

# Associations between Consumption of Ultra-Processed Foods and Intake of Nutrients Related to Chronic Non-Communicable Diseases in Mexico



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## ABSTRACT

**Background** Ultra-processed foods are highly palatable and can be consumed anywhere at any time, but typically have a poor nutritional profile. Therefore, their contribution to total energy intake has been proposed as an indicator for studying overall dietary quality.

**Objective** The aim of this study was to investigate the associations between the energy contribution from ultra-processed foods and the intake of nutrients related to chronic non-communicable diseases in Mexico.

**Design** This study used a secondary analysis of cross-sectional data from the 2012 Mexican National Health and Nutrition Survey.

**Participants/setting** This study included participants aged 1 year and older ( $n=10,087$ ) who had completed a 1-day 24-hour recall.

**Main outcome measures** Intake from added sugar (% kcal), total fat (% kcal), saturated fat (% kcal), protein (% kcal), dietary fiber (g/1,000 kcal), and dietary energy density (kcal/g) were measured.

**Statistical analysis** Multiple linear regression models adjusted for sociodemographic variables were fitted to assess the association between quintiles of energy contribution from ultra-processed foods and nutrient intake.

**Results** Mean reported energy contribution from ultra-processed foods to the Mexican population's diet ranged from 4.5% kcal in quintile 1 (Q1) to 64.2% kcal in quintile 5 (Q5). An increased energy contribution from ultra-processed foods was positively associated with intake from added sugar (Q1: 7.4% kcal; Q5: 17.5% kcal), total fat (Q1: 30.6% kcal; Q5: 33.5% kcal) and saturated fat (Q1: 9.3% kcal; Q5: 13.2% kcal), as well as dietary energy density (Q1: 1.4 kcal/g; Q5: 2.0 kcal/g) ( $P\leq 0.001$ ); and inversely associated with intake from protein (Q1: 15.1% kcal; Q5: 11.9% kcal) and dietary fiber (Q1: 16.0 g/1,000 kcal; Q5: 8.4 g/1,000 kcal) ( $P\leq 0.001$ ).

**Conclusions** In the Mexican population, an increased energy contribution from ultra-processed foods was associated with a lower dietary quality with regard to intake of nutrients related to chronic non-communicable diseases. Future research is needed to identify barriers to eating a variety of unprocessed and minimally processed foods for the Mexican population, as well as effective public health strategies and policies to overcome these barriers.

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ULTRA-PROCESSED FOODS ARE CONVENIENT AND ready-to-eat formulations. They contain substances derived from foods but with no common culinary use (eg, protein isolates, modified starches, hydrogenated fats), additives that give them attractive sensorial properties (eg, flavor enhancers, dyes, artificial sweeteners), and little, if any, whole food. Due to their ingredients, they are typically energy-dense, have a high glycemic load, contain excessive amounts of free sugars and unhealthy fats, and contain low amounts of dietary fiber and micronutrients. Most ultra-processed foods are highly palatable, attractively

packaged, and aggressively marketed. Ultra-processed foods include sweet or savory energy-dense packaged snacks, carbonated and non-carbonated drinks, preprepared frozen or shelf-stable dishes, breakfast cereals, pastries, candies, spreads, and dressings.<sup>1</sup>

Increased production, distribution, and sales of ultra-processed foods characterize the food supply across the globe.<sup>2-6</sup> Worldwide, the replacement of traditional culinary preparations by ultra-processed foods has been driven by aggressive marketing strategies of transnational food industries, supermarkets, and fast-food chains.<sup>7</sup> Other drivers

include sociodemographic changes such as the increase in consumers' purchasing power; urbanization; the proportion of women employed outside the home; and new dietary habits, such as snacking and eating away from home.<sup>8-10</sup> Studies from nationally representative dietary surveys have shown that consumption of ultra-processed foods accounts for 15.9% of total energy intake in Colombia,<sup>11</sup> 20.4% in Brazil,<sup>12</sup> 28.6% in Chile,<sup>13</sup> 48.0% in Canada,<sup>14</sup> 56.8% in the United Kingdom,<sup>15</sup> and 58.5% in the United States.<sup>16</sup>

Because ultra-processed foods have a poor nutritional profile, their contribution to total energy intake has been proposed as an indicator of dietary quality, especially for studying the intake of nutrients related to chronic non-communicable diseases (NCDs).<sup>17-19</sup> In Mexico, the consumption of ultra-processed foods is 29.8% of total energy intake.<sup>20</sup> Concurrently, nationally representative studies have documented excessive intakes of added sugar and saturated fat, low intake of dietary fiber,<sup>21</sup> and high energy-density diets<sup>22</sup> in the population. Therefore, the objective of this study was to evaluate the association between the energy contribution of ultra-processed foods and intake of nutrients relevant to NCDs in Mexico.

## METHODS

### Data Source and Population

The data used in this study came from the 2012 Mexican National Health and Nutrition Survey (Encuesta Nacional de Salud y Nutrición [ENSANUT] 2012) conducted by the National Institute of Public Health of Mexico (Instituto Nacional de Salud Pública [INSP]) between October 2011 and May 2012. The ENSANUT 2012 is a probabilistic-based survey with a complex multi-stage and stratified sampling design, representative at national, regional, and state levels, for urban and rural areas. Two teams of interviewers (health and nutrition) collected information from the sampled households on different days. First, interviewers from the health team used a structured questionnaire to collect sociodemographic information from all participants, such as sex, age, rural/urban residence area, geographic region, socioeconomic status, and educational level. Then, interviewers from the nutrition team used a 24-hour recall (24HR) to collect dietary information from a subsample of 10,886 participants (approximately 11% of the total ENSANUT 2012 sample). A detailed description of the design strategy is available elsewhere.<sup>23</sup> Informed consent was obtained from each participant before the data were collected. The survey was approved by the INSP Research, Biosafety, and Ethics Committees in Cuernavaca, Mexico.

For this study, the following participants were excluded: pregnant and lactating women (n=154); children aged younger than 1 year (n=411); breastfed children aged 1 year and older (n=107); participants with incomplete sociodemographic information (n=4); and participants with extreme energy intakes (n=123), which were defined as those values below -3 standard deviations (SDs) and above +3 SDs of the median ratio of daily energy intake to estimated energy requirements.<sup>24</sup> A final sample of 10,087 participants aged 1 year and older was studied.

## RESEARCH SNAPSHOT

**Research Question:** Is the consumption of ultra-processed foods associated with the intake of nutrients related to chronic non-communicable diseases in Mexico?

**Key Findings:** In this study, which included data for 10,087 Mexicans aged 1 year and older taken from the 2012 Mexican National Health and Nutrition Survey, increased energy contribution from ultra-processed foods was associated with increased intake from added sugar, total and saturated fat; decreased intake from protein and dietary fiber; and increased dietary energy density.

### Sociodemographic Characteristics

ENSANUT 2012 participants were grouped as preschool-aged children (1 to 4 years), school-aged children (5 to 11 years), adolescents (12 to 19 years), adults (20 to 59 years), and elderly (60 years and older). Residence area was classified as rural (locations with <2,500 inhabitants) and urban (locations with ≥2,500 inhabitants). The country was divided according to common geographic, economic, social, and cultural characteristics into three geographic regions: South (considered the least developed region in the country, it has the largest rural and indigenous population and has limited access to basic and health services); Central (has a developed economy, large developed cities and many rural towns, and has access to basic and health services); and North (the most industrialized region with the highest degree of development, it has adequate access to basic and health services, as well as close cultural and economic relations with the border states of the United States).<sup>25</sup> A socioeconomic status index, constructed through use of principal component analysis, was used to assess socioeconomic status. The socioeconomic status index included household characteristics (eg, material used for floor and roof construction, number of bedrooms, bathroom and lights, exclusive kitchen); basic services (eg, water, electricity, cable, Internet); and material goods (eg, possession of television, computer, refrigerator, stove); and was used to classify participants into low, medium, and high tertiles of socioeconomic status.<sup>26</sup> Head of household educational level was classified according to the maximum years of study completed, as follows: no formal education, elementary school, middle school education, high school, and college.

### Dietary Data

Trained interviewers used a single 24HR interview, adapted from the US Department of Agriculture automated multiple-pass method,<sup>27</sup> to obtain each participant's reported dietary intake on a randomly selected day between Monday and Sunday. Respondents aged younger than 15 years were assisted by the person who cooked and prepared their meals in the household, while those aged 15 years and older were asked directly. All participants report their intake from the previous day as: 1) individual foods, 2) custom recipes (individual ingredients that make up the recipe as reported by participants), and 3) standard recipes (sets of default ingredients that make up a recipe when the participant was not able to provide one).<sup>21</sup> For the present analysis, custom and

### 1. Unprocessed or minimally processed foods

Unprocessed foods are food of plant or animal origin obtained directly from nature. Minimally processed foods are foods altered in ways that do not add or introduce any substance but involve the removal of inedible or unwanted parts of the food. Processes involved in this group include drying, crushing, grinding, fractioning, skinning, boiling, roasting, pasteurization, refrigeration, freezing or vacuum packaging. The purposes of the processes used in this group are to extend the life of unprocessed foods and facilitate or diversify food preparation.

| Food subgroups        | Examples   |
|-----------------------|--|
| Corn tortillas        | Corn tortilla, wheat tortilla, blue corn tortilla                |
| Milk                  | Whole cow's milk, low-fat cow's milk, milk with added vitamins   |
| Red meat              | Lamb, pork, beef   |
| Cereals (except corn) | Rice, pasta, oats, wheat   |
| Fruits                | Apple, banana, oranges, natural fruit juices without added sugar |
| Poultry and game      | Chicken, duck, iguana, turkey, maguery worm (caterpillar)        |
| Beans                 | White beans, pink beans, pot of beans                            |
| Eggs                  | Scrambled egg, boiled egg, fresh egg                             |
| Vegetables            | Pumpkin flower, squash, peppers, lettuce, tomatoes               |
| Corn                  | Corn flour, corn, tamale, maize (whole grain)                    |
| Starchy vegetables    | Potato, sweet potato, yucca root                                 |
| Coffee and tea        | Coffee and tea without sugar                                     |
| Seafood               | Fish, crustaceans, octopus, squid                                |
| Other                 | Nuts and seed without salt, ginger root, lentils, peas, parsley  |

### 2. Processed culinary ingredients

Substances extracted and purified by industry from food constituents or obtained from nature. Processes involved in this group include pressing, refining, milling or spray drying. The purpose of the processes involved in this group is to make products used in the home or restaurant kitchens to prepare varied and enjoyable hand-made dishes.

| Food subgroups | Examples                                     |
|----------------|--|
| Oils and fats  | Olive oil, canola oil, coconut oil, lard     |
| Sweeteners     | Honey, sugar, sweetened condensed milk       |
| Other          | Chicken and beef broth, Mexican "mole," salt |

### 3. Processed foods

Products preserved in sugar, oil or salt. Most of these products have two or three ingredients in their composition. Processes involved in this group include canning, bottling, fermentation, salting, salt-pickling, or curing. The purposes of the processes used in this group are to increase the durability of unprocessed or minimally processed foods, modify or enhance sensory qualities of unprocessed or minimally processed foods and resist microbial contamination.

| Food subgroups                | Examples  |
|-------------------------------|---|
| Unpackaged freshly made bread | Freshly made bread  |
| Cheeses                       | Mexican cheese, panela cheese, ricotta cheese                   |
| Other                         | Beer, jalapeno canned, jam, fruit with syrup, beer, cider, wine |

### 4. Ultra-processed foods

Industrial formulations manufactured from five or more ingredients commonly used in food processing industries, such as substances derived from foods (eg, oils, fats, sugar, casein, lactose, whey and gluten) or synthesized from other organic sources (eg, hydrogenated or interesterified oils, soy protein isolate, maltodextrin, inverted sugar and high-fructose corn syrup), preservatives and additives (eg, humectants, emulsifiers, solvents, bulking agents, non-sugar sweeteners, colorings, and flavorings). Processes involved in this group include hydrogenation, hydrolysis, extruding, molding, reshaping, frying, or baking. The purpose of the processes involved in this group is to create products ready to heat, drink, or eat anywhere.

*(continued on next page)*

**Figure 1.** The NOVA food framework: classification of foods according to their nature, extent, and purpose of processing.<sup>1</sup>

| Food subgroups                           | Examples  |
|--|---|
| Cookies, pastries, and sweet bread       | All types of cookies, pancakes, rice cereal bar, fried dough  |
| Carbonated sugar-sweetened beverages     | Soda, grape soda, orange soda, lemon-lime soda  |
| Salty snacks                             | Nuts and seeds with salt, tortilla chips, potato chips  |
| Packaged tortillas and bread             | Fried tortillas, hamburger buns, hot dog buns, multi-grain breads   |
| Candies and sweets                       | Chocolates, peanut butter, cotton candy, marshmallows   |
| Yogurt and milk-based beverages          | Milkshakes, yogurt with fruit, chocolate milk   |
| Sausages and other ultra-processed meats | Ham, bologna, fried hamburger patty, pork sausage, canned fish  |
| Non-carbonated sugar-sweetened beverages | Nectars, energy drinks, coffee with sugar   |
| Breakfast cereals                        | Ready-to-eat chocolate cereal, other flavored cereals   |
| Other                                    | Food supplements, baby food in a jar, chicken nuggets, pizza, butter, mayonnaise, cheddar cheese, cream cheese, whiskey, gin, vodka |

**Figure 1.** (continued) The NOVA food framework: classification of foods according to their nature, extent, and purpose of processing.<sup>1</sup>

standard recipes were disaggregated into their individual ingredients.

Foods and beverages reported in the 24HR interview were classified according to the NOVA food framework,<sup>1</sup> which classifies foods according to the nature, extent, and purpose of their processing into: 1) unprocessed or minimally processed foods (those obtained directly from nature or altered in ways that do not introduce any additional substances but may involve removal of inedible parts); 2) processed culinary ingredients (substances derived from NOVA group 1 foods or nature through methods, such as pressing, refining, grinding, milling, and drying and used in the preparation and cooking of NOVA group 1 foods); 3) processed foods (those manufactured products made from foods in NOVA groups 1 and 2); and 4) ultra-processed foods (manufactured formulations that have in their list of ingredients either food substances not commonly used in culinary preparations, and/or additives). Thus, every food and beverage was classified into one of the four NOVA food groups and into 1 of 30 food subgroups (see Figure 1 for food group definitions and examples).

To evaluate dietary quality, all macronutrients that are relevant for the prevention of NCDs, according to the World Health Organization (WHO) were considered. WHO provides goals for protein (10% kcal to 15% kcal), carbohydrates (55% kcal to 75% kcal), added sugar (<10% kcal), total fat (15% kcal to 30% kcal), saturated fat (<10% kcal), and dietary fiber (>12.5 g/1,000 kcal).<sup>18</sup> Dietary energy density was also evaluated using the recommended upper level of  $\leq 1.25$  kcal/g proposed by the World Cancer Research Foundation (WCRF) for the prevention of obesity.<sup>28</sup> Energy and nutrients intakes were estimated using the food composition database (version 2014) compiled by the Center for Nutrition and Health Research of the INSP.<sup>29</sup> Dietary energy density was calculated by dividing the food's total energy by the food's total weight (eg, cooked weight) in grams, as proposed by the WCRF<sup>28</sup> (for this estimation, beverages were excluded). Added sugar intake was estimated according to Sánchez-Pimienta and colleagues.<sup>30</sup> Briefly, for all foods without added sugar or with naturally occurring sugar (eg, fruits, vegetables, unprocessed cereals, legumes, starchy vegetables), their

added sugar value was zero; for foods in which all sugar is added (eg, sodas, confectionary products, processed meats, breakfast cereals, pastries), their added sugar value was equal to their total sugar content; and for all other foods that have a mix of naturally occurring sugar and added sugar, a portion of the total sugar was estimated as added sugar by subtracting lactose content in the case of flavored milk, yogurt, flan/crème caramel; or by subtracting known amounts of naturally occurring sugars based on similar foods that do not have added sugars (eg, comparing the sugar content of 100% juice vs fruit juices with added sugar).

### Statistical Analysis

Participants were classified in quintiles according to the energy contribution of ultra-processed foods (% kcal) to their diet. To identify the adjusted mean energy intake (% kcal) of all NOVA food groups and subgroups across quintiles of energy contribution of ultra-processed foods, multiple linear regression models were run using each NOVA food group and subgroup as the dependent variable and the quintiles as the dummy independent variable. The models were adjusted for age group, residence area, region, socioeconomic status, and head of household educational level.

The nutrient intake was estimated from the entire diet and for two fractions of it. One fraction included exclusively ultra-processed foods and the other fraction included only non-ultra-processed foods (unprocessed or minimally processed foods, processed culinary ingredients, and processed foods). Sample size changed in each fraction of the diet because there were participants who did not consume either ultra-processed foods (n=673) or non-ultra-processed foods (n=12); therefore, they were not included in the estimation of each fraction (sample sizes were n=9,414 and n=10,075, respectively). Moreover, because the dietary energy density was only evaluated in foods and some individuals consumed only beverages in their ultra-processed foods diet fraction (n=1,327) or in their non-ultra-processed foods diet fraction (n=41), the sample size for energy density was even smaller (n=8,760 and n=10,046, respectively). Student's *t* test was used to evaluate differences in the mean intake of each nutrient between the two diet fractions.

**Table 1.** Distribution of sociodemographic characteristics for the whole population and across quintiles (first, third, and fifth) of energy contribution of ultra-processed foods in a Mexican population aged 1 year and older (ENSANUT<sup>a</sup> 2012)

| Characteristics                            | Total sample, <sup>b</sup><br>unweighted n | Estimated population,<br>in millions, <sup>c</sup><br>weighted n | Quintiles of Energy<br>Contribution of Ultra-<br>Processed Foods |       |       |       |
|--|--|--|--|-------|-------|-------|
|  |  |  | All  | First | Third | Fifth |
|  |  |  | ←—————weighted %—————→   |       |       |       |
| <b>Sex</b>                                 |  |  |  |       |       |       |
| Male                                       | 4,893                                      | 55.1   | 49.5   | 48.6  | 50.9  | 49.5  |
| Female                                     | 5,194                                      | 56.2   | 50.5   | 51.4  | 49.1  | 50.5  |
| <b>Age group</b>                           |  |  |  |       |       |       |
| Preschool-aged children (1 to 4 y)         | 2,108                                      | 8.4  | 7.6  | 4.4   | 7.2   | 12.6  |
| School-aged children (5 to 11 y)           | 2,751                                      | 17.9   | 16.1   | 11.0  | 16.8  | 21.1  |
| Adolescents (12 to 19 y)                   | 2,055                                      | 16.1   | 14.5   | 8.7   | 15.1  | 20.4  |
| Adults (20 to 59 y)                        | 2,157                                      | 55.7   | 50.0   | 57.3  | 51.4  | 40.4  |
| Elderly (60 y and older)                   | 1,016                                      | 13.1   | 11.8   | 18.6  | 9.5   | 5.5   |
| <b>Residence area<sup>d</sup></b>          |  |  |  |       |       |       |
| Rural                                      | 3,782                                      | 30.0   | 27.0   | 42.0  | 23.3  | 15.9  |
| Urban                                      | 6,305                                      | 81.3   | 73.0   | 58.0  | 76.7  | 84.1  |
| <b>Region</b>                              |  |  |  |       |       |       |
| South                                      | 3,504                                      | 35.1   | 31.6   | 40.7  | 30.8  | 18.5  |
| Central                                    | 4,184                                      | 54.1   | 48.6   | 47.0  | 52.9  | 47.1  |
| North                                      | 2,399                                      | 22.0   | 19.8   | 12.3  | 16.3  | 34.4  |
| <b>Socioeconomic status<sup>e</sup></b>    |  |  |  |       |       |       |
| Low  | 3,675                                      | 33.8   | 30.4   | 46.8  | 28.3  | 18.5  |
| Medium                                     | 3,542                                      | 35.7   | 32.0   | 26.0  | 33.0  | 35.6  |
| High                                       | 2,870                                      | 41.8   | 37.6   | 27.2  | 38.7  | 45.9  |
| <b>Head of household educational level</b> |  |  |  |       |       |       |
| No formal education                        | 988  | 11.0   | 10.0   | 17.2  | 7.0   | 7.1   |
| Elementary school                          | 4,384                                      | 46.3   | 41.6   | 47.3  | 42.8  | 34.8  |
| Middle school                              | 2,661                                      | 26.8   | 24.1   | 19.9  | 26.8  | 27.2  |
| High school                                | 1,307                                      | 15.8   | 14.2   | 9.8   | 16.0  | 16.3  |
| College                                    | 747  | 11.3   | 10.1   | 5.8   | 7.4   | 14.6  |

<sup>a</sup>ENSANUT=Encuesta Nacional de Salud y Nutrición (Mexican National Health and Nutrition Survey).

<sup>b</sup>Total sample n=10,087.

<sup>c</sup>Estimated population n=111,276,088.

<sup>d</sup>Rural n<2,500 inhabitants; urban n=2,500 inhabitants.

<sup>e</sup>Tertiles of a socioeconomic status index based on household characteristics and material goods.

To evaluate the association between quintiles of energy contribution of ultra-processed foods and the intake of nutrients related to NCDs, two multiple linear regression models were run, adjusted for age group, residence area, region, socioeconomic status, and head of household educational level: 1) one with a dummy variable for each quintile, to estimate the adjusted mean nutrient intake with each quintile of energy contribution of ultra-processed foods; and 2) another with a continuous variable for the quintiles to

evaluate whether there was a linear trend in the nutrient intake across quintiles of energy contribution of ultra-processed foods. For this analysis, the *P* values for the linear trend were assessed. In addition, the same two models described were repeated, but including an interaction term between each sociodemographic variable and the quintiles of energy contribution (only quintiles 1 and 5 are presented). One model per sociodemographic characteristic for selected nutrients (added sugar, saturated fat, dietary fiber, and

**Table 2.** Distribution of total energy intake (% kcal) according to NOVA food groups and subgroups for the whole population and across quintiles of energy contribution of ultra-processed foods (% kcal) in a Mexican population aged 1 year and older (ENSANUT<sup>a</sup> 2012)

| NOVA food groups and subgroups                       | Quintiles of Energy Contribution of Ultra-Processed Foods <sup>b</sup> |                                    |                                     |                                    |                                     |                                    |
|--|--|------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|------------------------------------|
|  | All<br>(n=10,087)<br>(1,923 kcal)                                      | First<br>(n=2,018)<br>(1,785 kcal) | Second<br>(n=2,017)<br>(2,095 kcal) | Third<br>(n=2,018)<br>(1,929 kcal) | Fourth<br>(n=2,017)<br>(1,827 kcal) | Fifth<br>(n=2,017)<br>(1,987 kcal) |
|  | ← % kcal →   |                                    |                                     |                                    |                                     |                                    |
| <b>Unprocessed or minimally processed foods</b>      | 53.9   | 74.5                               | 62.1                                | 53.0                               | 43.0                                | 28.0***                            |
| Corn tortillas                                       | 19.0   | 27.2                               | 22.8                                | 18.0                               | 14.3                                | 9.4***                             |
| Milk   | 4.9  | 5.4                                | 5.4                                 | 5.3                                | 4.8                                 | 3.3***                             |
| Red meat   | 4.7  | 5.3                                | 6.0                                 | 5.5                                | 3.7                                 | 2.3***                             |
| Cereals (except corn)                                | 4.6  | 6.9                                | 5.1                                 | 4.8                                | 3.5                                 | 1.8***                             |
| Fruits   | 4.2  | 5.5                                | 4.5                                 | 4.2                                | 3.7                                 | 2.5***                             |
| Poultry and game                                     | 3.6  | 5.4                                | 4.5                                 | 3.8                                | 2.3                                 | 1.2***                             |
| Beans  | 3.1  | 5.4                                | 3.2                                 | 2.4                                | 2.1                                 | 1.5***                             |
| Eggs   | 2.3  | 2.9                                | 2.7                                 | 2.1                                | 2.1                                 | 1.7***                             |
| Vegetables   | 2.0  | 2.4                                | 2.2                                 | 2.1                                | 1.8                                 | 1.4***                             |
| Corn   | 1.6  | 2.8                                | 1.8                                 | 1.1                                | 1.0                                 | 0.7***                             |
| Starchy vegetables                                   | 1.4  | 2.0                                | 1.7                                 | 1.3                                | 1.3                                 | 0.6***                             |
| Coffee and tea                                       | 0.8  | 1.1                                | 0.8                                 | 0.7                                | 0.9                                 | 0.6*                               |
| Seafood  | 0.7  | 0.8                                | 0.5                                 | 0.8                                | 0.8                                 | 0.4                                |
| Other <sup>c</sup>                                   | 0.9  | 1.3                                | 1.0                                 | 1.0                                | 0.6                                 | 0.4***                             |
| <b>Processed culinary ingredients</b>                | 10.1   | 13.5                               | 12.1                                | 10.4                               | 8.1                                 | 4.9***                             |
| Oils and fats  | 6.5  | 8.6                                | 8.0                                 | 6.6                                | 5.1                                 | 3.0***                             |
| Sweeteners   | 3.3  | 4.4                                | 3.7                                 | 3.4                                | 2.8                                 | 1.8***                             |
| Other <sup>d</sup>                                   | 0.3  | 0.5                                | 0.4                                 | 0.3                                | 0.2                                 | 0.2***                             |
| <b>Processed foods</b>                               | 6.0  | 7.4                                | 7.2                                 | 6.2                                | 5.3                                 | 2.9***                             |
| Unpackaged freshly made bread                        | 2.7  | 3.2                                | 2.8                                 | 2.9                                | 2.4                                 | 1.7**                              |
| Cheeses  | 2.2  | 2.7                                | 2.8                                 | 2.4                                | 1.8                                 | 0.8***                             |
| Other <sup>e</sup>                                   | 1.1  | 1.6                                | 1.6                                 | 0.9                                | 1.0                                 | 0.3***                             |
| <b>Ultra-processed foods</b>                         | 30.0   | 4.5                                | 18.6                                | 30.4                               | 43.6                                | 64.2***                            |
| Cookies, pastries and sweet bread                    | 9.5  | 0.6                                | 5.8                                 | 10.8                               | 15.0                                | 20.6***                            |
| Carbonated sugar-sweetened beverages                 | 4.0  | 0.8                                | 3.8                                 | 4.3                                | 5.6                                 | 6.1***                             |
| Salty snacks   | 3.2  | 0.5                                | 1.5                                 | 2.4                                | 4.5                                 | 8.7***                             |
| Packaged tortillas and bread                         | 2.5  | 0.4                                | 1.1                                 | 2.1                                | 3.8                                 | 6.2***                             |
| Candies and sweets                                   | 2.0  | 0.7                                | 1.2                                 | 2.3                                | 2.9                                 | 3.0***                             |
| Yogurt and milk-based beverages                      | 1.9  | 0.5                                | 1.2                                 | 2.0                                | 2.3                                 | 4.4***                             |
| Sausages and other ultra-processed meats             | 1.7  | 0.4                                | 0.9                                 | 1.6                                | 2.4                                 | 3.8***                             |
| Noncarbonated sugar-sweetened beverages <sup>f</sup> | 1.3  | 0.4                                | 0.7                                 | 1.5                                | 1.9                                 | 2.1***                             |
| Breakfast cereals                                    | 1.0  | 0.4                                | 0.6                                 | 0.8                                | 1.4                                 | 2.0***                             |

(continued on next page)

**Table 2.** Distribution of total energy intake (% kcal) according to NOVA food groups and subgroups for the whole population and across quintiles of energy contribution of ultra-processed foods (% kcal) in a Mexican population aged 1 year and older (ENSANUT<sup>a</sup> 2012) (continued)

| NOVA food groups and subgroups | All<br>(n=10,087)<br>(1,923 kcal) | Quintiles of Energy Contribution of Ultra-Processed Foods <sup>b</sup> |                                     |                                    |                                     |                                    |
|--------------------------------|-----------------------------------|--|-------------------------------------|------------------------------------|-------------------------------------|------------------------------------|
|                                |                                   | First<br>(n=2,018)<br>(1,785 kcal)                                     | Second<br>(n=2,017)<br>(2,095 kcal) | Third<br>(n=2,018)<br>(1,929 kcal) | Fourth<br>(n=2,017)<br>(1,827 kcal) | Fifth<br>(n=2,017)<br>(1,987 kcal) |
| Other <sup>g</sup>             | 2.9                               | 0.9  | 1.8                                 | 2.4                                | 3.7                                 | 7.1***                             |
| <b>Total</b>                   | <b>100</b>                        | <b>100</b>   | <b>100</b>                          | <b>100</b>                         | <b>100</b>                          | <b>100</b>                         |

<sup>a</sup>ENSANUT=Encuesta Nacional de Salud y Nutrición (Mexican National Health and Nutrition Survey). Values are margin means obtained after multivariate linear regression models. One model per NOVA food groups and subgroups. Values adjusted for age group (1 to 4 y, 5 to 11 y, 12 to 19 y, 20 to 59 y, 60 y and older), residence area (rural, urban), region (South, Central, North), socioeconomic status (low, medium, high), and head of household educational level (no formal education, elementary school, middle school, high school, and college).

<sup>b</sup>Mean dietary energy contribution of ultra-processed foods per quintile: first=4.5% kcal (range=0% kcal to 11.8%); second=18.6% kcal (range=11.9% kcal to 24.6% kcal); third=30.4% kcal (range=24.7% kcal to 36.8% kcal); fourth=43.6% kcal (range=36.9% kcal to 51.7% kcal); 5th=64.2% kcal (range=51.8% kcal to 100% kcal).

<sup>c</sup>Nuts and seed (unsalted), other legumes, dried herbs.

<sup>d</sup>Chicken and beef broth, Mexican “mole,” and condiments.

<sup>e</sup>Nuts and seeds (salted); salted, dried, or oil-preserved canned fish and meat; canned fruits; vegetables; legumes; and undistilled alcoholic beverages.

<sup>f</sup>Nectars, energy drinks, fruit drinks, and powder to prepare drinks.

<sup>g</sup>Food supplements, baby food in a jar, ready-to-eat-meal (eg, chicken nuggets, pizza), ultra-processed culinary ingredients (eg, butter, mayonnaise), ultra-processed cheeses (eg, cheddar cheese, cream cheese), and distilled alcoholic beverages (eg, whiskey, gin, vodka).

\*P≤0.05 for the linear trend across quintiles.

\*\*P≤0.01 for the linear trend across quintiles.

\*\*\*P≤0.001 for the linear trend across quintiles.

**Table 3.** Mean nutrient intake in the overall diet and in two diet fractions in a Mexican population aged 1 year and older (ENSANUT<sup>a</sup> 2012)

| Nutrient               | Overall diet | Diet Fractions Composed of <sup>b</sup> : |  | Dietary nutrient intake goals |
|------------------------|--------------|---|--|-------------------------------|
|                        |              | Ultra-processed foods                     | Non-ultra-processed foods <sup>c</sup> |                               |
|                        |              | ←—————% kcal—————→                        |  |                               |
| Protein                | 13.7         | 8.5***                                    | 16.0                                   | 10-15 <sup>d</sup>            |
| Carbohydrates          | 55.4         | 60.0***                                   | 53.6                                   | 55-75 <sup>d</sup>            |
| Added sugar            | 12.5         | 30.6***                                   | 6.1                                    | <10 <sup>d</sup>              |
| Total fat              | 32.2         | 31.5***                                   | 32.5                                   | 15-30 <sup>d</sup>            |
| Saturated fat          | 11.2         | 14.7***                                   | 10.0                                   | <10 <sup>d</sup>              |
|                        |              | ←—————g/1,000 kcal—————→                  |  |                               |
| Dietary fiber          | 12.2         | 4.4***                                    | 15.3                                   | >12.5 <sup>de</sup>           |
|                        |              | ←—————kcal/g—————→                        |  |                               |
| Dietary energy density | 1.6          | 3.6***                                    | 1.3                                    | ≤1.25 <sup>fg</sup>           |

<sup>a</sup>ENSANUT=Encuesta Nacional de Salud y Nutrición (Mexican National Health and Nutrition Survey). Values are means. Comparison using Student’s *t* tests for each nutrient.

<sup>b</sup>Sample sizes: for macronutrients n=9,414 (ultra-processed foods diet fraction), and n=10,075 (non-ultra-processed foods diet fraction); for energy density n=8,760 (ultra-processed foods diet fraction), and n=10,046 (non-ultra-processed foods diet fraction).

<sup>c</sup>Includes the following NOVA food groups: unprocessed or minimally processed foods, processed culinary ingredients, and processed foods.

<sup>d</sup>World Health Organization.<sup>18</sup>

<sup>e</sup>Recommended value based on a 2,000-kcal diet.

<sup>f</sup>World Cancer Research Foundation.<sup>28</sup>

<sup>g</sup>Beverages excluded.

\*\*\*P≤0.001 for the difference with non-ultra-processed foods.

**Table 4.** Mean nutrient intake across quintiles of energy contribution of ultra-processed foods (% kcal) in a Mexican population aged 1 y and older (ENSANUT<sup>a</sup> 2012)

| Nutrients              | Quintiles of Energy Contribution of Ultra-Processed Foods <sup>b</sup> |                  |                 |                  |                 | $\beta^c$ | Dietary nutrient intake goals, % kcal |
|------------------------|--|------------------|-----------------|------------------|-----------------|-----------|---------------------------------------|
|                        | First (n=2,018)  | Second (n=2,017) | Third (n=2,018) | Fourth (n=2,017) | Fifth (n=2,017) |           |                                       |
|                        | ← % kcal →   |                  |                 |                  |                 |           |                                       |
| Protein                | 15.1   | 14.5             | 13.6            | 12.9             | 11.9            | −0.78***  | 10-15 <sup>d</sup>                    |
| Carbohydrates          | 56.3   | 54.6             | 55.0            | 56.1             | 54.7            | −0.17     | 55-75 <sup>d</sup>                    |
| Added sugar            | 7.4  | 10.8             | 13.2            | 15.7             | 17.5            | 2.52***   | <10 <sup>d</sup>                      |
| Total fat              | 30.6   | 32.4             | 32.8            | 32.1             | 33.5            | 0.55***   | 15-30 <sup>d</sup>                    |
| Saturated fat          | 9.3  | 10.7             | 11.7            | 11.9             | 13.2            | 0.89***   | <10 <sup>d</sup>                      |
|                        | ← g/1,000 kcal →   |                  |                 |                  |                 |           |                                       |
| Dietary fiber          | 16.0   | 13.2             | 11.5            | 10.5             | 8.4             | −1.78***  | >12.5 <sup>de</sup>                   |
|                        | ← kcal/g →   |                  |                 |                  |                 |           |                                       |
| Dietary energy density | 1.4  | 1.5              | 1.6             | 1.7              | 2.0             | 0.13***   | ≤1.25 <sup>fg</sup>                   |

<sup>a</sup>ENSANUT=Encuesta Nacional de Salud y Nutrición (Mexican National Health and Nutrition Survey). Values are margin means obtained after multivariate linear regression models. One model per nutrient. Values adjusted for age group (1 to 4 y, 5 to 11 y, 12 to 19 y, 20 to 59 y, 60 y and older), residence area (rural, urban), region (South, Central, North), socioeconomic status (low, medium, high) and head of household educational level (no formal education, elementary school, middle school, high school, and college).

<sup>b</sup>Mean dietary energy contribution of ultra-processed foods per quintile: first=4.5% kcal (range=0% kcal to 11.8% kcal); second=18.6% kcal (range=11.9% kcal to 24.6% kcal); third=30.4% kcal (range=24.7% kcal to 36.8% kcal); fourth=43.6% kcal (range=36.9% kcal to 51.7% kcal); fifth=64.2% kcal (range=51.8% kcal to 100% kcal).

<sup>c</sup>Associated linear change with each quintile increment.

<sup>d</sup>World Health Organization.<sup>18</sup>

<sup>e</sup>Recommended value based on a 2,000-kcal diet.

<sup>f</sup>World Cancer Research Foundation.<sup>28</sup>

<sup>g</sup>Beverages excluded.

\*\*\* $P < 0.001$  for linear trend across quintiles.

dietary energy density) was conducted. The analyzed socio-demographic variables were those that had been used previously to study ultra-processed food intake in the Mexican population (sex, age group, urban/rural area, region, socioeconomic status, and head of family educational level).<sup>20</sup> For this analysis, the  $P$  value of the interaction terms between the linear trend of the nutrient intake and the sociodemographic characteristic dummy variables was assessed with a Wald chunk test.

To estimate the continuous association between the energy contribution of ultra-processed foods and the intake of added sugar, saturated fat, dietary fiber and dietary energy density, Gaussian regression analyses were run, adjusted for age group, residence area, region, socioeconomic status, and head of household educational level. The Wald test was used to evaluate these associations.

All analyses were performed using Stata, version 12.0<sup>31</sup> with the survey prefix command (svy) to account for the design effect and sample weights of complex surveys. To identify statistical significance, a  $P$  value  $\leq 0.05$  was established.

## RESULTS

Information from 10,087 study participants representing 111,276,088 Mexicans at the national level is presented in Table 1. In the study sample, 50.5% of participants were females, 50.0% were adults aged 20 to 59 years, 73.0% lived in urban areas, 48.6% were from the Central region of the

country, and 41.6% lived in a house where the head of household had a maximum educational level of elementary school.

The mean reported energy contribution of ultra-processed foods ranged from a mean of 4.5% kcal (quintile 1 [Q1]) to 64.2% kcal (quintile 5 [Q5]) (see Table 2). As the reported energy contribution of ultra-processed foods increased across quintiles, the reported energy contribution of all food subgroups from ultra-processed foods increased uniformly ( $P \leq 0.001$ ), whereas the reported energy contribution of food subgroups from unprocessed or minimally processed foods (except for seafood), processed culinary ingredients, and processed foods decreased ( $P \leq 0.05$ ).

The quality of the nutrient profile of the diet fraction made of ultra-processed foods was generally much lower compared to the diet fraction made of non-ultra-processed foods (see Table 3). Compared to the fraction composed of non-ultra-processed foods, the nutrient content of the diet fraction made up of ultra-processed foods was 400% higher for added sugar, 180% higher for dietary energy density, 50% higher for saturated fat, 10% higher for carbohydrates, 3% lower for total fat, 250% lower for dietary fiber, and 90% lower for protein. All of these differences were statistically significant ( $P \leq 0.001$ ). WHO<sup>18</sup> and WCRF<sup>28</sup> dietary nutrient intake goals are presented in Table 3 as references.

There were linear trends in the reported mean nutrient intake across quintiles of the energy contribution of ultra-processed foods (see Table 4). As the energy contribution of ultra-processed foods increased across quintiles, the

intake of added sugar (Q1: 7.4% kcal; Q5: 17.5% kcal), total fat (Q1: 30.6% kcal; Q5: 33.5% kcal), saturated fat (Q1: 9.3% kcal; Q5: 13.2% kcal), and dietary energy density (Q1: 1.4 kcal/g; Q5: 2.0 kcal/g) increased significantly ( $P < 0.001$ ), whereas the intake of protein (Q1: 15.1% kcal; Q5: 11.9% kcal) and dietary fiber (Q1: 16.0 g/1,000 kcal; Q5: 8.4 g/1,000 kcal) decreased significantly ( $P < 0.001$ ). WHO<sup>18</sup> and WCRF<sup>28</sup> dietary nutrient intake goals are presented in Table 4 as references.

The association between nutrient intake and quintiles of the energy contribution of ultra-processed foods was stronger for adults aged 20 to 59 years (vs preschool-aged children, for added sugar), in the rural area (vs urban; for added sugar and dietary fiber), in the South (vs the North, for saturated fat), in the low socioeconomic status (vs medium and high; for saturated fat and dietary fiber), and in the households in which the head had no formal education (vs elementary school, middle school, high school, or college education; for saturated fat and dietary fiber) (see Table 5). For example, the energy contribution of added sugar increased by approximately 3.0 percentage points with each quintile increase in the rural area, vs an approximately 2.4 increase in the urban area. The stronger association among these subgroups (adults aged 20 to 59 years of age, rural, South, low socioeconomic status, and no formal education) was driven by the healthier diet found among those in the lowest quintiles. The only exception was that the association of added sugar was stronger among adults aged 20 to 59 years of age because those in the highest quintiles had a higher intake.

In Gaussian regression analyses, the energy contribution of ultra-processed foods was positively associated with the reported intake of added sugar, saturated fat, and dietary energy density ( $P < 0.001$ ); and inversely associated with the reported intake of dietary fiber ( $P < 0.001$ ) (see Figure 2). Overall, each 10% kcal increase in the energy contribution of ultra-processed foods was associated with an increased intake of 2.8% kcal in added sugar, 1.5% kcal in saturated fat and 0.1 kcal/g in dietary energy density, and a decreased intake of 2.6 g/1,000 kcal in dietary fiber.

## DISCUSSION

In this nationally representative study, an increased energy contribution of ultra-processed foods was associated with a higher intake of added sugar, total fat, and saturated fat; lower intake of protein and dietary fiber; and higher dietary energy density. To our knowledge, this is the first study to evaluate the association between the energy contribution of ultra-processed foods and the intake of nutrients related to NCDs in Mexico.

Ultra-processed foods are formulated with low cost substances that enhance their organoleptic properties and make them shelf stable and highly palatable.<sup>1</sup> Moreover, the techniques employed in their formulation, such as extruding, molding, reshaping, frying, or baking, make them convenient food choices.<sup>32</sup> Nevertheless, ultra-processed foods have poor nutritional quality compared to other foods with a lesser extent of processing.<sup>33-35</sup> Therefore, the main recommendation of the national dietary guidelines of Brazil and Uruguay is to prefer culinary preparations made of unprocessed or minimally processed foods with small quantities of processed culinary ingredients and avoid ultra-processed foods.<sup>36,37</sup>

Considering repeated findings from studies conducted in Colombia,<sup>11</sup> Brazil,<sup>33</sup> Canada,<sup>34</sup> and Chile,<sup>35</sup> the current study's results show that the Mexican dietary fraction composed of ultra-processed foods was higher in added sugar, saturated fat, and dietary energy density, and lower in protein, total fat, and dietary fiber compared to the fraction composed of non-ultra-processed foods (unprocessed or minimally processed foods, processed culinary ingredients, and processed foods).

As shown in the current analyses, the high consumption of ultra-processed foods in Mexico was associated with the previously reported high intake of added sugar and saturated fat, low intake of dietary fiber,<sup>21</sup> and high energy-density diets.<sup>22</sup> Similar findings have been found in nationally representative dietary surveys from Colombia,<sup>11</sup> Brazil,<sup>12</sup> Canada,<sup>14</sup> United Kingdom,<sup>15</sup> and United States.<sup>38</sup> The stratification of the Mexican population, based on quintiles of the energy contribution of ultra-processed foods, indicates that 60% of Mexicans (Q3 to Q5) with the highest consumption of ultra-processed foods ( $\geq 24.7\%$  kcal) exhibit evidence of low dietary quality with regard to intake of nutrients related to NCDs. This group exceeded the recommended upper limit for added sugar (13.2% kcal to 17.5% kcal vs  $< 10\%$  kcal), total fat (32.8% kcal to 33.5% kcal vs  $< 30\%$  kcal), and saturated fat (11.7% kcal to 13.2% kcal vs  $< 10\%$  kcal), and was below the minimum recommended intake for dietary fiber (11.5 to 8.4/1,000 kcal vs  $> 12.5$  g/1,000 kcal).<sup>18</sup> Moreover, the group exceeded the recommended upper level for dietary energy density (1.6 to 2.0 kcal/g vs  $\leq 1.25$  kcal/g).<sup>28</sup> Conversely, among the 20% of Mexicans (Q1) with the lowest consumption of ultra-processed foods ( $\leq 11.8\%$  kcal), their mean nutrient intake was below the recommended maximum limit for added sugar (7.4% kcal vs  $< 10\%$  kcal) and for saturated fat (9.3% kcal vs  $< 10\%$  kcal), and was above the recommended intake for dietary fiber (16.0 vs  $> 12.5$  g/1,000 kcal).<sup>18</sup> However, even for these individuals, their dietary energy density (1.4 kcal/g) still exceeded the recommended upper level ( $\leq 1.25$  kcal/g).<sup>28</sup>

Taking a closer look at the diets of individuals in Q1, representing the lowest energy contribution of ultra-processed foods, it was found that even these individuals did not completely meet the Mexican Dietary Guidelines.<sup>39</sup> For instance, for individuals in Q1, the intake of meat and animal products was 14.4% kcal (sum of red meat, poultry and game, eggs, and seafood), and the intake of minimally processed cereals was 36.9% kcal (sum of corn tortillas, cereals, and corn); whereas, the Mexican Dietary Guidelines recommend 10% kcal and 33% kcal, respectively.<sup>39</sup> In addition, for individuals in Q1, it was found that the intake of beans was 5.4% kcal, and the intake of fruits and vegetables was 7.9% kcal (sum of fruits and vegetables), whereas the Mexican Dietary Guidelines recommend an intake of at least 12% kcal for each of these food groups.<sup>39</sup> Thus, the high dietary energy density identified for individuals in Q1 may potentially be due to the discrepancy between reported dietary intake of unprocessed and minimally processed foods compared to Mexican Dietary Guidelines.<sup>39</sup> Indeed, it has been shown that low energy-density diets are high in fruits and vegetables<sup>40</sup> and adhere more closely to food-based dietary guidelines.<sup>41</sup> Furthermore, the intake of energy from meat and other animal food sources in Q1 may be reflected in protein and total fat intakes (15.1% kcal and 30.6% kcal, respectively)

**Table 5.** Mean energy contribution of ultra-processed foods (% kcal) and mean intake of selected nutrients in extreme quintiles of energy contribution of ultra-processed foods, by sociodemographic characteristics in a Mexican population aged 1 year and older (ENSANUT<sup>3</sup> 2012)

| Characteristics                            | Ultra-processed foods (% kcal), quartile 1 to 5 | Added Sugar (% kcal) |           |                             | Saturated Fats (% kcal) |           |                             | Dietary Fiber (g/1,000 kcal) |           |                             | Dietary Energy Density (kcal/g) |           |                             |
|--|---|----------------------|-----------|-----------------------------|-------------------------|-----------|-----------------------------|------------------------------|-----------|-----------------------------|---------------------------------|-----------|-----------------------------|
|  |   | Quartile 1 to 5      | $\beta^b$ | <i>P</i> value <sup>c</sup> | Quartile 1 to 5         | $\beta^b$ | <i>P</i> value <sup>c</sup> | Quartile 1 to 5              | $\beta^b$ | <i>P</i> value <sup>c</sup> | Quartile 1 to 5                 | $\beta^b$ | <i>P</i> value <sup>c</sup> |
| <b>Sex</b>                                 |   |                      |           | 0.467                       |                         |           | 0.941                       |                              |           | 0.574                       |                                 |           | 0.989                       |
| Male                                       | 4.5-64.3  | 7.3-17.2             | 2.64      |                             | 9.3-13.3                | 0.89      |                             | 15.8-8.0                     | -1.84     |                             | 1.4-2.0                         | 0.13      |                             |
| Female                                     | 4.6-64.0  | 7.6-17.8             | 2.44      |                             | 9.4-13.0                | 0.88      |                             | 16.1-8.8                     | -1.74     |                             | 1.4-2.0                         | 0.13      |                             |
| <b>Age group</b>                           |   |                      |           | <b>0.014</b>                |                         |           | <b>0.384</b>                |                              |           | <b>0.086</b>                |                                 |           | <b>0.102</b>                |
| Preschool-aged children (1 to 4 y)         | 5.5-66.8  | 7.1-15.7             | 2.06      |                             | 11.6-14.6               | 0.64      |                             | 12.7-7.6                     | -1.34     |                             | 1.3-1.8                         | 0.13      |                             |
| School-aged children (5 to 11 y)           | 5.0-63.5  | 7.1-15.7             | 2.07      |                             | 9.9-14.0                | 0.97      |                             | 15.0-8.6                     | -1.58     |                             | 1.4-2.0                         | 0.14      |                             |
| Adolescents (12 to 19 y)                   | 4.7-65.8  | 7.0-17.7             | 2.55      |                             | 9.5-13.5                | 0.92      |                             | 16.2-8.5                     | -1.79     |                             | 1.5-2.2                         | 0.17      |                             |
| Adults (20 to 59 y)                        | 4.4-63.6  | 7.7-19.0             | 2.87      |                             | 8.8-12.6                | 0.89      |                             | 16.6-8.2                     | -1.92     |                             | 1.4-2.0                         | 0.12      |                             |
| Elderly (60 y and older)                   | 3.6-61.4  | 7.8-13.6             | 1.90      |                             | 9.2-13.5                | 0.91      |                             | 15.8-8.8                     | -1.79     |                             | 1.3-1.9                         | 0.11      |                             |
| <b>Residence area<sup>d</sup></b>          |   |                      |           | <b>0.012</b>                |                         |           | <b>0.090</b>                |                              |           | <b>&lt;0.001</b>            |                                 |           | <b>0.455</b>                |
| Rural                                      | 3.9-63.1  | 6.3-18.3             | 2.95      |                             | 8.7-13.3                | 1.05      |                             | 17.1-7.7                     | -2.29     |                             | 1.4-1.9                         | 0.12      |                             |
| Urban                                      | 4.8-64.5  | 8.1-17.4             | 2.37      |                             | 9.6-13.2                | 0.83      |                             | 15.3-8.5                     | -1.61     |                             | 1.4-2.0                         | 0.14      |                             |
| <b>Region</b>                              |   |                      |           | <b>0.289</b>                |                         |           | <b>0.012</b>                |                              |           | <b>0.299</b>                |                                 |           | <b>0.060</b>                |
| South                                      | 4.0-64.0  | 7.2-18.7             | 2.73      |                             | 9.1-13.0                | 0.97      |                             | 16.2-7.9                     | -1.98     |                             | 1.4-2.0                         | 0.13      |                             |
| Central                                    | 4.7-63.2  | 7.4-17.0             | 2.50      |                             | 9.2-13.6                | 1.00      |                             | 16.2-8.9                     | -1.70     |                             | 1.4-1.9                         | 0.12      |                             |
| North                                      | 4.9-65.9  | 8.2-17.6             | 2.31      |                             | 10.3-12.7               | 0.54      |                             | 14.9-7.8                     | -1.73     |                             | 1.4-2.1                         | 0.16      |                             |
| <b>Socioeconomic status<sup>e</sup></b>    |   |                      |           | <b>0.167</b>                |                         |           | <b>&lt;0.001</b>            |                              |           | <b>&lt;0.001</b>            |                                 |           | <b>0.446</b>                |
| Low  | 4.0-64.5  | 7.0-18.2             | 2.88      |                             | 8.0-13.4                | 1.27      |                             | 17.2-7.8                     | -2.33     |                             | 1.4-2.0                         | 0.14      |                             |
| Medium                                     | 4.7-64.7  | 7.3-17.4             | 2.41      |                             | 9.5-13.8                | 1.02      |                             | 15.1-7.8                     | -1.75     |                             | 1.5-2.1                         | 0.15      |                             |
| High                                       | 5.1-63.7  | 8.2-17.4             | 2.34      |                             | 10.6-12.9               | 0.48      |                             | 15.2-8.9                     | -1.38     |                             | 1.4-2.0                         | 0.12      |                             |
| <b>Head of household educational level</b> |   |                      |           | <b>0.398</b>                |                         |           | <b>&lt;0.001</b>            |                              |           | <b>0.002</b>                |                                 |           | <b>0.349</b>                |
| No formal education                        | 3.6-63.1  | 5.3-18.8             | 3.11      |                             | 8.1-12.6                | 1.25      |                             | 18.3-7.8                     | -2.55     |                             | 1.4-2.0                         | 0.14      |                             |
| Elementary school                          | 4.2-64.2  | 7.6-17.0             | 2.36      |                             | 8.5-13.5                | 1.16      |                             | 16.7-8.6                     | -1.90     |                             | 1.4-2.0                         | 0.14      |                             |

(continued on next page)

**Table 5.** Mean energy contribution of ultra-processed foods (% kcal) and mean intake of selected nutrients in extreme quintiles of energy contribution of ultra-processed foods, by sociodemographic characteristics in a Mexican population aged 1 year and older (ENSANUT<sup>a</sup> 2012) (continued)

| Characteristics | Ultra-processed foods (% kcal) |                 | Added Sugar (% kcal) |                      | Saturated Fats (% kcal) |           | Dietary Fiber (g/1,000 kcal) |                 | Dietary Energy Density (kcal/g) |                      |
|-----------------|--------------------------------|-----------------|----------------------|----------------------|-------------------------|-----------|------------------------------|-----------------|---------------------------------|----------------------|
|                 | quartile 1 to 5                | Quartile 1 to 5 | $\beta^b$            | P value <sup>c</sup> | Quartile 1 to 5         | $\beta^b$ | P value <sup>c</sup>         | Quartile 1 to 5 | $\beta^b$                       | P value <sup>c</sup> |
| Middle school   | 4.7-63.7                       | 7.6-18.4        | 2.70                 |                      | 9.9-13.1                | 0.72      |                              | 15.2-8.4        | -1.66                           | 0.11                 |
| High school     | 5.9-66.4                       | 8.5-17.6        | 2.36                 |                      | 11.8-13.8               | 0.42      |                              | 13.6-7.4        | -1.41                           | 0.16                 |
| College         | 4.9-63.5                       | 8.4-16.7        | 2.36                 |                      | 10.8-12.7               | 0.45      |                              | 14.1-8.7        | -1.33                           | 0.12                 |

<sup>a</sup>ENSANUT=Encuesta Nacional de Salud y Nutrición (Mexican National Health and Nutrition Survey). Values are margin means obtained after multivariate linear regression models that included interaction terms between quintiles of energy contribution of ultra-processed foods and sociodemographic characteristics. One model per nutrient and sociodemographic characteristic. Values adjusted by age group (1 to 4 y, 5 to 11 y, 12 to 19 y, 20 to 59 y, 60 y and older), residence area (rural, urban), region (South, Central, North), socioeconomic status (low, medium, high), and head of household educational level (no formal education, elementary education, middle education, high school education, college graduate education).

<sup>b</sup>Associated linear change with each quintile increment (quintiles  $\beta$ +quintiles sociodemographic variable  $\beta$ ).

<sup>c</sup>P value for the interaction terms between the quintiles of energy contribution of ultra-processed foods (linear trend) and sociodemographic characteristics; statistically significant P values in bold.

<sup>d</sup>Rural n<2,500 inhabitants; urban n $\geq$ 2,500 inhabitants.

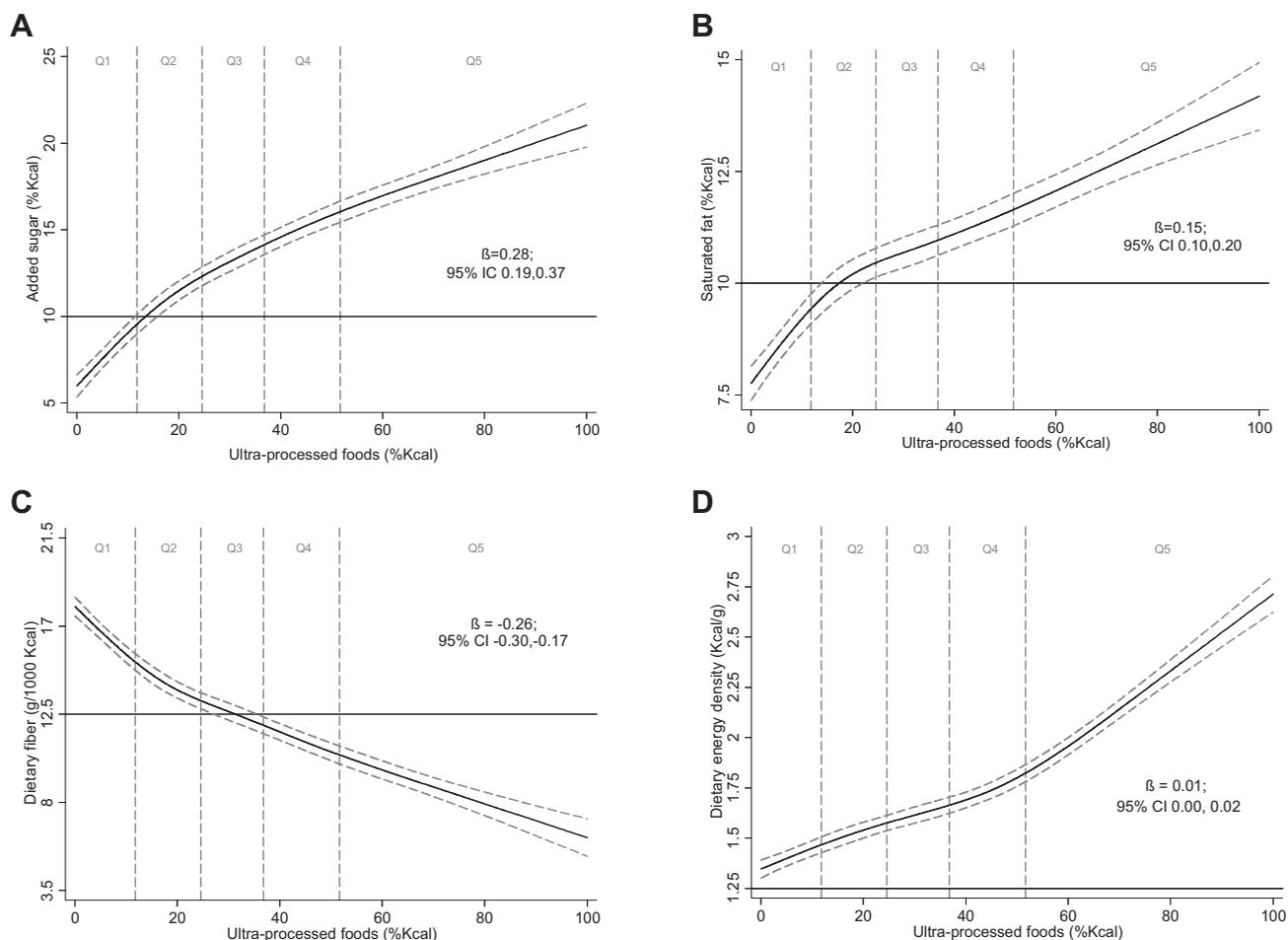
<sup>e</sup>Tertiles of a socioeconomic status index based on household characteristics and material goods.

slightly above the recommended dietary goal levels. On the other hand, the intake of energy from corn tortillas (27.2% kcal) in Q1 is possibly responsible for the high intake of dietary fiber reported for this group.

Recent evidence has shown that sociodemographic characteristics are important drivers in the consumption of ultra-processed foods.<sup>14,16,20 33,35</sup> Interestingly, in the current study findings, the association between the energy contribution of ultra-processed foods and the nutrient intake also differed by socioeconomic characteristics, such as in individuals living in rural areas, in the southern region, in families of low socioeconomic status, and in households where the head of the family had no formal education. These stronger associations could be related to the greater differences in the intake of ultra-processed foods between those in the lowest and highest quintiles of these subpopulations. It is noteworthy that adults aged 20 to 59 years old also had a stronger association with the intake of added sugar, but this might be driven by the type of food subgroups consumed by adults. It has been shown that the intake of carbonated beverages is higher among adults compared to other age groups.<sup>42</sup>

The Mexican government has designed several strategies to improve the dietary quality of the population. Since 2014, there are mandatory taxes on sugar-sweetened beverages and nonessential energy-dense foods (eg, chips, snacks, candies, cereal based products), front-of-package food labels (Guideline Daily Amounts), restrictions on television food marketing to children, and regulations on food availability in schools.<sup>43</sup> However, some initiatives need improvements; for example, the front-of-package labeling system is confusing<sup>44</sup> and the food marketing regulation is lax.<sup>45</sup> Also, the regulations on food availability in schools has been poorly implemented because school personnel have not received resources, been trained, monitored, or held accountable for complying with the regulations.<sup>46</sup> In order to improve the dietary quality of the Mexican population, the current study findings support the importance of reducing the intake of ultra-processed foods and promoting a varied intake of unprocessed and minimally processed foods that include more fruits, vegetables, and legumes. Hence, further efforts and research are needed to ascertain barriers to healthy eating as well as effective strategies and resources needs to overcome these barriers.

Limitations for the current study should be considered. For some foods and beverages reported in the 24HR interview, their description was not detailed enough to correctly classify them into one of the four NOVA food groups (eg, for the item "Mexican cheese" some brands only add salt, whereas other brands have additives and other ingredients that would classify them as ultra-processed foods). Moreover, some ready-to-eat products could have been classified as home-made. For the current analysis, in addition to corn tortilla, 5.2% of foods and beverages (12.0% kcal) had ambiguous descriptions, and were more prone to misclassification. Because one single 24HR was used for this study, the habitual diet of the population could not be estimated.<sup>47</sup> Nevertheless, one single 24HR is acceptable for surveying the mean consumption of foods and nutrients of a large population group.<sup>47</sup> Because added sugar information was not available in the food database and was estimated according to a previous methodology,<sup>30</sup> the reported intake of this nutrient might be under- or overestimated.



**Figure 2.** Association between the reported energy contribution of ultra-processed foods (% kcal) and the reported intake of added sugar (% kcal) (A), saturated fat (% kcal) (B), dietary fiber (g/1,000 kcal) (C), and dietary energy density (kcal/g) (D). Mexican population aged 1 year and older (Encuesta Nacional de Salud y Nutrición [Mexican National Health and Nutrition Survey 2012]). Results are from Gaussian regression analyses. Dashed lines represent 95% CIs and the solid line represents the predicted values. Vertical lines represent the range of energy contribution of ultra-processed foods across quintiles (Q): Q1=0% kcal to 11.8% kcal; Q2=11.9% kcal to 24.6% kcal; Q3=24.7% kcal to 36.8% kcal; Q4=36.9% kcal to 51.7% kcal; and Q5=51.8% kcal to 100% kcal. Horizontal solid line represents the World Health Organization<sup>18</sup> and the World Cancer Research Foundation<sup>28</sup> recommendations: added sugar (<10.0% kcal); saturated fat (<10.0% kcal); dietary fiber (>12.5 g/1,000 kcal); and dietary energy density ( $\leq 1.25$  kcal/g). The models were adjusted for age group (1 to 4 y, 5 to 11 y, 12 to 19 y, 20 to 59 y, and 60 y and older), residence area (rural, urban), region (South, Central, North), socioeconomic status (low, medium, high), and head of household educational level (no formal education, elementary school, middle school, high school, and college).

Despite these limitations, the current study has several strengths as well. It included a nationally representative sample of the Mexican population with individual-level dietary information rather than aggregated data with household-level information.<sup>33-35</sup> By using the NOVA food framework, the current study's results can be compared to those from studies conducted using the same framework in other countries.<sup>11,12,14,15,38</sup> Finally, the dietary information was collected by a 24HR interview with the automated multiple-pass method, which improves precision and reduces the degree of measurement error.<sup>27</sup>

## CONCLUSIONS

For individuals in Mexico aged 1 year and older, a higher energy contribution of ultra-processed foods was associated

with lower dietary quality, which was characterized by higher intake of added sugar, total fat, and saturated fat; lower intake of protein and dietary fiber; and higher dietary energy density. In order to improve the quality of the Mexican population's diet, further research is needed to identify the barriers to decreasing the consumption of ultra-processed foods and increasing the consumption of a variety of unprocessed and minimally processed foods including fruits, vegetables, and legumes, as well as research on effective public health strategies and policies to overcome these barriers.

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## STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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## AUTHOR CONTRIBUTIONS

J. A. Marrón-Ponce performed the analysis and wrote the manuscript; J. A. Marrón-Ponce and C. Batis classified and/or revised the food groups; M. Flores, G. Cediel, C. A. Monteiro, and C. Batis revised various stages of the manuscript and helped in the supervision of the statistical analyses; and J. A. Marrón-Ponce and C. Batis had primary responsibility for final content. All authors read and approved the final manuscript.