

176 Nutrient profile systems can help quantify the relative amounts of foods that need to be reduced or

177 increased in order to achieve a healthy diet[14,22]. Moreover, they show that foods with an

178 unfavorable nutrient profile need not be avoided altogether. Indeed, only a partial replacement of

179 class-4 (and class-3) foods by class-1 (and class-2 foods) was needed to design a nutritionally

180 adequate diet for each person from our sample of French adults.

181 The present study has some limitations. First, the results of diet optimization depends on the design

182 of a particular model, including the constraints used to define nutritional adequacy[23]. However, in

183 an earlier linear programming study, we used three different official sets of nutritional

184 recommendations and this did not change our conclusions about the foods and nutrients limiting the

185 design of optimal diets for young children in a developing country[24]. Moreover, in the present

186 study, the use of individual diet modelling is likely to limit the risk of drawing conclusions that are

187 too specific to the model applied. Indeed, the present conclusions were based on the results obtained

188 from 1171 individual-specific models, each of them being unique in terms of objective function and

189 constraints[18].

190 A second limitation is that the nutrient profiling approach may fail to correctly classify some key

191 foods[25,26]. Nevertheless, our results were fully consistent with studies from the UK[22] showing that

192 foods deemed as least healthy using the UK Food Standard Agency nutrient profile contributed as

193 much as 39% of energy to the most healthy diets (based on the Diet Quality Index), a figure in close

194 agreement with the present estimate of 41%. Given that the two studies, conducted in the UK and

195 France respectively, differed in methodology (observational and modelling studies, respectively),

196 such correspondence suggests that the amount of "discretionary" calories can be higher than

197 previously envisaged. According to MyPyramid, most discretionary calorie allowances are very

198 small, between 100 and 300 calories, that is to say between 5 and 15% of daily energy intakes[3].

199 Limiting so much the amount of discretionary calories could be more restrictive than effectively

200 needed to reach nutritional adequacy.

201 Nutritionally adequate diets were in accordance with habitual dietary advice as they had a low

202 energy density and contained plenty of foods of plant origin and reasonable amounts of animal

203 products. The current debate on nutrient profiling leaves the consumer and the health professional

204 alike with the impression that only the most nutrient rich foods have a place in a healthy diet.

205 Based on sophisticated mathematical techniques, the present study showed, to the contrary, that

206 foods from all SAIN,LIM classes could be a part of individually-tailored nutritionally adequate food

207 diets. In this population of French adults, current nutrient recommendations were compatible with

208 the consumption of one-fifth of energy-dense foods that were nutrient-poor (class-4), provided that

209 the diets also contained almost two-third of nutrient-dense foods (class-1).

210 In many countries, consumers already receive information about the nutrient profile of individual

211 foods and this is considered as a possible way of favourably influencing food choices. For instance,

212 in Sweden, the 'Green Keyhole' symbol has been in use since 1989, to help consumers identify low-

213 fat and high-fibre alternatives[27], and in France, the ministry of health is currently considering the

214 introduction of a healthy food label based on nutrient profiling[28]. Thus, translating the results of

215 the present study into concrete and quantified advice to increase the consumption of food with a

216 favourable nutrient profile (to at least two-third the basket weight) at the expense of foods with an

217 unfavourable nutrient profile (to a maximum of one-fifth the basket weight), may have very

218 tangible public health implications.

219 All too often dietary advice is either vague or solely based around avoiding or severely restricting a

220 specific nutrient or food. Nutrient profiling models that accurately capture the nutrient density of

221 foods can be an effective platform for nutrition education.

222 **Acknowledgments**

229 **Author's contributions**: MM and ND conceived the study. MM conducted data modeling and

230 statistical analyses. AD participated substantially in interpretation of the results and writing of the

231 report. All authors participated in the interpretation of the results and writing of the report.

232

233   Table 1. Number of foods from each food group in each SAIN,LIM class and average contribution

234   of each food group to total diet weight among observed and optimized diets.

235

236

237   Figure 1 Title.

238   Relative contributions of each nutrient profiling class to total diet energy (Panel A) and to total diet

239   weight (Panel B) among observed and optimized diets.

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311 n°2474.

312   Table1. Number of foods from each food group in each SAIN,LIM class and average contribution of each food group to total weight among observed

313   and optimised diets.

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	Number of foods in each SAIN,LIM Class				Contribution to total diet weight, %			
	Class 1	Class 2	Class 3	Class 4	Observed		Optimised	
					Mean	SE	Mean	SE
Fruits & vegetable[1]	87	11	7	1	23.1	11.4	33.6*	7.4
Unrefined starches	13	5	0	2	5.4	3.6	7.9*	3.8
Refined starches	0	6	0	5	12.6	6.6	13.7*	4.7
Milk[2] & yogurts	15	1	6	13	13.2	9.8	15.6*	7.1
Cheese	0	0	35	17	3.0	2.3	1.4*	1.1
Meats	34	1	26	40	11.9	5.5	7.9*	3.0
Fish	45	5	13	1	2.5	2.5	4.1*	1.9
Mixed dishes & salted snacks	18	11	18	46	13.9	9.2	5.5*	4.7
Added fats	9	0	18	11	2.4	1.3	1.3*	0.8
Sweets[3]	1	5	4	83	11.9	8.6	9.1*	5.1

315   * Mean values are significantly different from that of observed diets.

316   [1] The mean contribution of fruit juice to total weight was 3% and 2.5% in observed and modelled diets, respectively

317   [2] The mean contribution of milk to total weight was 8.1% and 8.4% in observed and modelled diets, respectively

318   [3] The mean contribution of soft drinks to total weight was 2.5% and 1.4% in observed and modelled diets, respectively

319   Figure 1. Relative contributions of each nutrient profiling class to total diet energy (Panel A) and to

320   total diet weight (Panel B) among observed and optimized diets.

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322