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Impact of ultra-processed foods on micronutrient content in the Brazilian diet

ABSTRACT

OBJECTIVE: To evaluate the impact of consuming ultra-processed foods on the micronutrient content of the Brazilian population's diet.

METHODS: This cross-sectional study was performed using data on individual food consumption from a module of the 2008-2009 Brazilian Household Budget Survey. A representative sample of the Brazilian population aged 10 years or over was assessed (n = 32,898). Food consumption data were collected through two 24-hour food records. Linear regression models were used to assess the association between the nutrient content of the diet and the quintiles of ultra-processed food consumption – crude and adjusted for family income *per capita*.

RESULTS: Mean daily energy intake *per capita* was 1,866 kcal, with 69.5% coming from natural or minimally processed foods, 9.0% from processed foods and 21.5% from ultra-processed foods. For sixteen out of the seventeen evaluated micronutrients, their content was lower in the fraction of the diet composed of ultra-processed foods compared with the fraction of the diet composed of natural or minimally processed foods. The content of 10 micronutrients in ultra-processed foods did not reach half the content level observed in the natural or minimally processed foods. The higher consumption of ultra-processed foods was inversely and significantly associated with the content of vitamins B12, vitamin D, vitamin E, niacin, pyridoxine, copper, iron, phosphorus, magnesium, selenium and zinc. The reverse situation was only observed for calcium, thiamin and riboflavin.

CONCLUSIONS: The findings of this study highlight that reducing the consumption of ultra-processed foods is a natural way to promote healthy eating in Brazil and, therefore, is in line with the recommendations made by the *Guia Alimentar para a População Brasileira* (Dietary Guidelines for the Brazilian Population) to avoid these foods.

DESCRIPTORS: Industrialized Foods. Food Composition. Micronutrients. Food Quality. Food Consumption.

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INTRODUCTION

Micronutrient deficiencies are among the 20 most important risk factors for diseases and affect around two billion people worldwide.[14] At least half the world's population of children aged between six months and five years, most of whom live in developing countries, suffer from one or more micronutrient deficiencies.[29]

Although micronutrient deficiencies can be caused by factors that are unrelated to diet, such as iron deficiency caused by intestinal parasites, they are mainly caused by insufficient quantities of micronutrients in the diet.[26] Studies based on a food consumption survey that were performed between 2008 and 2009, using a representative sample of the Brazilian adolescent, adult and elderly population, documented a high prevalence of dietary inadequacy in several vitamins and minerals.[1,5,30] Regional studies that were restricted to children also indicate inadequate micronutrient intake in Brazil.[2,6,27]

Based on a food consumption survey from 2008-2009, this study's authors evaluated the impact of consuming ultra-processed foods[18,19,21-23] on nutritional indicators of diet associated with chronic noncommunicable diseases.[15] The consumption of ultra-processed foods proved to be directly linked to the energy density of the diet and the content of saturated fats, trans fats and free sugar, and proved to be inversely associated to fiber and protein content, thereby demonstrating the potential harmful characteristics of these foods related to increasing the risk of obesity, diabetes, cardiovascular disease and some types of cancer. This study's objective was to evaluate the impact of ultra-processed foods on the micronutrient content of food consumed by the Brazilian population.

METHODS

The data analyzed in this study was taken from the individual food consumption module of the Brazilian Household Budget Survey (HBS), which was performed by the Brazilian Institute of Geography and Statistics (IBGE) between May 2008 and May 2009.[10]

This module from the HBS was applied to all residents aged 10 years or over, from a probabilistic sample of 13,569 households, totaling 34,003 individuals. The sample of households was randomly selected using a conglomerates plan with a census sector draw in the first stage, and households, in the second. The census tracts were grouped prior to the draw in strata with sufficient geographical and socioeconomic homogeneity. The households drawn in each stratum were uniformly distributed for study over the four quarters in the year.[9]

The 2008-2009 HBS obtained data on each individual's food consumption with two 24-hour food records.

The individuals were asked to record all the food and beverages that they consumed during a 24-hour period over two nonconsecutive days, the objective of which was to show the quantities consumed using homemade measurements as well as the preparation method. The quantity of each food or drink was converted into grams or milliliters using a measurement table that refers to food consumed in Brazil.[11] These amounts were subsequently converted into kilocalories of energy and into grams or milligrams of nutrients based on the Table of Nutritional Composition of Food Consumed in Brazil.[12]

The 1,120 food items listed in the 2008-2009 HBS database were divided into three main groups according to the industrial processing characteristics to which the items were submitted: natural or minimally processed (including culinary preparations based on these foods), processed foods and ultra-processed foods.[18,19,21-23]

Natural or minimally processed foods include: foods obtained directly from plants or animals (like leaves, fruit, eggs and milk) and acquired for consumption without having undergone any alteration following their harvest; and foods that, prior to their acquisition, were cleaned, had their inedible or unwanted parts removed, been subjected to drying, packing, pasteurization, freezing, refinement, fermentation as well as other processes that do not include adding substances to the original food. Included in this food group are culinary preparations that contain one or more natural or minimally processed foods, these may include the food that is used as the main recipe item and other ingredients, including any other foods or food substances used in the culinary process such as salt, sugar, vinegar and oils.[18,19,21-23]

Processed foods are manufactured products that are primarily made by adding salt or sugar (and eventually oil, vinegar or other culinary substances) to an natural or minimally processed food.[18,19,21-23]

Ultra-processed foods are industrial formulations that are entirely or predominantly made from substances that are extracted from food (oils, fats, sugar, proteins), and these are derived from food constituents (hydrogenated fats, modified starch) or synthesized in a laboratory from organic materials (colorants, flavorings, flavor enhancers and various additives that are used to give the products desirable sensory properties).[18,19,21-23] A detailed list of foods from each of the three groups can be found in a previous publication.[15]

The individuals who completed their records, referring to the two days of food consumption, were analyzed (96.8% of the total number of individuals studied in the individual consumption module of the HBS). Food and

nutrient consumption was estimated based on the mean values obtained during the two days.

The micronutrients evaluated were vitamins A, B12, C, D and E, niacin, pyridoxine, riboflavin and thiamine, and the minerals assessed were calcium, copper, iron, phosphorus, magnesium, manganese, selenium and zinc. The content of each nutrient in the diet was expressed in mg or μg per 1,000 kcal.

Firstly, the mean content of each micronutrient in the total diet of the Brazilian population was estimated. The mean content of each nutrient in the fraction of the diet composed only by ultra-processed foods was compared to the fraction of the diet that was restricted to natural or minimally processed foods and with the fraction restricted to processed foods. The statistical significance of the differences found during the comparisons was evaluated with the Student's *t*-test.

The individuals were classified into five strata in accordance with their consumption of ultra-processed foods. These strata corresponded to quintiles of the population distribution according to the contribution of ultra-processed foods to the total caloric value of the diet. The micronutrient content of the diet in these strata was subsequently evaluated. Linear regression analyses were used to describe the trend and the statistical significance of the association between the quintiles of relative ultra-processed food consumption and micronutrient content of the diet, with and without adjustment for monthly household income *per capita*. The household location (urban or rural), region of the country (Midwest, North, Northeast, Southeast and South), age and gender characteristics did not alter the regression model estimates and therefore were not included in the analyses.

The statistical analyses performed in this study were done using Stata version 13.0 software, considering the complex sample design of the 2008-2009 HBS and its weighting factors. This study was approved by the Committee of Ethics in Research at the Faculdade de Saúde Pública of the Universidade de São Paulo (Protocol 128,958, 10/19/2012).

RESULTS

The mean daily energy consumption by Brazilians was 1,866 kcal, of which 69.5% was natural or minimally processed foods, 9.0% processed foods and 21.5% ultra-processed foods (Table 1).

Table 2 shows the micronutrient content in the Brazilian diet and in the fractions of this diet referring to natural or minimally processed foods, processed foods and ultra-processed foods, respectively.

Table 1. Means for the absolute and relative consumption of natural or minimally processed foods, processed foods and ultra-processed foods in the Brazilian population aged 10 years or over (2008-2009).

Group	Kcal/day	% of total energy intake
Natural or minimally processed foods[a]	1275.5	69.5
Processed foods[b]	167.1	9.0
Ultra-processed foods[c]	423.4	21.5
Total	1866.0	100

[a] Includes rice and other cereals, beans and other legumes, meats, and poultry, fruits, roots and tubers, milk, coffee and tea, fish and other seafood, vegetables, eggs, nuts and other seeds.
[b] Includes "French bread" (bread rolls), cheeses, canned vegetables, and dried and salted meats.
[c] Includes cakes, tarts and cookies, fast food snacks, soft drinks, soda, dairy drinks, loaf, burger bread, hot dog bread and other similar breads, sweets, crackers and chips, sausages and ready or semi-ready-to-eat meals.

For 16 of the 17 micronutrients studied, the content of such found in the fraction referring to the ultra-processed foods was below the level found in the fraction referring to the natural or minimally processed foods. Contents of vitamin B12, vitamin C, vitamin D, vitamin E, niacin, pyridoxine, copper, magnesium, manganese and zinc found in the ultra-processed foods were at least two times lower than the contents found in the natural or minimally processed foods. The observed differences for vitamin B12, vitamin C and magnesium were particularly evident, whose contents were respectively four, five and 13 times lower in the ultra-processed foods. For vitamin A, iron and phosphorus, the content found in ultra-processed foods represented between 70.0% and 60.0% of that found in the natural or minimally processed foods. Less intense disadvantages for ultra-processed foods were found for riboflavin, calcium and selenium content. Thiamine was the only micronutrient whose content in the fraction of ultra-processed foods exceeded that found in the fraction of natural or minimally processed foods, albeit only to a slight extent.

Less striking contrasts concerning micronutrient content are evident when comparing ultra-processed and processed food. In general terms, this comparison also tends to put ultra-processed foods at a detriment, as is the case with the contents of vitamin B12, pyridoxine, riboflavin, thiamin, calcium, phosphorus, magnesium, manganese, and zinc. This comparison is detrimental for processed foods in the case of vitamin A, vitamin C, vitamin D, vitamin E, and niacin. The processed foods and ultra-processed foods had similar levels of copper, iron, and selenium.

Table 3 describes the crude analyses of the association between the quintiles of relative consumption of ultra-processed foods and micronutrient content in the diet. The mean contribution of ultra-processed foods to the total caloric intake ranged from 1.8% in the lower quintile, to 49.2%, in the upper quintile. There was a significant and negative association between relative consumption of ultra-processed foods and micronutrient content in the diet for 11 of the 17 micronutrients studied, namely: vitamin B12, vitamin D, vitamin E, niacin, pyridoxine, copper, iron, phosphorus, magnesium, selenium, and zinc. Three micronutrients – vitamin A, vitamin C and manganese – showed no significant association between the consumption of ultra-processed foods and the nutrient content in the diet. A significant decrease in micronutrient content in the diet along with the increase in ultra-processed food consumption was found only for calcium, thiamine and Riboflavin, although with very small magnitude in the last two cases.

Table 4 describes the analyses of the association between relative consumption of ultra-processed foods and micronutrient content in the diet that have been adjusted for household income *per capita*. The adjustment for income does not substantially alter the results of this association. The only highlights are the decrease in the magnitude

of the positive association between relative consumption of ultra-processed foods and calcium content in the diet, and the negative association between the relative consumption of these foods and the content of vitamin C in the diet, which is close to being statistically significant.

DISCUSSION

The results from this study, which are representative of the Brazilian diet, show that the micronutrient content in ultra-processed foods tends to be lower than this content that exists in other foods. The inferiority of ultra-processed foods is even more evident when they are compared with natural or minimally processed foods. For 16 of the 17 micronutrients under study, the mean content found in the set of ultra-processed foods consumed by Brazilians was lower than the mean content found in the natural or minimally processed foods. The content of 10 micronutrients (vitamin B12, C, D, E, niacin, pyridoxine, copper, magnesium, manganese, and zinc) that are present in the ultra-processed foods was not even half the content observed in the natural or minimally processed foods. Crude and adjusted for family income analysis indicate that the content of the diet in 11 of the 17 micronutrients under study decreased significantly with the increase in the

Table 2. Mean micronutrient content in total food consumption and in fractions of this consumption relating to natural or minimally processed foods, processed foods and ultra-processed foods. Brazilian population aged 10 years or over (2008-2009).

Micronutrient	Total food consumption	Food consumption fraction		
		Natural or minimally processed foods	Processed foods	Ultra-processed foods
Vitamins				
Vitamin A (µg/1,000 kcal)	286.7	340.5	118.7	239.1*
Vitamin B12 (µg/1,000 kcal)	2.8	3.5	1.2	1.0*
Vitamin C (mg/1,000 kcal)	87.4	121.2	1.9	23.8*
Vitamin D (µg/1,000 kcal)	1.7	2.1	0.6	0.9*
Vitamin E (mg/1,000 kcal)	2.2	2.7	0.4	1.4*
Niacin (mg/1,000 kcal)	14.1	17.1	4.7	7.3*
Pyridoxine (mg/1,000 kcal)	0.8	0.8	1.6	0.4*
Riboflavin (mg/1,000 kcal)	0.9	0.8	1.9	0.7*
Thiamin (mg/1,000 kcal)	0.6	0.5	1.1	0.7*
Minerals				
Calcium (mg/1,000 kcal)	278.7	265.8	312.3	243.1*
Copper (mg/1,000 kcal)	0.7	0.9	0.4	0.4*
Iron (mg/1,000 kcal)	6.2	7.0	3.5	4.1*
Phosphorus (mg/1,000 kcal)	522.4	548.6	578.4	356.3*
Magnesium (mg/1,000 kcal)	129.2	150.2	91.9	66.4*
Manganese (mg/1,000 kcal)	6.5	9.6	1.3	0.7*
Selenium (µg/1,000 kcal)	46.6	28.6	18.9	24.6*
Zinc (mg/1,000 kcal)	6.0	7.0	4.3	3.0*

* Value significantly different (p < 0.05) from the value that was estimated for natural or minimally processed foods and for processed foods.

Table 3. Mean micronutrient content in the diet according to quintiles of ultra-processed food contribution to the total energy consumption. Brazilian population aged 10 years or over (2008-2009).

Micronutrient	Quintiles of ultra-processed food consumption					Crude regression coefficient*	p
	Q1	Q2	Q3	Q4	Q5		
Vitaminas							
Vitamin A (µg/1,000 kcal)	254.6	290.5	339.3	300.0	249.3	-0.12	0.974
Vitamin B12 (µg/1,000 kcal)	3.2	3.0	3.1	2.7	2.2	-0.23	< 0.001
Vitamin C (mg/1,000 kcal)	74.1	98.5	106.2	87.6	71.0	-1.71	0.147
Vitamin D (µg/1,000 kcal)	2.1	1.9	1.7	1.6	1.5	-0.14	< 0.001
Vitamin E (mg/1,000 kcal)	2.4	2.3	2.3	2.1	1.9	-0.10	< 0.001
Niacin (mg/1,000 kcal)	14.7	14.6	14.3	13.9	13.1	-0.41	< 0.001
Pyridoxine (mg/1,000 kcal)	0.8	0.8	0.8	0.8	0.7	-0.02	< 0.001
Riboflavin (mg/1,000 kcal)	0.8	0.9	0.9	0.9	0.9	0.01	< 0.001
Thiamin (mg/1,000 kcal)	0.6	0.6	0.6	0.6	0.7	0.03	< 0.001
Minerals							
Calcium (mg/1,000 kcal)	248.9	254.5	271.0	291.5	327.9	19.50	< 0.001
Copper (mg/1,000 kcal)	0.7	0.7	0.8	0.7	0.6	-0.03	< 0.001
Iron (mg/1,000 kcal)	6.7	6.3	6.2	6.0	5.7	-0.22	< 0.001
Phosphorus (mg/1,000 kcal)	543.9	528.7	522.2	512.5	504.7	-9.47	< 0.001
Magnesium (mg/1,000 kcal)	147.2	136.8	130.8	121.5	109.7	-9.02	< 0.001
Manganese (mg/1,000 kcal)	6.2	6.3	7.0	7.3	5.9	0.02	0.913
Selenium (µg/1,000 kcal)	52.4	49.0	46.3	43.9	41.7	-2.66	< 0.001
Zinc (mg/1,000 kcal)	6.6	6.2	6.1	5.8	5.3	-0.9	< 0.001

* Regression coefficient of the micronutrient content in the diet on the percentage of the total caloric value of the diet from ultra-processed foods.

relative consumption of ultra-processed foods. There was only an inverse situation found for three micronutrients: calcium, thiamine and riboflavin, with the association found in the case of thiamin and riboflavin being of very small magnitude.

The positive association between the relative consumption of ultra-processed foods and the calcium content in the diet was unexpected, since the content of this mineral in these foods is smaller than in natural or minimally processed foods. Detailed analyses (not shown in this article) of the variation in the composition of ultra-processed items in the diets according to the quintiles of the relative consumption of those foods show a significant increase in ultra-processed items that are particularly rich in calcium, such as ready and semi-ready-to-eat meals, fast foods (all often containing cheese in their ingredients) and dairy drinks with added sugar.

Despite the lack of other studies that evaluated the association between consumption of ultra-processed foods and micronutrient content in the diet, evidence that their consumption could dilute the concentration of micronutrients in the diet was documented by studies that focused on soft drink[4,16,32] or fast-food consumption.[24]

The negative impact of ultra-processed foods on micronutrient content in the diet, as was observed during this study, is of great importance when the critical roles that vitamins and minerals play in cell signaling are considered, as they are critical for hormone production, immune responses and the development and maintenance of the vital functions.[31] Although micronutrient deficiency does not always manifest itself clinically, subclinical deficiencies can be harmful to health.[31]

Deficiencies in iron, zinc, and vitamin A, nutrients that are present in smaller quantities in ultra-processed foods when compared to natural or minimally processed foods, are among the nutritional problems of greatest magnitude in the world, affecting mainly children, pregnant women, and populations in developing countries.[14] The consequences of these are extremely relevant to public health, they include stunted growth and development of children and increased fetal and maternal mortality.[14]

Iron, zinc, and vitamin A, as well as vitamin B12, vitamin C, riboflavin and selenium act as immunomodulators that influence infectious disease susceptibility and the severity of their effects.[7,31] Sufficient intake of vitamin D, calcium, magnesium and phosphorus is in turn important for bone mass development and maintenance,[25] while the vitamins of the B complex (thiamine, riboflavin, niacin and pyridoxine) are involved in maintaining cognitive function.[8]

Table 4. Micronutrient content in the diet according to quintiles of ultra-processed food contributionto the total energy consumption, adjusted for household income *per capita*. Brazilian population aged 10 years or over (2008-2009).

Indicator	Q1	Q2	Q3	Q4	Q5	Adjusted regression coefficient*	p
Micronutrient density							
Vitamins							
Vitamin A (µg/1,000 kcal)	290.2	286.8	283.4	280.1	276.7	-4.00	0.437
Vitamin B12 (µg/1,000 kcal)	3.3	3.1	2.8	2.6	2.4	-0.22	< 0.001
Vitamin C (mg/1,000 kcal)	92.4	89.2	85.9	82.6	79.3	-3.27	0.066
Vitamin D (µg/1,000 kcal)	2.0	1.9	1.8	1.6	1.5	-0.13	< 0.001
Vitamin E (mg/1,000 kcal)	2.4	2.3	2.2	2.1	2.0	-0.11	< 0.001
Niacin (mg/1,000 kcal)	15.1	14.5	13.9	13.4	12.8	-0.56	< 0.001
Pyridoxine (mg/1,000 kcal)	0.8	0.8	0.8	0.7	0.7	-0.01	< 0.001
Riboflavin (mg/1,000 kcal)	0.9	0.9	0.9	0.9	0.9	0.01	< 0.001
Thiamin (mg/1,000 kcal)	0.6	0.6	0.6	0.7	0.7	0.02	< 0.001
Minerals							
Calcium (mg/1000 kcal)	245.2	259.2	273.2	287.2	301.2	14.00	< 0.001
Copper (mg/1000 kcal)	0.7	0.7	0.7	0.7	0.7	-0.02	< 0.001
Iron (mg/1000 kcal)	6.6	6.4	6.2	5.9	5.7	-0.23	< 0.001
Phosphorus (mg/1000 kcal)	545.7	531.8	517.9	504.0	490.1	-13.9	< 0.001
Magnesium (mg/1000 kcal)	147.4	138.2	129.1	119.9	110.8	-9.15	< 0.001
Manganese (mg/1000 kcal)	6.6	6.5	6.4	6.3	6.3	-0.08	0.746
Selenium (µg/1000 kcal)	52.0	49.3	46.6	43.9	41.2	-2.71	< 0.001
Zinc (mg/1000 kcal)	6.6	6.3	6.0	5.6	5.3	-0.33	< 0.001

* Regression coefficient of the micronutrient content in the diet regarding the percentage of the total caloric value of the diet from ultra-processed foods after adjustment for monthly family income *per capita*.

Lastly, micronutrients with antioxidant functions such as vitamins C and E and minerals selenium and zinc have key roles in the etiology and prognosis of chronic diseases.[3,13]

Documenting the negative effects, which result from consuming ultra-processed foods, on micronutrient content in the diet becomes even more important because of the rapidly increasing sales of these foods in Brazil and, more generally, in middle income countries.[20,28] Household food budget surveys performed in Brazilian metropolitan areas from 1987 to1988 and 2008 to 2009 confirm that consumption of ultra-processed foods is increasing and consumption of natural or minimally processed foods and culinary ingredients such as oils, fats and sugar is decreasing.[17]

The strong aspects of this study were the rigorously probabilistic nature of the studied sample, the fact that more than 30,000 people residing in urban and rural areas from all regions of the country were included in the study and that there were two 24-hour food consumption recording periods in 96.8% of those studied in the individual consumption module of the HBS. The limitations of this study include inaccuracies when quantifying the consumption of foods and nutrients that are inherent to food records and food composition tables. To minimize these inaccuracies, we have employed various quality control procedures and food composition tables that had been specifically built for this research.[10] In addition, the survey performed in 2008-2009[10] did not include people younger than 10 years of age, which means that its results are not necessarily applicable to the diet of infants and preschoolers.

The results relating to the adverse impact from consuming ultra-processed foods on micronutrient content in the diet, in addition to the results documenting the equally unfavorable impact related to macronutrient content – increase in energy density and content of saturated fats, trans fats and free sugar, and decrease in fiber and protein content[15] – show that reducing ultra-processed food consumption is a natural way to promote healthy eating in Brazil.

Moreover, our study, while also considering the study on the macronutrient content in the Brazilian diet,[15] support the recommendations set out in the new edition of the Dietary Guidelines for the Brazilian Population, particularly the recommendation for basing the diet on natural or minimally processed foods, moderating the consumption of processed foods and avoiding ultra-processed foods.[18]

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