J Hum Nutr Diet. Author manuscript; available in PMC 2024 October 01.

Published in final edited form as:
J Hum Nutr Diet. 2023 October ; 36(5): 1942–1950. doi:10.1111/jhn.13175.

Associated substitution and complementation effects of processed discretionary foods and drinks on total energy and added sugar intake

Carolina Batis[1], **Tonatiuh Barrientos-Gutiérrez**[2], **Ana Basto-Abreu**[2]

[1]CONACYT – Health and Nutrition Research Center, National Institute of Public Health, Avenida Universidad 655 Colonia Santa María Ahuacatitlán, Cuernavaca, CP 62100, Mexico.

[2]Center for Research in Population Health, National Institute of Public Health, Avenida Universidad 655 Colonia Santa María Ahuacatitlán, Cuernavaca, CP 62100, Mexico.

Abstract

Background: Processed discretionary foods and drinks (industrialized sugary drinks, sweet and savory snacks, and grain-based sweets) are often target of policies aimed at regulating the food environment. We aimed to understand if a lower intake of processed foods or drinks is associated with substitution or complementation patterns and overall intake.

Methods: We analyzed a subsample with two 24-hr dietary recalls of the Mexican National Health and Nutrition Survey 2012 (358 children, 253 adolescents, and 278 adults). We compared within-person, energy and added sugar intakes between days with and without consumption of each food group with fixed-effects regressions. We estimated the relative change (change in intake when not consumed / average intake when consumed *100)

Results: Processed discretionary foods were not fully substituted, as total energy was 200 to 400 kcal/d lower when these foods were not consumed. The change in total intake was larger than the intake when consumed (i.e., complemented) for industrialized sugary drinks in adolescents (−136%) and adults (−215%), and sweet, savory snacks for children (−141%). The change was lower (i.e., partially substituted) for grain-based sweets among children (−78%) and adolescents (−73%). For added sugars, most processed discretionary groups were complemented.

Conclusions: Days without intake of processed discretionary foods were associated with lower total energy and added sugar intake compared to days when those discretionary foods were consumed. This suggests that regulatory policies to reduce the intake of processed foods could have a meaningful impact on improving overall diet.

Graphical Abstract

Corresponding autor: Ana Basto-Abreu (ana.basto@insp.mx).

Authorship
CB, TBG, ABA, conceptualized the study design, aims and interpreted the data; CB performed the statistical analysis; CB drafted the first version of the manuscript; CB, TBG, ABA, revised the manuscript; all authors read and approved the final manuscript.

Conflict of interest
The authors declare they have no conflicts of interest.

Ethics statement
The survey protocol was reviewed and approved by the Ethics Committee of the Mexican National Institute of Public Health.

Comparing two 24-dietary recalls within-subjects, not consuming processed discretionary food and beverages is associated with lower energy and added sugars, because these are not substituted. These results suggest that policies regulating processed discretionary food and beverages could reduce total energy and added sugars intake.

Keywords

Substitution; complementation; processed discretionary foods; energy intake; added sugar intake; Mexico

INTRODUCTION

Sugary drinks and nonessential energy-dense foods (often termed “discretionary food” or “junk food”) are major sources of calories and added sugars with little or no nutritional value. Systematic reviews have shown an association between the intake of sugary drinks and energy-dense foods with weight gain, metabolic syndrome, and diabetes [1–7]. Despite the harms, the consumption of discretionary foods/drinks, such as sodas, bottled fruit drinks, salty snacks, breakfast cereals, biscuits, pastries and sweets, is increasing in most regions, especially in middle-income countries [8,9]. In Mexico processed (and usually packaged) discretionary foods and sugary drinks account for 20% of the total energy intake and 62% of added sugar intake [10]. International recommendations advocate for the implementation of policies to reduce unhealthy eating to improve population health [11].

In Mexico, several policies such as regulation of school’s food availability, taxes, and front-of-package warning labels, have been implemented to decrease the intake of unhealthy products. The nutrient criteria and definitions of the drinks and foods regulated by each policy differ, but consistently, processed discretionary foods and sugary drinks are at the core of these policies [12–15]. Although there are other several unhealthy foods such as homemade sugary drinks and desserts, these are not subject to regulatory policies. The effect of policies targeting unhealthy or discretionary processed foods and drinks on overall dietary intake is influenced by the substitution and complementation patterns that occur when decreasing the targeted food/drink group. Substitution is the dietary adjustment that occurs when the consumption of a food or drink is reduced or eliminated, but another food or drink is eaten instead [16]. Full substitution occurs when the reduction in consumption is completely offset by the substitute; partial substitution occurs when only some of the calories are substituted. Complements are foods that are eaten in combination with target foods/drinks. For example, sugary drinks intake has been associated with the intake of energy-dense food, but not with vegetables [17]. If the intake of target food/drink food group is decreased, then its complements might also decrease. Thus, the net effect of reducing a target food/ drink on total energy or nutrient intake will be the result of the reductions in the target product, its complements, and the reactive adjustment of intake through substitutes. A previous cross-over experimental study assigned to 15 subjects a liquid load (450 kcal of soda) for 4 weeks and a solid load (450 kcal of jelly beans) for another 4 weeks [18]. The rest of the dietary intake was ad libitum. Comparing to the non-load periods, they found that during the soda load both the total intake and the ad libitum intake were higher and that subjects not only did not make substitutions or reduced the intake of other foods/beverages, but they actually ate more (e.g., complemented). The total intake with or without the solid load was similar suggesting full substitution.

Given that processed discretionary foods and drinks are often target of policies aimed at reducing the intake of total energy and/or harmful nutrients such as added sugars, it is of interest to understand in free-living individuals, outside experimental conditions, if the reduction of processed discretionary foods and drinks leads to substitution and complementary changes. An approach to gain insight of these behaviors, even if causality cannot be established, is to identify how individuals change their eating behavior and total intake between the days in which they do not consume and the days they do consume (or the days in which they consume more or less) these target products. Previous studies using this approach have reported that an increase of a ~230g serving of sugary drink was associated with an increase of ~100 kcal in total energy intake [(19,20)]. Other studies conducting within-person comparisons between repeated recalls of the same individual found that when individuals consumed pizza [(21)], or at fast-food restaurants [(22)], the total energy intake increased by ~ 200 kcal, suggesting these are not fully substituted.

When identifying substitution and complementation patterns associated with the intake of processed food groups, it is of interest to understand the association with total energy intake, (regardless of the source of the substitution), and total sugars due to the potential outcomes on body weight and effect on quality of diet, respectively. In this study, we analyzed a subsample of individuals with two 24-hr recalls from the 2012 National Health and Nutrition Survey (ENSANUT). We used fixed effects regression to estimate the relation between within-person changes in consumption of processed discretionary food/drink categories and changes in total energy and added sugar intake.

METHODS

Participants

The ENSANUT 2012 is a cross-sectional, multi-stage probabilistic survey representative of the Mexican population. It was conducted between October 2011 and May 2012. The survey measures the health and nutrition status of the Mexican population and monitors trends across time.[(23)] Informed consent was obtained from each subject or parent/guardian. The survey protocol was reviewed and approved by the Ethics Committee of the Mexican National Institute of Public Health.

Dietary intake assessment

Dietary intake was collected with a 24-hour recall in 10,886 participants, and a second recall was applied in a random subsample of ≈9% (n=981). We included non-pregnant non-lactating subjects ≥1-year-old of the subsample with two recalls and excluded 30 subjects with extreme energy intake (outside ±3 SD of the log-energy intake/energy requirements ratio). Our analytic sample size consisted of 889 participants, including 358 children (1—9 years old), 253 adolescents (10—19 y old), and 278 adults (≥20 years old).

Dietary 24-hr recalls were collected in person by trained interviewers using a multiple five-pass probing method. Interviewers recorded the types and amounts of all food items consumed. To estimate the quantity of food consumed, interviewers used scales (if a food similar to the one consumed was available in the household) or common household measuring items such as spoons and cups. Respondents, particularly those younger than 15 years, were assisted by the person who cooked and prepared their meals in the household.[24] Dietary recalls were collected in all days of the week (including the weekend). The second 24-hr recalls were obtained in-person on nonconsecutive days (average of 2.4 days) after the first recall.

Food group classification

To define the processed discretionary groups, we followed the definition of the taxes implemented in Mexico starting in 2014 (after survey's data collection). The sugary drinks tax covers all industrialized water-based non-alcoholic beverages (including concentrates and powders) with added sugar. The food tax covers non-essential foods with an energy density ≥275kcal/100g, such as chips and snacks, candies and sweets, chocolate, puddings, peanut and hazelnut butter, ice-cream, ice-pops, ready-to-eat cereals, and baked goods with added sugar. We divided processed discretionary groups into three groups: 1) industrialized sugary drinks (e.g., soft drinks, sports drinks, flavored drinks, juices with added sugar), 2) sweet and savory snacks (e.g., chocolate, candies, ice cream, sorbets, spreads, jellies, chips, salted peanuts, and popcorn), and 3) grain-based sweets (e.g., pastries, sweet bread, cakes, cookies, cereal bars, and ready-to-eat cereals).

To assess whether substitution and complementation patterns were unique to discretionary processed foods or could be observed in other food groups, we also analyzed the remaining of the diet (classified into 19 food groups) (see Supplemental Tables 1–3).

Energy and added sugar intake assessment

We calculated energy intake using the food composition database compiled by the Mexican National Institute of Public Health, which is based on the USDA Standard Reference database, product labels, and standard recipes. This food composition table does not include added sugar; this nutrient was estimated as described by Sánchez-Pimienta, et al. [25].

Statistical analysis

We conducted a descriptive analysis of the food group's intake in the two 24-hr recalls, among all and stratifying by age group (1—9 y, 10—19 y, and ≥20 y). For each food group we calculated the mean daily energy contribution (% kcal) per capita using the subject's two-day mean, the percentage of consumers on neither, one, or both recalls, and the mean daily intake (kcal) separately for those who consumed the food group in one recall versus both recalls (two-day mean for consumers on both days).

We ran models for the total intake of energy (kcal) and added sugar (g). We fit fixed-effects linear regression models among all and for each age group to assess intra-individual differences between the two 24-hour recalls. This model eliminates the effect of time-invariant observed and unobserved characteristics because it is equivalent to modeling the differences between days with consumption *vs* days without consumption in each outcome and exposure variable. For each food group, we ran the following model:

$$\gamma\, TI = \alpha + \beta 1\, FG + \beta 2\, recall\ sequence + \beta 3\, weekend + \beta 4\, location + \varepsilon$$

Total intake (TI) was the dependent variable (total energy or total added sugar), and the main independent variable was whether the food group (FG) was consumed or not, with “yes” as reference, so that the beta coefficient represents the change in total intake from consuming to not consuming the food group. As the model is fixed-effects, the outcome total intake (TI) is equivalent to the change in total intake from one day to the other (ΔTI or TI_{day1}-TI_{day2}), and food group (FG) is the change in food group (ΔFG or FG_{day1} - FG_{day2}).

If the change in total intake was not statistically significant, we assumed the food group was fully substituted. If it did change (i.e., was lower), we identified if the change in total intake was due to complementation or partial substitution with other food groups (or neither substituted nor complemented). We compared the change in total intake when not consumed from the model above with the 1-day consumers average intake when consumed. We estimated the relative change (change in intake when not consumed / average intake when consumed *100) and classified it as follows: complemented if when not consumed the change in total intake was larger than the intake when consumed (< −120%), neither substituted nor complemented if it was similar (~ −100%), and partially substituted if it was lower (> −80%).

All models were adjusted by diet recall sequence (1^{st} or 2^{nd} diet recall), by the day of the diet recall (weekday or weekend), and by location (all meals consumed at home, work, school, or transportation vs. at least one meal consumed at restaurant, street, street stand, or other), as these variables are time-varying and can affect the reported intake. The food group coefficient reflects the information only from the subjects that had variation (those that consumed the food group in one of the two days). Yet, we included the entire sample because all subjects had variation in the covariates and hence contributed to the adjustment of the coefficient of interest. Finally, we ran equivalent models treating food group consumption as continuous rather than categorical. Results of continuous models show the association with reducing one kcal of energy or one g of added sugar in each food group (instead of changing from consuming to not consuming as in our main models). Variance estimation in regression models was adjusted considering the clustering at the primary sampling unit (cluster of households) defined for the multi-stage probabilistic sampling design of ENSANUT. We performed all analyses in STATA 14 (StataCorp, College Station, TX).

RESULTS

Table 1 shows that 41% of the sample were children, 28% were adolescents, and 31% were adults. The mean age for children was 5 years, for adolescents it was 14, and for adults it was 50 years. More than 60% of the sample lived in urban areas.

The energy contribution of processed discretionary groups was ~20% kcal across age groups (5—6% kcal industrialized sugary drinks, 2—6% kcal sweet and savory snacks, and 9—12% kcal grain-based sweets) (Table 2). Around 1/3 of the sample consumed each of the processed discretionary groups in one of the two days. The average intake was usually higher among 2-d consumers vs. 1-d consumers.

Table 3 shows the average intake among 1-day consumers and the change in total intake associated with changing from consuming to not consuming each food group. We estimated the relative change for food groups showing a statistically significant reduction in total intake, otherwise they were fully substituted. For energy intake, we found that adolescents and adults complemented industrialized sugary drinks. For instance, adolescents consumed on average 168 kcal/day of industrialized sugary drinks on the day these were consumed, and not consuming them was associated with 228 kcal/day less (−136%). Thus, the change in energy intake came not only from not consuming industrialized sugary drinks, but also from not consuming other complementary items. Also, among adolescents and adults, we found that sweet and savory snacks were fully substituted. In these cases, the change in total intake when not consumed was not statistically significant, suggesting that an equivalent energy content from other sources were consumed instead. Children, on the contrary, fully substituted industrialized sugary drinks and complemented sweet and savory snacks. Moreover, we found that children and adolescents partially substituted grain-based sweets, whereas adults fully substituted these. For example, children consumed on average 335 kcal/day of grain-based sweets on the day these were consumed, and not consuming them was associated with 262 kcal/day less (−78%). Hence, the intake of other sources was higher, but not to the point of full substitution.

In the case of added sugar, we found that the change in total intake when not consumed was −11 to −37 g/day (or −161 to −433%) across all age groups and processed discretionary food groups. Meaning that in all cases there was complementation, not only a change in added sugar driven by not consuming the processed discretionary item, but also for not consuming the added sugar of other complementary sources. The only exception were sweet and savory snacks among adolescents, which were fully substituted.

In Supplemental Table 2 we present the results for other not processed discretionary food groups among all subjects. For energy, out of 19 food groups we found complementation in five and neither substitution nor complementation in two; the remaining were fully substituted. Total added sugars intake was fully substituted for all food groups, the only exception were sugar and sweeteners which were neither substituted nor complemented.

Supplemental Table 3 shows the change in total intake associated with a one-unit change (−1 kcal of energy or −1 g of added sugar) in the intake of each food group. These results can be interpreted as relative changes. For instance, −1 kcal in industrialized sugary drinks was associated with −1.22 kcal in total energy intake (total change of −122%). According to these models, for energy, industrialized sugary drinks were complemented, and sweet and savory snacks, and grain-based sweets were neither complemented nor substituted. For added sugars, all processed discretionary food groups were neither substituted nor complemented. Thus, results were consistent with previous models with the binary categorization; processed discretionary food groups were not fully substituted. However, for other non-processed discretionary food groups, we found that only one (out of 19) was fully substituted, whereas in the binary model, 12 were fully substituted (Supplemental Table 2).

DISCUSSION

We aimed to identify the association between days with/without intake of processed discretionary groups and total energy and added sugar intake, and improve our understanding of their substitution and complementary patterns. We found that most processed discretionary food groups were not fully substituted, as not consuming them was associated with less total energy or added sugar intake. The patterns of changes differed by food group and age group. Industrialized sugary drinks were complemented (adolescents and adults), but fully substituted in children. In complemented products, the total energy intake was lower as a result of lowering both the target product and the complements. Grain-based sweets were partially substituted (children, and adolescents, but fully substituted in adults). In partially substituted products, the total energy intake was also lower when not consumed in comparison to when consumed, but in a lower magnitude. Sweet and savory snacks had a less consistent pattern: complemented among children, and fully substituted among adolescents and adults.

Our results suggest that when industrialized sugary drinks are not consumed, total energy intake is lower. Plus, subjects not only do not substitute the intake of industrialized sugary drinks, but they might also lower the intake of complementary items. The finding that sugary drinks are not substituted is supported by previous experimental and within-person observational studies [18–20]. These results provide important insight into the estimation of the potential effectiveness of policies aimed at reducing the intake of unhealthy items. Previous modeling studies estimating the impact of interventions to reduce sugary drinks intake have assumed that a part of the reduced energy will be substituted [26,27]. If policies induce similar changes to the ones observed here, then simulation studies may have underestimated the total impact on total energy intake and obesity.

We found that the change in total energy intake when not consumed was lower for sweet and savory snacks, and grain-based sweets than with sugary drinks. Grain-based sweets were partially substituted implying a lower total energy intake, but snacks had varied results by age group and in two cases these were fully substituted. Grain-based sweets might serve as a carbohydrate-rich staple of ordinary main meals. It could be that, given their important function at meals, they are substituted with other sources, but at the same time they are easy to over-consume and hence substitution is only partial. While the energy intake is relevant for weight outcomes, the findings from added sugar are relevant for other chronic diseases such as diabetes.[28] We found that the added sugar of all processed discretionary groups was complemented. Also, the change in total added sugar when the items were not consumed was much larger for processed discretionary groups compared to non-processed sources of added sugars (Supplemental Table 2). In this sense, processed discretionary groups are a better target than other groups for policies aimed at reducing the added sugar intake of the population, even if all sources of added sugars should be discouraged. For non-processed homemade sugary drinks, we even found that both the energy and added sugar were fully substituted. A possible explanation is that homemade sugary drinks are not substituted with plain water or other non-caloric beverages, but with other caloric beverages including industrialized sugary drinks, thus not consuming these was not associated with a change in total energy or added sugar intake.

It has been reported that solids produce more satiety compared to liquids [18]. However, if we look at our analysis of all food groups, including non-processed discretionary foods, the pattern of substitution or complementation was not related to the liquid or solid form. Moreover, in our results, it does not seem to be related to the nutritional composition, energy contribution to total diet, or the frequency in which it is consumed (e.g., % consuming 1-day in Table 2 and Supplemental Table 1). Perhaps the associated substitution or complementary changes have to do more with their meaning and role in dietary habits and the common substitutes. For instance, industrialized sugary drinks, red meat, fish and seafood, cheese and yogurt, and sugar and sweeteners, not fully substituted, might be consumed at snacks or more special main meals, hence their consumption might be more optional and are not substituted when not consumed.

Substitution patterns might depend on the cultural/culinary role of food groups, but these might also depend on whether we decide not to consume at all in a day or to lower the quantity consumed. With food policies, a subject may decide to decrease the frequency of consumption (i.e. avoid consuming the food item in the entire day) instead of decreasing the amount. A previous evaluation of the food tax in Mexico found that the decrease in household purchases after the tax implementation was driven largely by reductions in the probability of purchases and less in the amount purchased [29]. In our main analysis, we observed important substitutions comparing days in which food and beverages were not consumed. To understand the substitution patterns for each unit of change (e.g. −1 kcal or −1 g of added sugar), we ran the models using a continuous measure of consumption (Supplemental Table 3). Most food groups (processed or non-processed) were not fully substituted, suggesting that small changes in consumption that free-living individuals make in the amount consumed across days may not lead to clear substitution patterns. An important consideration of our results with categorical food group consumption, is that this applies only to the subjects that consumed the food group in one of the two days of recall, as subjects that did not show variation (did not consume the food group in either of the two days or consumed it in both days) do not contribute to the estimation of the coefficient of interest in the fixed-effects model. Likely, substitution or complementation results may differ among “light” or “heavy” consumers.

Our analysis has several limitations and strengths. Our models might not represent the substitution and complementation effects over longer term periods, but as other similar analyses with repeated recalls, these models are useful to get the association with total energy intake for specific food groups [19–22,30–32]. Other limitations exist inherent to self-reported dietary intake measures. However, important efforts to reduce the degree of measurement error were conducted in the ENSANUT 2012. The use of the multiple five-pass probing method improves precision and limits the number of omitted items [33]. Another strength of using the ENSANUT survey is that study population came from a nationally representative sample. Additionally, conducting two recalls in this subsample is an important strength. Both recalls were collected in person increasing the comparability; and having two recalls enabled us to use fixed-effects models to perform within-person comparison, eliminating all unmeasured person-specific bias. Yet, two recalls were collected in a subsample, thus our sample size and ability to stratify by finer age groups were limited.

In sum, this study provides insights into the complexity of eating behaviors, where substitutes and complements play an important role. Our findings suggest that not consuming processed discretionary foods and drinks is associated with lower energy and added sugars, because these are not substituted. Processed discretionary foods and sugary drinks are common targets of food policies, and thus it is relevant to learn about their role in the total energy and added sugar intake of the population.

Transparency Declaration

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported. The reporting of this work is compliant with STROBE guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

We thank Steven Gortmaker and Michael Long for constructive comments about the method and results.

Funding sources

This work was supported in part by grants from Bloomberg Philanthropies (grant to the National Institute of Public Health, Mexico), the NIH R01DK108148, and the Robert Wood Johnson Foundation (Grant No. 77202). Tonatiuh Barrientos-Gutiérrez also received support from Harvard University through the Lown Scholars. The funding sources had no role in the design, collection, analysis, or writing of this manuscript.

Biographies

Carolina Batis has a PhD in Nutrition Epidemiology; her research focuses on the study of population’s dietary intake including their determinants, methods for dietary assessment, and the evaluation of food policies.

Ana Abreu has a PhD in Public Health and works at the National Institute of Public Health. Her interests lie on estimating the causes and distributions of chronic diseases.

Tonatiuh Barrientos has PhD in Epidemiology from the University of Texas at Houston and is the Director of the Population Health Research Center of the National Institute of Public Health.

List of abbreviations

ENSANUT	National Health and Nutrition Survey

REFERENCES

1. Rouhani MH, Haghighatdoost F, Surkan PJ, Azadbakht L. Associations between dietary energy density and obesity: A systematic review and meta-analysis of observational studies. Nutrition. 2016;32:1037–47. [PubMed: 27238958]
2. Malik VS, Pan A, Willett WC, Hu FB. Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. Am J Clin Nutr. 2013;98:1084–102. [PubMed: 23966427]
3. Malik VS, Popkin BM, Bray GA, Després J-P, Hu FB. Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. Circulation. 2010;121:1356–64. [PubMed: 20308626]
4. Malik VS, Popkin BM, Bray GA, Després J-P, Willett WC, Hu FB. Sugar-Sweetened Beverages and Risk of Metabolic Syndrome and Type 2 Diabetes: a meta-analysis. Diabetes Care. 2010;33:2477–83. [PubMed: 20693348]
5. Imamura F, O'Connor L, Ye Z, Mursu J, Hayashino Y, Bhupathiraju SN, et al. Consumption of sugar sweetened beverages, artificially sweetened beverages, and fruit juice and incidence of type 2 diabetes: systematic review, meta-analysis, and estimation of population attributable fraction. Br J Sport Med. 2016;50:496–504.
6. Rodríguez-Monforte M, Sánchez E, Barrio F, Costa B, Flores-Mateo G. Metabolic syndrome and dietary patterns: a systematic review and meta-analysis of observational studies. Eur J Nutr. 2017;56:925–47. [PubMed: 27605002]
7. Jannasch F, Kröger J, Schulze MB. Dietary Patterns and Type 2 Diabetes: A Systematic Literature Review and Meta-Analysis of Prospective Studies. J Nutr. 2017;147:1174–82. [PubMed: 28424256]
8. Monteiro CA, Moubarac JC, Cannon G, Ng SW, Popkin B. Ultra-processed products are becoming dominant in the global food system. Vol. 14, Obesity Reviews. 2013. p. 21–8. [PubMed: 24102801]
9. Pan American Health Organization. Ultra-processed food and drink products in Latin America: Trends, impact on obesity, policy implications [Internet]. Washington; 2015 [cited 2019 Oct 1]. Available from: http://iris.paho.org/xmlui/bitstream/handle/123456789/7699/9789275118641_eng.pdf
10. Batis C, Pedraza LS, Sánchez-Pimienta TG, Aburto TC, Rivera-Dommarco JA. Energy, added sugar, and saturated fat contributions of taxed beverages and foods in Mexico. Salud Publica Mex. 2017;59:512–7. [PubMed: 29267647]
11. World Health Organization. Global Strategy [Internet]. Vol. 2002. Geneva; 2004. Available from: http://www.who.int/dietphysicalactivity/strategy/eb11344/strategy_english_web.pdf
12. Pérez-Ferrer C, Barrientos-Gutierrez T, Rivera-Dommarco JA, Prado-Galbarro FJ, Jiménez-Aguilar A, Morales-Ruán C, et al. Compliance with nutrition standards in Mexican schools and their effectiveness: a repeated cross-sectional study. BMC Public Health [Internet]. 2018 [cited 2022 Jan 18];18. Available from: https://pubmed.ncbi.nlm.nih.gov/30591040/
13. Colchero MA, Rivera-Dommarco J, Popkin BM, Ng SW, Arantxa Cochero M, Rivera-Dommarco J, et al. In Mexico, evidence of sustained consumer response two years after implementing a sugar-sweetened beverage tax. Health Aff. 2017;36:564–71.
14. Taillie LS, Rivera JA, Popkin BM, Batis C. Do high vs. low purchasers respond differently to a nonessential energy-dense food tax? Two-year evaluation of Mexico's 8% nonessential food tax. Prev Med (Baltim). 2017;105:S37–42.
15. White M, Barquera S. Mexico Adopts Food Warning Labels, Why Now? Heal Syst reform [Internet]. 2020 [cited 2022 Feb 11];6. Available from: https://pubmed.ncbi.nlm.nih.gov/32486930/
16. U.S. Department of Agriculture. USDA ERS - Food Demand Analysis [Internet]. 2021 [cited 2020 Jul 5]. Available from: https://www.ers.usda.gov/topics/food-choices-health/food-consumption-demand/food-demand-analysis/
17. Cornwell TB, McAlister AR. Contingent choice. Exploring the relationship between sweetened beverages and vegetable consumption. Appetite. 2013;62:203–8. [PubMed: 22595286]
18. Dimeglio DPDP Mattes RD. Liquid versus solid carbohydrate: Effects on food intake and body weight. Int J Obes. 2000;24:794–800.

19. Gibson S, Horgan G, Francis L, Gibson A, Stephen A. Low Calorie Beverage Consumption Is Associated with Energy and Nutrient Intakes and Diet Quality in British Adults. Nutrients. 2016;8:9. [PubMed: 26729159]

20. Wang YC, Ludwig DS, Sonneville K, Gortmaker SL. Impact of Change in Sweetened Caloric Beverage Consumption on Energy Intake Among Children and Adolescents. Arch Pediatr Adolesc Med. 2009;163:336. [PubMed: 19349562]

21. Powell LM, Nguyen BT, Dietz WH. Energy and Nutrient Intake From Pizza in the United States. Pediatrics. 2015;135:322–30. [PubMed: 25601973]

22. Nguyen BT, Powell LM. The impact of restaurant consumption among US adults: effects on energy and nutrient intakes. Public Health Nutr. 2014;17:2445–52. [PubMed: 25076113]

23. Romero-Martínez M, Shamah-Levy T, Franco-Núñez A, Villalpando S, Cuevas-Nasu L, Gutiérrez JP, et al. [National Health and Nutrition Survey 2012: design and coverage]. Salud Publica Mex. 2013;55:S332–40. [PubMed: 24626712]

24. López-Olmedo N, Carriquiry AL, Rodríguez-Ramírez S, Ramírez-Silva I, Espinosa-Montero J, Hernández-Barrera L, et al. Usual Intake of Added Sugars and Saturated Fats Is High while Dietary Fiber Is Low in the Mexican Population. J Nutr. 2016;146:1856S–65S. [PubMed: 27511932]

25. Sánchez-Pimienta TG, Batis C, Lutter CK, Rivera JA. Sugar-Sweetened Beverages Are the Main Sources of Added Sugar Intake in the Mexican Population. J Nutr. 2016;146:1888S–1896S. [PubMed: 27511931]

26. Basto-Abreu A, Braverman-Bronstein A, Camacho-García-Formentí D, Zepeda-Tello R, Popkin BM, Rivera-Dommarco J, et al. Expected changes in obesity after reformulation to reduce added sugars in beverages: A modeling study. PLOS Med. 2018;15:e1002664. [PubMed: 30289898]

27. Sánchez-Romero LM, Penko J, Coxson PG, Fernández A, Mason A, Moran AE, et al. Projected Impact of Mexico’s Sugar-Sweetened Beverage Tax Policy on Diabetes and Cardiovascular Disease: A Modeling Study. Blakely T, editor. PLoS Med. 2016;13:e1002158.

28. Stanhope KL. Sugar consumption, metabolic disease and obesity: The state of the controversy. Crit Rev Clin Lab Sci [Internet]. 2016 [cited 2022 Sep 5];53:52–67. Available from: https://pubmed.ncbi.nlm.nih.gov/26376619/

29. Batis C, Rivera JA, Popkin BM, Taillie LS. First-Year Evaluation of Mexico’s Tax on Nonessential Energy-Dense Foods: An Observational Study. PLoS Med. 2016;13:e1002057. [PubMed: 27379797]

30. Kant AK, Graubard BI. Complementary and compensatory dietary changes associated with consumption or omission of plain water by US adults. Appetite. 2018;128:255–62. [PubMed: 29920322]

31. An R, McCaffrey J Plain water consumption in relation to energy intake and diet quality among US adults, 2005–2012. J Hum Nutr Diet. 2016;29:624–32. [PubMed: 26899737]

32. Kant AK, Graubard BI. Within-person comparison of eating behaviors, time of eating, and dietary intake on days with and without breakfast: NHANES 2005–2010. Am J Clin Nutr. 2015;102:661–70. [PubMed: 26178722]

33. Blanton CA, Moshfegh AJ, Baer DJ, Kretsch MJ. The USDA Automated Multiple-Pass Method Accurately Estimates Group Total Energy and Nutrient Intake. J Nutr. 2006;136:2594–9. [PubMed: 16988132]

Key points:

- Not consuming processed discretionary food and beverages is associated with lower energy and added sugars.
- Substitution patterns depends on age and food groups.
- Industrialized beverages were generally complemented; when not consumed, not only the energy from beverages was lower but also from complementary food.
- Our results suggest that policies regulating processed discretionary food and beverages could reduce total energy and added sugars intake.

Table 1.

Sociodemographic characteristics of participants.

	Children (1—9 y old)	Adolescents (10—19 y old)	Adults (≥ 20 y old)
Sample size, n (%)	358 (40.6%)	253 (28.0%)	278 (31.2%)
Age, y	5.3 ± 2.6	14.2 ± 2.8	49.6 ± 18.4
Female sex, %	46.8	49.0	58.5
Urban area (>2,500 inhabitants), %	63.4	59.8	63.9
Geographic region[1], %			
North	19.9	22.1	26.7
Center	34.9	33.3	33.6
Mexico City	3.6	3.6	3.3
South	41.6	41.0	36.5
Total energy intake, kcal	1502.9 ± 748.7	2101.7 ± 1032.3	1935.3 ± 1123.7

[1] North: Baja California Norte, Baja California Sur, Coahuila, Chihuahua, Durango, Nuevo León, Sonora, Tamaulipas; Center: Aguascalientes, Colima, Estado de México, Guanajuato, Jalisco, Michoacán, Morelos, Nayarit, Querétaro, San Luis Potosí, Sinaloa, Zacatecas; South: Campeche, Chiapas, Guerrero, Hidalgo, Oaxaca, Puebla, Quintana Roo, Tabasco, Tlaxcala, Veracruz, Yucatán.

Table 2.

Mean energy contribution (% kcal) per capita, percentage of consumers, and mean intake (kcal) per consumer by day of recall among all and by age group.[1]

	% kcal / per capita	% consuming			kcal / per consumer	
	Mean ± SD (2-d mean)	0-d	1-d	2-d	1-d consumers Mean ± SD	2-d consumers Mean ± SD (2-d mean)
Children (1—9 y old), n=358						
Industrialized sugary drinks	5 ± 6	34	33	33	111 ± 84	148 ± 93
Sweet and savory snacks[2]	5 ± 7	36	35	29	176 ± 165	207 ± 167
Grain-based sweets[3]	12 ± 11	25	36	39	335 ± 353	333 ± 219
Adolescents (10—19 y old), n=253						
Industrialized sugary drinks	6 ± 6	19	36	45	168 ± 114	198 ± 118
Sweet and savory snacks[2]	6 ± 8	35	35	29	329 ± 551	267 ± 244
Grain-based sweets[3]	12 ± 12	25	35	39	409 ± 387	478 ± 526
Adults (≥ 20 y old), n=278						
Industrialized sugary drinks	5 ± 6	35	32	33	176 ± 144	225 ± 129
Sweet and savory snacks[2]	2 ± 5	62	28	10	171 ± 233	231 ± 331
Grain-based sweets[3]	9 ± 9	34	41	25	336 ± 224	371 ± 186
All, n=889						
Industrialized sugary drinks	5 ± 6	30	34	36	147 ± 117	187 ± 117
Sweet and savory snacks[2]	5 ± 7	44	33	23	220 ± 350	235 ± 229
Grain-based sweets[3]	11 ± 11	28	37	35	355 ± 326	388 ± 348

[1] %kcal/per capita estimated with subject's 2-day mean; % consuming in 0, 1, or 2 days; and kcal/per consumer among those that consumed the food group on 1 day, and those that consumed it on the 2 days (estimated with subject's 2-day mean).

[2] Chocolate, candies, ice cream, sorbets, spreads, jellies, chips (potato, corn, or wheat), salted peanuts, and popcorn.

[3] Pastries, sweet bread, cakes, cookies, cereal bars, and ready-to-eat cereals.

Table 3.

Change in total energy and added sugar intake associated with the change between a day in which the food group was consumed versus a day with no food consumption among all and by age group.

	Energy, kcal			Added sugar, g		
	Food group's mean intake when consumed (1-d consumers)	Change in total intake when not consumed[1]	Relative change and effect type[2]	Food group's mean intake when consumed (1-d consumers)	Change in total intake when not consumed[1]	Relative change and effect type[2]
	Mean ± SD	*β (95% CI)*	*%*	*Mean ± SD*	*β (95% CI)*	*%*
Children (1—9 y old), n=358						
Industrialized sugary drinks	111 ± 84	−64 (−202, 73)	(FS)	9 ± 19	**−19 (−27, −12)**	−211% (C)
Sweet and savory snacks[3]	176 ± 165	**−249 (−390, −108)**	−141% (C)	5 ± 9	**−11 (−17, −4)**	−220% (C)
Grain-based sweets[4]	335 ± 353	**−262 (−385, −140)**	−78% (PS)	7 ± 20	**−18 (−26, −10)**	−257% (C)
Adolescents (10—19 y old), n=253						
Industrialized sugary drinks	168 ± 114	**−228 (−446, −10)**	−136% (C)	23 ± 31	**−37 (−52, −22)**	−161% (C)
Sweet and savory snacks[3]	329 ± 551	−109 (−393, 176)	(FS)	6 ± 17	−19 (−41, 3)	(FS)
Grain-based sweets[4]	409 ± 387	**−300 (−546, −53)**	−73% (PS)	14 ± 24	**−24 (−37, −11)**	−171% (C)
Adults (≥ 20 y old), n=278						
Industrialized sugary drinks	176 ± 144	**−378 (−695, −60)**	−215% (C)	20 ± 29	**−37 (−48, −26)**	−185% (C)
Sweet and savory snacks[3]	171 ± 233	−254 (−520, 12)	(FS)	3 ± 6	**−13 (−22, −4)**	−433% (C)
Grain-based sweets[4]	336 ± 224	−220 (−454, 13)	(FS)	6 ± 12	**−14 (−23, −4)**	−233% (C)
All, n=889						
Industrialized sugary drinks	147 ± 117	−204 (−329, −79)	−139% (C)	17 ± 27	**−30 (−37, −24)**	−176% (C)
Sweet and savory snacks[3]	220 ± 350	**−199 (−325, −72)**	−90% (NSNC)	5 ± 11	**−14 (−22, −6)**	−280% (C)
Grain-based sweets[4]	355 ± 326	**−268 (−377, −159)**	−75% (PS)	9 ± 19	**−18 (−24, −13)**	−200% (C)

[1] A separate model was conducted for each food group, so each row is from a separate analysis.

[2] Relative change between food group's mean intake when consumed and change in total intake when not consumed.

Patterns are as follows, if when not consumed the cut in total intake is:
- larger than intake when consumed (< −120%) → Complemented (C)
- similar to intake when consumed (~ −100%) → Neither substituted nor complemented (NSNC)
- lower than intake when consumed (> −80%) → Partially substituted (PS)

no different than intake when consumed (change in total intake is not statistically significant) → Fully substituted (FS) (% change not estimated)

[3]Chocolate, candies, ice cream, sorbets, spreads, jellies, chips (potato, corn, or wheat), salted peanuts, and popcorn.

[4]Pastries, sweet bread, cakes, cookies, cereal bars, and ready-to-eat cereals.