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ORIGINAL ARTICLE

An assessment of the potential health impacts of food reformulation

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BACKGROUND/OBJECTIVES: Policies focused on food quality are intended to facilitate healthy choices by consumers, even those who are not fully informed about the links between food consumption and health. The goal of this paper is to evaluate the potential impact of such a food reformulation scenario on health outcomes.
SUBJECTS/METHODS: We first created reformulation scenarios adapted to the French characteristics of foods. After computing the changes in the nutrient intakes of representative consumers, we determined the health effects of these changes. To do so, we used the DIETRON health assessment model, which calculates the number of deaths avoided by changes in food and nutrient intakes.
RESULTS: Depending on the reformulation scenario, the total impact of reformulation varies between 2408 and 3597 avoided deaths per year, which amounts to a 3.7–5.5% reduction in mortality linked to diseases considered in the DIETRON model. The impacts are much higher for men than for women and much higher for low-income categories than for high-income categories. These differences result from the differences in consumption patterns and initial disease prevalence among the various income categories.
CONCLUSIONS: Even without any changes in consumers' behaviors, realistic food reformulation may have significant health outcomes.

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INTRODUCTION

Policies focused on food quality are intended to facilitate healthy choices by consumers, even those who are not fully informed about the links between food consumption and health. Decreasing the salt and fat content in foods and increasing the whole grain content are good examples of food composition changes being made to address health-related issues. In this respect, some governments are partnering with the food industry and the retail sector to generate changes on the supply side.

To what extent may such policies focused on the nutritional quality of foods contribute to health benefits? Few studies have investigated the potential impacts of already existing quality standards on consumers' diets.[1,2] For instance, one study[3] assessed the impacts on diets if all food products complied with the International Choices Programme (ICP).[4–6] According to simulations, the impact of the 'Choices' standard on the population's average nutrient intake could be substantial.[7,8] In Roodenberg *et al.*[9] and Vyth *et al.*[10] the authors modeled the potential impact of 'Choices' adoption on health-related risk factors. They calculated the effect of consuming a diet that complies with the criteria of a front-of-package label on a specific cardiovascular risk factor, such as cholesterol levels, for the total Dutch adult population. When non-complying products were replaced with products that comply with the 'Choices' standard, the median saturated fatty acids (SFA) intake decreased from 14.5 to 9.8%.

In line with this recent research, the goal of this paper is to evaluate the potential impact of food reformulation on health outcomes. To ensure, as much as possible, that the tested scenarios are within a domain of food characteristics acceptable by the consumers and feasible by the producers, we restricted the reformulation assumptions to ranges of nutritional values already existing in each food group in the French market. The simulation results provide the magnitude of health benefits that would be obtained if all participants in the food industry comply with a nutritional quality standard. These potential benefits are discussed in the light of changes already observed in the nutritional quality of foods available on the French market.

MATERIALS AND METHODS

Method and data

To assess the impact of dietary changes on mortality, we linked a simple model of changes in nutrient intake to the epidemiological model DIETRON.[11–13]

Formally, we denote as $x_{i,j}$ the consumption of product j by consumer i and as $a_{j,k}$ the content of nutrient k in product j. The consumption of nutrient k by consumer i, denoted as $N_{i,k}$, is given by the following formula: $N_{i,k} = \sum_j x_{i,j} a_{j,k}$.

The information for $x_{i,j}$ comes from the INCA2 database (INCA2 is a cross-sectional national dietary survey that was conducted in 2006–2007 by the ANSES (the French Agency for Food, Environmental and Occupational Health and Safety). See https://www.anses.fr/fr/content/les-études-inca), which describes the daily intake of 1343 food products for 1918 adults in France. The information for $a_{j,k}$ comes from the CIQUAL (https://pro.anses.fr/tableciqual/PH01.htm) database. Rather than using the food intakes of each consumer, we defined eight types of adult consumers based on gender and income level. We distinguished the four quartiles of incomes defined as 'modest', 'lower average', 'upper average' and 'well-off' consumers.

To define the reformulation scenarios—that is, to define the likely nutrient content changes for each food product—we first used the ICP classification. The ICP classification ranks food products in 21 groups. Using the definitions of these 21 groups, we allocated each product from the INCA2 database to one of the 21 ICP groups. We denoted S_g as the set of products j in the group g. It was then possible to determine how much of nutrient k that

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consumer i consumes from foods in the product group g, which we denoted as $N^g_{i,k}$. We determined $N^g_{i,k} = \sum_{j \in S_g} x_{i,j} a_{j,k}$ and $N_{i,k} = \sum_g N^g_{i,k}$.

Then we calculated the average starting point. That is, we used the CIQUAL data set to determine the average nutrient content for each ICP group, $\tilde{a}^g_k$, given the observed consumption of the 1343 food products by all consumers. If X_j is the consumption of product j by the INCA2 population (with $X_j = \sum_i x_{i,j}$), then $\tilde{a}^g_k = \sum_{j \in S_g} a_{j,k} X_j / \sum_{j \in S_g} X_j$.

The reformulation scenarios rely on the definition of a target nutrient content for each product group (denoted $\overline{a}^g_k$). These targets will be defined in the next section. Using these targets we calculated the percent change in nutrient k for product group g that is needed to reach the target $\overline{a}^g_k$ $\left(\Delta a^g_k = 100\left(\tilde{a}^g_k - a^g_k\right)/\tilde{a}^g_k\right)$. Using this percent change in nutrient content for each ICP group, it was possible to compute the change in nutrient intake for each consumer, which is defined as $\Delta N_{i,k} = \sum_g N^g_{i,k} \Delta a^g_k$. We thus assumed that the percent change in the nutrient k composition of any food product j in a given product group g is equal to Δa^g_k.

To assess the impact of food product reformulation on health outcomes, we used an epidemiological model (the DIETRON model) that links changes in food and nutrient intakes to changes in adverse health outcomes.[11–13] A full description of the development, parameterization and assumptions supporting the DIETRON model is available in Scarborough *et al*.

Adapting the DIETRON model to France required data on the number of deaths in France and their causes. Thus, the relative risks used in the model to translate a change in diet to a change in the risk of mortality from disease are taken from an international meta-analysis and are not country specific. We mainly used INSERM (French Institute of Medical Research) data on the total mortality in France from the major diet-related diseases: ten types of cancers, strokes and coronary heart disease (CHD). Our analysis focused on the effects of consumption changes on premature deaths, that is, those occurring before the age of 75 years. The diseases considered in DIETRON account for slightly more than one-third of the total mortality in France.

The reformulation scenarios

To define the reformulation scenarios, we used three sets of data. First, the CIQUAL data set was used to determine the initial average nutrient content of foods in each food group $\left(\tilde{a}^g_k\right)$. The data used in this study have been collected in 2008. Second, we used data provided by the French Observatory of Food Quality (Oqali) (http://www.oqali.fr), which records, on the basis of nutritional labels, the nutrient content of brands marketed in different food sectors in France (in 2011, 2012 or 2013 depending on the food groups). This data set provides the nutrient contents in branded products available on the French market. We used these data to ensure that the target values were already reached by some products in each food category and thus already feasible by some producers and acceptable to some consumers. Finally, to determine the target values, we used the nutrient profiles determined for the 'Choices' program as a benchmark (see the online supplementary file in Roodenburg *et al*.[3] for a full description of the product groups and the ICP criteria (http://www.nature.com/ejcn/journal/v65/n11/extref/ejcn2011101x5.doc)).

On this basis we defined two reformulation scenarios. The 'high reformulation scenario' is based on the following rules used to determine the target values in each food group:

1. If the gap between the initial and the ICP values is between 15 and 25%, the target value is the ICP value.
2. If the gap between the initial and the ICP values is $<15\%$, the target value is the initial value minus 15% (in this case, the target value is more demanding than the ICP value).
3. If the gap between the initial and the ICP values is $>25\%$, the target value is the initial value minus 25% (in this case, the target value is less demanding that the ICP value).

In all cases, we checked with the Oqali data set that the target value was already reached by some products available in each food group, in order to ensure that the scenario was realistic in that it has been already adopted by some food processors for some products. Doing so, we assumed that the variations in the average nutrient values were due to the improvement in the quality of the lowest-quality products in each food group (and not due to the launching of new healthier products). An example is given in Figure 1.

The 'low reformulation scenario' is based on the same rules, except that, in this case, we imposed the maximum gap between the initial and the ICP values to be lower than 20% and suppressed the rule 2 (the target value cannot be lower than the ICP value).

Table 1 displays the reformulation scenarios. We focused on the food categories that are the main contributors of salt, SFA, fiber and added sugar intakes. For each food category and each nutrient, the tables provide the ICP values, the average initial values and the variations in the nutrient

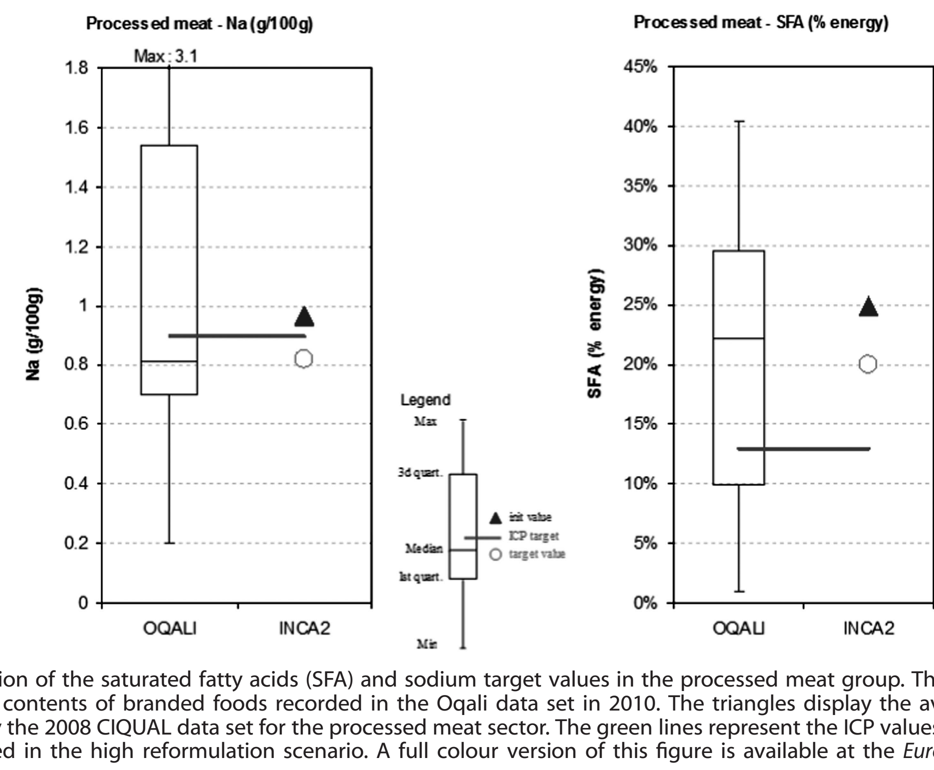

Figure 1. Determination of the saturated fatty acids (SFA) and sodium target values in the processed meat group. The two box plots display the SFA and sodium contents of branded foods recorded in the Oqali data set in 2010. The triangles display the average SFA and sodium contents provided by the 2008 CIQUAL data set for the processed meat sector. The green lines represent the ICP values. The red circles denote the target values used in the high reformulation scenario. A full colour version of this figure is available at the *European Journal of Clinical Nutrition* journal online.

Table 1. Changes in sodium, fibers, saturated fatty acids and added sugar contents simulated in the 'high reformulation scenario'

Sodium	*ICP prod.* *Δ Content*	*Processed F&V* *− 20%*	*Bread* *− 25.5%*	*Processed meat* *− 15%*	*Processed fish* *− 24.6%*	*Main course* *− 15%*	*Filled sandwiches…* *− 15%*	*Meal sauces* *− 15%*	*Other sauces (emulsions)* *− 22.1%*	*Total*
Initial contribution	%	3.5%	26.4%	11.4%	2.4%	12.3%	2.7%	1.0%	2.8%	62.4%
Δ On init. contribution	%	− 0.7%	− 6.7%	− 1.7%	− 0.6%	− 1.8%	− 0.4%	− 0.1%	− 0.6%	− 12.7%
Initial content	mg/100 g	198	671	967	594	398	544	499	962	
Final content	mg/100 g	159	500	822	448	338	462	424	750	
ICP target value	mg/100 g	100	500	900	450			450	750	
Initial content	mg/100 kcal	317	243	373	368	246	200	532	275	
Final content	mg/100 kcal	253	181	317	277	209	170	453	214	
ICP target value	mg/100 kcal					220	190			

Fibers	*ICP prod.* *Δ Content*	*Bread* *+15%*	*Rice* *+25%*	*Grains and cereal prod.* *+15%*	*Fruit juices* *+21%*	*Main course* *+25%*	*Filled sandwiches…* *+15.2%*	*Total*
Initial contribution	%	21.3%	0.5%	0.5%	0.3%	7.6%	1.6%	31.8%
Δ On init. contribution	%	3.2%	0.1%	0.1%	0.1%	1.9%	0.2%	5.6%
Initial content	g/100 kcal	1.16	0.37	1.22	0.62	0.90	0.69	
Final content	g/100 kcal	1.34	0.46	1.40	0.75	1.12	0.80	
ICP target value	g/100 kcal	1.30	0.70	1.30	0.75	1.25	0.80	

SFA	*ICP prod.* *Δ Content*	*Potatoes processed…* *− 15%*	*Processed meat* *− 25%*	*Cheese prod.* *− 15%*	*Oils, butter and fats* *− 16.5%*	*Main course* *− 15%*	*Filled sandwiches…* *− 25.5%*	*Snacks…* *− 25%*	*Total*
Initial contribution	%	2.3%	7.4%	16.5%	22.2%	6.7%	2.2%	19.5%	76.8%
Δ On init. contribution	%	− 0.3%	− 1.9%	− 2.5%	− 3.7%	− 1.0%	− 0.6%	− 4.9%	− 14.8%
Initial content	g/100 g	1.16	7.31	16.52	29.69	2.55	5.14	6.83	
Final content	g/100 g	0.99	5.48	14.04	24.79	2.17	3.83	5.12	
ICP target value	g/100 g	1.10	1.10	15.00		1.10	1.10	1.10	
Initial content	% energy	7.9%	24.9%	44.2%	35.1%	13.9%	16.7%	19.4%	
Final content	% energy	6.8%	20.0%	40.3%	31.1%	12.1%	13.0%	15.3%	
ICP target value	% energy		13.0%			13.0%	13.0%	13.0%	
Initial content	% total fat	36.2%	37.2%	63.0%	35.9%	32.2%	42.6%	47.9%	
Final content	% total fat	30.8%	27.9%	53.6%	30.1%	27.4%	31.8%	35.9%	
ICP target value	% total fat				30.0%				

Added sugar	*ICP prod.* *Δ Content*	*Beverages* *− 20%*	*Snacks…* *− 20%*	*Processed F&V* *− 20%*	*Bread toppings…* *− 28.9%*	*Total*
Initial contribution	%	13.4%	37.1%	4.9%	11.5%	67.0%
Δ On init. contribution	%	− 2.7%	− 7.4%	− 1.0%	− 3.3%	− 14.4%
Initial content	g/100 g	1.27	17.29	4.25	42.24	
Final content	g/100 g	1.01	13.83	3.40	30.03	
ICP target value	g/100 g		20.00	0.00	30.00	

Abbreviations: F&V, fruits and vegetables; ICP, International Choices Programme; Init, Initial; Prod, Production; SFA, saturated fatty acids.

contents used in the simulations. In addition, the tables present the variation in the different nutrient intakes resulting from the reformulation process.

RESULTS

As shown in Table 1, the high reformulation scenario leads to average variations in consumers' intakes, which depend on the nutrients: − 12.7% for sodium, +5.6% for fiber, − 14.8% for SFA and − 14.4% for added sugars. The impacts on diseases (Cardiovascular disease (CVD) and strokes, and cancers) and mortality for each individual nutrient are reported in Table 2.

The magnitude of the impacts depends on the food category (and its contribution to consumers' nutrient intakes), the magnitude of the reformulation scenario for each food category–nutrient pair and the relative risks related to each nutrient.

The greatest impact results from the SFA reduction in the 'oils, butter and fats' and 'snacks' categories and, to a lesser extent, in the 'cheese' and 'processed meats' categories. The reduction in salt content and increase in fiber content in the 'bread' category and reduction in added sugar in the 'snack' category also have significant impacts.

Regarding nutrients, it seems that the highest-impact reformulation target is SFA, which has the greatest effect on the number of deaths avoided (DA) (1897), followed by sugar and sodium, which have similar impacts (746 and 608 DA, respectively). The reformulation of fiber has a lower impact (223 DA).

Table 3 displays the total effects of the high reformulation scenario according to causes of mortality and for men and women. The results differ for men and women according to income classes. The total impact of reformulation is 3597 avoided deaths, that is, a 5.5% reduction in mortality due to chronic diseases taken into account in the DIETRON model. This impact is not exactly equal to the number of avoided deaths shown in Table 2. Indeed, in Table 3, we consider all of the effects

Table 2. Impacts of the 'high reformuation scenario' on DA for each individual nutrient and each food group

Sodium	*ICP prod.*	*Processed F&V*	*Bread*	*Processed meat*	*Processed fish*	*Main course*	*Filled sandwiches…*	*Meal sauces*	*Other sauces (emulsions)*
	Δ Content	*−20%*	*−25.5%*	*−15%*	*−24.6%*	*−15%*	*−15%*	*−15%*	*−22.1%*
DA for CVD and stroke		22	226	57	19	61	14	5	18
DA for cancers		10	101	25	8	27	6	2	8
Total DA		31	327	82	27	88	20	7	26
%		0.05%	0.50%	0.12%	0.04%	0.13%	0.03%	0.01%	0.04%
% Net of energy effect		0.05%	0.50%	0.12%	0.04%	0.13%	0.03%	0.01%	0.04%

Fibers	*ICP prod.*	*Bread*	*Rice*	*Grains and cereal prod.*	*Fruit juices*	*Main course*	*Filled sandwiches…*
	Δ Content	*+15%*	*+25%*	*+15%*	*+21%*	*+25%*	*+15.2%*
DA for CVD and stroke		128	5	2	2	76	10
DA for cancers		0	0	0	0	0	0
Total DA		128	5	2	2	76	10
%		0.19%	0.01%	0.00%	0.00%	0.11%	0.02%
% Net of energy effect		0.19%	0.01%	0.00%	0.00%	0.11%	0.02%

SFA	*ICP prod.*	*Potatoes processed…*	*Processed meat*	*Cheese prod.*	*Oils, butter and fats*	*Main course*	*Filled sandwiches…*	*Snacks…*
	Δ Content	*−15%*	*−25%*	*−15%*	*−16.5%*	*−15%*	*−25.5%*	*−25%*
DA for CVD and stroke		34	187	231	317	94	58	418
DA for cancers		14	74	94	135	39	23	179
Total DA		47	262	325	452	133	81	597
%		0.07%	0.40%	0.49%	0.69%	0.20%	0.12%	0.91%
% Net of energy effect		0.02%	0.12%	0.14%	0.21%	0.06%	0.04%	0.27%

Added sugar	*ICP prod.*	*Beverages*	*Snacks…*	*Processed F&V*	*Bread toppings…*
	Δ Content	*−20%*	*−20%*	*−20%*	*−28.9%*
DA for CVD and stroke		96	211	17	97
DA for cancers		66	165	19	74
Total DA		163	376	36	171
%		0.25%	0.57%	0.05%	0.26%
% Net of energy effect		0.00%	0.00%	0.00%	0.00%

Abbreviations: CVD, cardio-vascular disease; DA, deaths avoided; F&V, fruits and vegetables; ICP, International Choices Programme; Prod., Production; SFA, saturated fatty acids.

Table 3. Impacts of the 'high reformulation scenario' on death avoided for different consumer groups

	Men				*Women*				*All*				*Total*
	Modest	*Lower average*	*Upper average*	*Well-off*	*Modest*	*Lower average*	*Upper average*	*Well-off*	*Modest*	*Lower average*	*Upper average*	*Well-off*	
DA for DIETRON diseases													
CHD	572	498	376	341	72	53	38	27	644	551	414	368	1977
Stroke	211	149	99	75	7	5	4	2	217	154	102	78	551
M/L/P cancer	0	0	0	0	0	0	0	0	0	0	0	0	0
Oesophagus cancer	101	83	60	52	16	14	12	11	117	97	73	62	349
Lung cancer	0	0	0	0	0	0	0	0	0	0	0	0	0
Stomach cancer	53	39	33	27	11	10	9	7	64	48	41	34	188
Pancreas cancer	31	26	19	16	19	17	14	12	50	42	33	28	154
Colorectum cancer	52	43	32	27	32	28	24	21	84	71	56	48	259
Breast cancer	−1	−1	−1	−1	−83	−74	−63	−54	−84	−75	−64	−55	−278
Endometrial cancer	0	0	0	0	81	72	61	52	81	72	61	52	266
Kidney cancer	28	23	17	15	11	10	9	7	40	33	26	22	121
Gallbladder cancer	1	1	1	1	2	2	2	1	3	3	2	2	11
Total DA	1048	860	635	553	167	137	110	88	1215	997	744	640	**3597**
% DA/Total DA	86%				14%				34%	28%	21%	18%	
Δ Disparity index[a]	−0.002				0.002				0.001				

Abbreviations: CHD, coronary heart disease; M/L/P cancer, mouth, larynx, pharynx cancer. [a]Health disparity index $= \frac{\%death(\text{'modest'})/(100-\%death(\text{'modest'}))}{\%death(\text{'well-off'})/(100-\%death(\text{'well-off'}))}$. A decrease in this index means a reduction in health disparities between the two populations.

simultaneously and take into account multiplicative effects). The impacts are much higher for men (86%) than for women (14%). This difference is mainly explained by the magnitude of coronary heart disease and strokes reduction resulting from reformulation, because (i) the initial prevalence of these diseases is greater among men before the age of 74 years and (ii) the reformulation scenario modifies consumers' intakes of nutrients that are directly related to these diseases. In addition, in the DIETRON model, the relative risk related to the body mass index (BMI) is much higher for BMIs >25 than <25. The average BMI is >25 for men and slightly <25 for women. To ensure that the results were not caused by a threshold effect, we computed the health impacts using different BMI thresholds (between 24 and 26). In all cases, the impacts are much higher for men than for women, suggesting that this difference is mainly related to initial intakes and the nutrients targeted by the food reformulation process. Another reason for this gender difference is that a decrease in the BMI (induced by the change in nutrient intakes resulting from the reformulation process) may increase the prevalence of breast cancer for women.

The number of DA is much higher for low-income categories than for high-income categories: 34%, 28%, 21% and 18% for modest, lower average, upper average and well-off people, respectively. This difference results from the differences in consumption patterns and initial disease prevalence among the various income categories. These proportions are in line with the initial proportions of deaths (taken into account in the DIETRON model), which are 33%, 27%, 22% and 18%, respectively. These differences are also reflected in the health disparity index, which is not modified, meaning that the reformulation scenario does not clearly affect the health inequities in the population.

The low reformulation scenario has obviously smaller impacts. It leads to average variations in consumers' intakes, which depend on the nutrients: −9.3% for sodium, +4.5% for fiber, −11.7% for SFA and −4.6% for added sugars. The overall impact is 2408 DA, that is, a 3.7% reduction in mortality due to chronic diseases considered in the DIETRON model.

DISCUSSION

In this paper, we tested the impact of reformulation scenarios assuming that consumers do not change their diets. The results must be considered with caution given the uncertainties about food composition and health assessment impacts. In addition, food reformulation can require processing innovations or the use of new ingredients, resulting in higher production costs or additional investments that can limit firms' willingness to make voluntary changes.[1,2] Taste modifications resulting from decreased sugar, fat or sodium contents may also lead to rejection by consumers, which can limit firms' incentives to make such changes. Nevertheless, the results suggest that the modification of the nutritional quality of foods may induce significant health benefits even in the absence of changes in consumers' diet patterns. Although food reformulation alone would not be sufficient to markedly reduce the prevalence of chronic diseases related to food consumption, it can have an important role in that direction.[14] In comparison of the reformulation scenarios simulated in this paper, where do we stand in practice?

Many examples show that global food firms have engaged a product reformulation process.[15] Voluntary approaches often rely on agreements between regulatory agencies and firms.[16] For instance, in the processed meat sector, French firms' commitments had led to a 5% decrease in the salt and fat contents in different subgroups between 2008 and 2012.[17] In the processed potatoes sector, the mean content of saturated fats has decreased from 15.8 g/100 g in 2009 to 2.9 g/100 g in 2011.[18] The overall impact of these changes, however, remains modest: the overall effect of the commitments made by French firms since 2008 on consumers' caloric intakes had been estimated at only −10 kcal/day.[19]

In fact, if large global firms, for attesting their corporate social responsibility, have often engaged a reformulation process, most products are yet to be reformulated, especially those marketed by Small and Medium Enterprises (SMEs), which represent large market shares when considered as a whole.[20] Voluntary commitments by firms are often significant in what they pledge, but the final impacts are small because the number of committed firms remains limited.[21,22] This suggests that, in comparison with our reformulation scenarios, it is likely that the food reformulation process is only at half-way stage and has still to be generalized to the whole food sector. To fully get the potential health benefits induced by food reformulation, long-term partnerships between public health agencies and the food firms, based on collective agreements aiming at stimulating quality changes in the whole food industry, included SMEs, are clearly still required.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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