DEVELOPMENT OF A NOVEL CLASSIFICATION SYSTEM TO DETERMINE THE ROLE OF PROCESSED AND CONVENIENCE FOODS IN THE DIETS OF US HOUSEHOLDS

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ABSTRACT

Jennifer M. Poti: Development of a novel classification system to determine the role of processed and convenience foods in the diets of US households
(Under the direction of Barry M. Popkin)

Although excessive consumption of processed food is considered a risk factor for obesity, the caloric contribution of processed foods to US diet has not been accurately assessed, particularly for vulnerable populations. Further, conclusions about the nutritional quality of processed foods are discrepant.

Using food and beverage purchases of households (n=157,142) participating in the 2000-2012 Homescan longitudinal panel, this research aimed to develop an innovative approach for defining processed foods and to determine the nutritional role of these products in US diet.

In Aim 1, we developed a multidimensional classification system with explicitly defined criteria to categorize foods and beverages by level of processing and separately by level of convenience. We classified >1.2 million items using product-level information and ingredient lists. We further evaluated 13-year trends in the caloric contribution of processed and convenience foods to purchases. We found unshifting dominance of ultra-processed and ready-to-eat (RTE) foods as major calorie contributors to US diet. Aim 2 determined the longitudinal association of sociodemographic and economic household characteristics with processed and convenience food purchases. Less education and lower income were associated with higher ultra-processed food purchases, with associations strengthening across time. Non-Hispanic black households had higher ultra-processed beverage purchases yet lower ultra-processed food

purchases compared to non-Hispanic whites. Non-Hispanic black and Hispanic race/ethnicities and lower education were associated with lower RTE convenience food purchases, suggesting a greater role of cooking. In Aim 3, we compared nutrient densities of foods across categories of processing and convenience. The adjusted proportion of household-level food purchases exceeding recommended maximums for saturated fat, sugar, and sodium densities was significantly higher for ultra-processed and RTE food purchases compared to purchases of less-processed foods or foods requiring cooking.

In conclusion, our study suggests that ultra-processed and RTE convenience foods and beverages dominate diets in the US with remarkable stability and may contribute to sociodemographic disparities in diet. Our findings of higher saturated fat, sugar, and sodium content of ultra-processed and RTE foods support the need for future studies to examine the relationship of these products with diet and health outcomes.

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IFIC	International Food Information Council Foundation
NHANES	National Health and Nutrition Examination Survey
RTE	Ready-to-eat
RTH	Ready-to-heat
SES	Socioeconomic status
SSB	Sugar-sweetened beverage

Chapter 1. Introduction

Background

Popular culture and researchers alike link processed foods, such as chips, cookies, sugar sweetened beverages (SSBs), and prepared meals, to increases in calorie intake and the resulting US obesity epidemic. However, limited research specific to the US has quantified the nutritional contribution of processed foods to diet. This major gap in the literature arises primarily from a lack of a clear definition for processed foods. Various classification systems assess the degree and purpose of processing used by the food industry to turn unprocessed whole foods into manufactured products, and foods are classified along a spectrum, ranging from minimally to ultra-processed. Existing systems vary substantially in their definitions of processed foods, limiting comparability across studies. Some, but not all, processed foods are manufactured to be ready-to-eat (RTE), and these convenience foods are hypothesized to promote overconsumption through mechanisms independent of processing. However, no existing classification scheme makes the recommended separation of processing and convenience. Thus, the amount of these products in US diet has not been accurately assessed. Moreover, researchers suggest that differences in dietary intake across sociodemographic groups may mediate disparities in obesity and nutrition-related chronic disease among US children and adults. Yet no previous studies have examined whether between-group differences in the contribution of processed or convenience foods to diet contribute to inequalities across subpopulations defined by race, ethnicity, and socioeconomic status (SES). Importantly, conclusions about the nutritional quality of processed foods are discrepant. Some authors suggest that processed foods are nutritionally important to American diets, while other researchers found that processed foods are collectively higher in saturated fat, added sugar, sodium, and energy densities when compared to less-processed products. Lack of measurement clarity and research on the causes and consequences of processed food purchasing are key gaps.

This study will address these research gaps through the use of the Nielsen Homescan panel, a nationally representative longitudinal sample of 160,000 US households who use barcode scanners to record all food and beverage store purchases, which are subsequently linked to complete and up-to-date product- and brand-specific Nutrition Facts Panels for over 1.2 million barcoded products from 2000 to 2012. This dataset is unique in collecting detailed food descriptions and ingredient lists that facilitate classification of foods by level of processing and convenience. Its longitudinal design will enable assessment of recent trends in processed and convenience food purchasing as well as determination of time-varying longitudinal associations of sociodemographic and economic characteristics with ultra-processed and RTE food purchases. Product-specific current nutritional content will allow accurate examination of the association between processing and convenience with the nutrient density of household-level food purchases.

Research Aims

Aim 1: Develop a multidimensional classification system that separates processing and convenience. Determine trends from 2000-2012 in the contribution of processed and convenience foods to household purchases.

1a. Develop explicit category definitions, classification criteria, and decision rules for categorizing each food or beverage product based on the extent and purpose of food processing and for separately categorizing each product based on convenience of food preparation. Create a food grouping system to re-organize the data into nutritionally meaningful groups reflective of consumption patterns.

1b. Apply the classification system and food grouping system to the Homescan data at the barcoded product level using programming algorithms.

1c. Determine the percent contribution of each category of processing and convenience to purchases in terms of calories and grams for overall purchases and among foods, beverages, and food groups. Examine trends from 2000-2012 to determine whether shifts have occurred across time. Identify food groups that are top calorie contributors to each category.

This aim focused on development of a classification system including mutually exclusive categories for the extent and purpose of industrial food processing and including separate mutually exclusive categories for the convenience of food preparation. Using Perl-based "regular expression" pattern matching syntax to analyze product descriptions and ingredient lists, each food was placed into a category for processing and separately into a category for convenience. We hypothesized that processed and ultra-processed foods and beverages would contribute over 70% of calories purchased and that minimally processed foods are being replaced by ultra-processed RTE foods.

Aim 2: Determine the longitudinal association of sociodemographic and economic characteristics with the contribution of ultra-processed and ready-to-eat products to food

and beverage purchases. Identify key food groups that contribute to differences across subpopulations.

We hypothesized that non-Hispanic black race/ethnicity, less education, and lower income would be associated with a higher percentage of calories from ultra-processed foods and with a higher percentage of calories from RTE foods.

Aim 3: Determine whether processing and convenience are associated with higher saturated fat, total sugar, and sodium densities of household-level food purchases. Examine the likelihood that purchases in each category simultaneously exceed recommended maximums for all three of these food components to limit.

We hypothesized that household-level ultra-processed and RTE food purchases would be significantly associated with higher saturated fat, sugar, and sodium densities compared to less-processed foods and foods requiring cooking and/or preparation, respectively.

Impact: We will potentially identify novel dimensions of food that are associated with the nutrient profile of household-level food purchases. This work represents a first step toward refining the definition of processed foods to isolate products with less healthful nutrient profiles. Future longitudinal studies may be able to target dietary assessment data collection to relevant food details needed to classify foods by these dimensions and facilitate studies examining the association of food processing and convenience with obesity. Our findings could potentially have significant public health impact by informing dietary guidelines, providing support for or evidence against a recommendation to reduce ultra-processed food intake. We can potentially identify race/ethnic, education, or income groups who might benefit most from these guidelines and from future intervention and policy efforts to decrease purchasing of processed foods.

Chapter 2. Literature Review

Global shifts away from traditional diets toward industrially processed foods

About 90% of Americans purchase processed foods, which account for ¾ of global food sales totaling 3.2 trillion dollars.[1-3] These foods, such as soda, cookies, processed meats, and prepared meals, have rapidly become a pervasive part of the US food supply. This nutrition transition away from traditional diets and toward industrially manufactured processed foods is driven by large transnational food and beverage manufacturers who use processing technologies, including mass production of refined flour and concentrated sugar, to produce a wide variety of food products.[4-6] Aggressive and pervasive marketing of highly processed foods by these companies contributes to increasing sales and demand for these food and beverage products.[7-9] As a result, farmer's markets and other fresh markets have been replaced with supermarkets and convenience stores offering an abundant and diverse array of processed foods.[10,11]

Growing evidence suggests that processed foods dominate global dietary patterns.[12-17] Analysis from the European Prospective Investigation into Cancer and Nutrition (EPIC) found that 60-80% of total energy intake came from industrially processed foods.[17] Other studies reported that processed foods and beverages collectively contributed 61.7% of calories purchased in Canada in 2001 and 63.4% in the UK in 2008.[14,15,18] Market sales data suggest that processed foods have largely displaced staple foods in high-income countries, and purchases of these products remain stable at high levels.[12,16]

Lack of clear definition for processed foods hinders our ability to quantify their contribution to US diet

Despite mounting evidence of these shifts in the global food supply and the increasing dominance of processed foods in worldwide dietary patterns,[11,12] the contribution of processed foods to diet specifically among Americans has not been accurately quantified.[19] A primary reason for this gap in the research literature is the lack of clear, comprehensive, and universally accepted definition of processed foods.[20-22] Some scholars define processed foods as any foods that are not "whole," "natural" foods.[23,24] The US government supports a similar broad view and considers any food other than a raw agricultural commodity as a processed food.[25,26] Thus, a food is "processed" after undergoing even basic modifications such as freezing, pasteurization, drying, or mixing ingredients.

Other experts suggest that this broad definition is overly simplistic and classifies virtually all foods as processed.[20,27] Instead, the *degree* of processing might be more important than the mere presence of processing.[28] Because most researchers acknowledge that almost all food in modern diets have been processed in some way, many investigators classify processed foods based upon the extent and purpose of the processes used by the food industry to turn whole fresh foods into manufactured products.[17,19,20,27,29] These systems identify specific processing techniques that classify a food along a spectrum, such as minimally, moderately, and ultra-processed foods. However, these systems do not agree on where to place canning, freezing, preparation of mixtures, and seasoning along that spectrum. As a result, estimates of the contribution of processed foods to nutrient intakes are difficult to interpret and compare across studies. For example, estimates in the UK vary from 63% to 75% kcal when different classification systems are used.[15,17]

Additionally, many processed foods are manufactured to be ready-to-eat (RTE), requiring little or no preparation before quick, easy consumption.[1] Examples include candy, salty snacks, or soda. These convenient RTE foods are hypothesized to encourage rapid eating rate and eating while attention is distracted, such as eating while watching television; these eating behaviors may promote overconsumption independent of food processing.[30-35] Therefore, scholars suggest that processing and convenience should be analyzed separately; however, all current classification systems conflate these two dimensions.[1,35] Categories may include "processed RTE" or "processed prepared meals," but processed foods that require preparation (e.g., cake mix or boxed macaroni-and-cheese) are not clearly classified; further, less-processed foods are never distinguished by their convenience level.[19,27]

More importantly, definitions of processed foods still lack the refinement needed to distinguish processed foods that may contribute to food security and achievement of micronutrient needs from processed foods that contribute to higher saturated and trans fat, added sugar, and sodium intakes.[20,36] For example, every existing classification system considers all bread products, including those made from whole-grain, as ultra-processed.[17,19,20,27] The only existing US classification scheme refers to a heterogeneous mix of products, ranging from frozen vegetables, dried fruit, and fruit juice to candy bars and soda, collectively as processed foods.[19,37] As noted by Moubarac et al., there is a great need for definitions of ultra-processed foods that are discriminating and precise, with all terms explicitly defined, in order to understand the potential association of ultra-processed foods with health outcomes.[20]

Previous US studies

Only one previous study has estimated the contribution of processed foods to dietary intake among Americans; however, its findings were limited by use of the International Food Information Council (IFIC) Foundation classification system that was deemed "incomplete and unclear" by a recent systematic review.[19,20] Earning only 5 of 15 possible points in this evaluation, the IFIC system was considered to have limited utility because classifications of many foods, such as oil, butter, grains, legumes, and salt, were omitted.[19,20,29] IFIC categories were rated as only partially coherent and partially clear; the review noted that, for example, reasons why IFIC classified bread as a "mixture of combined ingredients" along with cake mix, but garlic bread as a processed RTE food were not provided.[19,20,29] Another key limitation of this study is that researchers present either four separate unranked categories of processed food intakes or a single aggregate of all processed foods, ranging from canned vegetables and dried fruit to soda and cookies; no further grouping is provided to help identify more extensively processed foods that might make disproportionate contributions to nutrient intakes.[19,37] On the contrary, the classification system developed by Monteiro and colleagues was rated highest of all methods identified globally, yet this system has not been applied in the US.[20,27]

Are sociodemographic or economic factors associated with the contribution of ultra-processed or ready-to-eat foods to diet?

Although the overall contribution of ultra-processed foods to global food sales is substantial, it remains unclear whether various race/ethnic or socioeconomic groups are disproportionately consuming these manufactured products.[8,12] Disparities in obesity and diet-related health outcomes are well-recognized among Americans.[38-41] Of note, the age-adjusted prevalence of obesity in 2009-2010 was substantially higher among black (49.5%) and Hispanic (39.1%) adults compared to whites (34.3%).[39] Further, the proportions of adults with hypertension and diabetes were significantly higher among blacks compared to whites.[41] Less education was associated with higher prevalence of obesity, hypertension, and diabetes.[41]

Differences in dietary intake across population groups may mediate these health inequalities.[42,43] In a literature review, Darmon and Drewnowski reported that higher SES groups generally have higher intakes of whole grains, lean meats, fish, fresh fruits and vegetables, and low-fat dairy products, whereas lower SES groups report higher intakes of refined grains, fatty meats, and added fats.[44] Similarly, cross-sectional analyses of NHANES data provided evidence that Healthy Eating Index 2005 scores and adherence to food-based dietary recommendations were positively associated with income and education.[45,46] Kirkpatrick et al. found that the prevalence of meeting recommendations was lower for blacks compared to whites, particularly for whole fruits, total vegetables, milk, and added sugars.[46] This evidence is in line with studies reporting lower serum concentrations of some protective nutrients among blacks compared to whites.[43]

These findings suggest that differential consumption of minimally processed and ultra-processed foods among various sociodemographic groups may contribute to disparities in dietary intake. However, no studies have evaluated this hypothesis that race/ethnicity, education, and income are associated with the contribution of ultra-processed or RTE foods in the diet. In parallel with global shifts toward higher production of ultra-processed products, disparities in dietary intake across sociodemographic groups have either remained unchanged or widened.[47-49] A recent study found that income and education were positively associated with Alternate Healthy Eating Index 2010 scores, and the gap between low vs high SES groups widened between 1999 and 2010. Related studies found disparities in fruit and vegetable intakes across SES groups have increased over time.[44,50] Positive associations of SES with energy density and intake of caloric beverages observed in the 1970s were reversed by 2008 among US children and adolescents.[49] Additional work reported no improvement in disparities between white and black Americans between 1971 and 2002, with black adults reporting lower vegetable, potassium, and calcium intakes than whites in all survey years.[48]

Although the association between the overall contribution of ultra-processed foods to the diet and sociodemographic factors is unknown, some evidence of between-group differences in consumption of individual ultra-processed foods or beverages has been reported. For example, higher purchasing and consumption of SSBs have been reported among blacks compared to whites.[51-53] Cohen et al. found that lower-income and less-educated adults consumed more calories from cookies, candy, soda, and salty snacks compared to higher-income and more-educated adults.[54] Previous analysis of NHANES data reported that low-income adults exceeded recommended intakes for processed meats, sweets, and bakery desserts.[55] Pechey and colleagues used scanner-based purchase data from the UK and found lower SES was associated with higher purchases of sweet snacks and low-fiber bread products as well as a higher percentage of calories from less healthy food groups collectively.[56] Variation in diet within groups has also been observed, with studies finding that Puerto Ricans had higher consumption of SSBs and refined carbohydrates compared to Hispanics of other backgrounds.[57]

Given this evidence, further studies are needed to identify sociodemographic predictors of the collective contribution of ultra-processed foods and beverages to diet among Americans.

Conclusions about the nutritional quality of processed foods are discrepant

Leading health organizations and nutrition researchers caution that excessive consumption of processed food may promote excess energy intake, poor dietary quality, obesity, and related chronic diseases.[6,27,58-60] Potential mechanisms linking processed foods to these poor health outcomes include high content of sugar, refined carbohydrates, saturated and trans fatty acids, and sodium and high energy density.[6,12,17] Moreover, hyperpalatable processed foods have been linked to both neurobiological and behavioral features of addiction, including downregulation of striatal dopamine receptors, reward system dysfunction, and diminished control over eating.[61,62] Gearhardt and Brownell note that high consumption of hyperpalatable ultra-processed foods with elevated reward potency, such as ice cream, can shift hedonic set points and reduce the appeal of less processed foods previously considered rewarding, such as fruit.[62] In support of these hypothesized mechanisms, studies in Canada and Brazil reported that processed and ultra-processed products collectively were higher in saturated fat, added sugar, sodium, and energy density compared to less-processed foods and beverages.[14,21] In Nordic and central European countries, Slimani et al. found that industrially processed foods made greater contributions to saturated fat intakes relative to total energy.[17]

In addition, many scholars suggest that excessive intake of ultra-processed foods can displace less-processed fruits, vegetables, whole grains, and other more healthful items.[63-65] Mozaffarian and Ludwig emphasize that healthy dietary patterns are characterized by higher contributions of minimally processed foods and vegetable oils and lower contributions of highly processed foods or beverages.[65] Analyzing prospective data from 3 cohort studies, Mozaffarian et al. concluded that increases in consumption of processed foods and beverages were positively associated with weight gain, while increases in consumption of minimally processed foods such as fruit, vegetables, nuts, and whole grains were inversely associated with weight gain.[64]

Direct evidence has also linked the overall amount of ultra-processed foods in the diet to health outcomes. In a cross-sectional study among adolescents in Brazil, Tavares et al. found that higher consumption of ultra-processed foods was associated with higher prevalence of metabolic syndrome.[66] The association remained significant but was somewhat attenuated after adjustment for total energy intake; authors suggest that the relationship was mediated partly by the contribution of ultra-processed foods to higher total energy intake, but also through mechanisms independent of energy such as higher refined carbohydrate content.[66] Of note, even adolescents who had no components of the metabolic syndrome consumed 930 g/d of ultra-processed foods, indicating that some consumption of these products can be included in diets of more healthy individuals.[66] Among households in Brazil, Canella et al. recently found that households in the highest vs lowest quartile of ultra-processed food purchases had higher BMI and prevalence of obesity.[22] Interestingly, there was no association between the contribution of processed food purchases and mean BMI or obesity prevalence; the authors suggest that the absence of association was likely explained because, unlike ultra-processed foods, processed foods lacked factors that stimulate overconsumption such as hyperpalatability, large portion size, and convenience.[22] Additionally, a higher share of household expenditures on ultra-processed products was associated with increased prevalence of obesity among adults in Guatemala.[67]

Convenient RTE foods may promote overconsumption and lead to excess energy intake through mechanisms independent of processing level. Rapid eating rate decreases the length of oro-sensory exposure time, giving insufficient cues for satiation and lowering postprandial release of anorexigenic gut hormones such as peptide YY and glucagon-like peptide 1 (GLP 1); regular physiologic signals do not have sufficient time to occur and may lead to increased energy intake.[30-33] Furthermore, RTE foods encourage eating while attention is distracted by other activities, such as eating while watching television or driving, which shifts attention away from internal signals of satiation and results in impaired satiety responses, also potentially leading to increased energy intake.[27,31,34,68] Researchers emphasize that products requiring cooking (particularly less-processed vegetables or meat) allow the consumer to retain control over the choice and amount of sugar, fat, or salt added during preparation; on the contrary, RTE and RTH products are typically pre-sweetened or pre-flavored and remove this control.[69] Shifts toward prepared convenience foods can potentially transfer regulation of the nutrient densities of foods away from the consumer and to food manufacturers.[9,70] Evidence is limited, but suggests that decreased time spent in food preparation and higher consumption of convenience foods are associated with higher BMI, body fat, or obesity.[71-74]

However, in a recent study using cross-sectional 2003-2008 NHANES data, Eicher-Miller et al. conclude that processing level is not a major determinant of foods' nutrient contributions to the diet and cannot identify foods that are clearly "healthy" or "unhealthy," as assessed by the 2010 Dietary Guidelines for Americans nutrients to encourage and components to reduce.[19,75] The authors suggest that each processing category encompasses a wide variety of foods with great variability in nutrient content.[19] Their main argument is that minimally processed products include eggs and meat, and therefore this category makes a disproportionately large contribution to cholesterol intakes; further, authors suggest that processed RTE foods make heterogeneous contributions to nutrient intakes because both fortified and enriched breads and cereals are included as well as carbonated soft drinks, cookies, cakes, candy, juice drinks, and ice cream.[19] The authors suggest that, rather than focus on a food's level of processing, the nutrient content as well as frequency and amount consumed are more important considerations when identifying healthy diets.[19] In a subsequent scientific statement by the American Society for Nutrition, Weaver et al. cite this NHANES study and conclude that processed foods are nutritionally important to US diets.[37]

However, as noted by Moubarac et al., Weaver's conclusion seems inconsistent with study findings that minimally processed foods did not make disproportionate contributions to saturated fat intakes, but did make larger contributions to fiber, protein, vitamins A and D, calcium, and potassium intakes relative to their small contribution to energy intake; further, minimally processed foods made minor contributions to added sugar intakes.[19,20,37] In addition, these studies provide little evidence that RTE processed foods made both positive and negative contributions to nutrient intakes; processed foods made disproportionately high contributions to added sugar and sodium intakes, yet disproportionately low contributions to dietary fiber and micronutrient intakes.[19,37] Further research is needed to resolve the discrepant findings in these US studies compared to previous evidence of the poor nutrient profiles and increased obesity risk associated with ultra-processed foods.[14,19,21,22,37,66,67]

To address these gaps in the research literature, the current study proposes to develop a multidimensional classification system that separately categorizes products by level of processing and convenience. Explicit definitions and a comprehensive list of examples will be developed for each mutually exclusive category. To avoid adding to the overabundance of disparate definitions for processed food, we will retain the terminology and framework developed by Monteiro et al.[20,27] However, we will operationalize and adapt this system for the complexity of the US food supply and the more refined detail collected by food purchase data. We will apply this system to purchase data collected among a large, nationally representative cohort of US households. First, we will determine the contribution of ultra-processed and convenience foods and beverages to purchases overall and among foods, beverages, and food groups. Next, the association of ultra-processed and ready-to-eat foods with sociodemographic and economic household characteristics will be examined. Finally, we will determine whether ultra-processed or RTE household-level food purchases are more likely to exceed recommended maximum nutrient densities compared to less-processed or less-convenient foods.

Advantages of using barcode-specific product attributes and nutrition information

The longitudinal Homescan dataset, including store purchases linked to Nutrition Facts Panel data, will uniquely allow us to categorize processing and convenience level of foods using ingredient lists and detailed brand- and product-specific information.[76,77] Many scholars note that research examining the contributions of processed foods to diet and health is scarce because current dietary assessment methods collect insufficient details needed to classify each product by processing level; thus, a main strength of the Homescan data is collection of enhanced detail at the barcode level, which is essential to facilitate classification.[14,17,21,37] Another major advantage afforded by our dataset is inclusion of product-specific nutrient content, which may improve the accuracy of saturated fat, sugar, and sodium information.[17,78,79] Whereas self-reported dietary measures might be limited by reporting bias (underreporting), recall errors (inability to remember all foods), and difficulty with portion estimation, the Homescan data could potentially minimize these sources of measurement error by using objective scanning of barcodes.[4] Whereas 2-3 days of 24-hour recall may not capture usual intake, particularly for episodically consumed foods or foods consumed seasonally, recording of purchases throughout an entire year may better reflect usual purchasing patterns.[80] However, potential for underreporting certainly exists in the Homescan data, likely due to participant burden.[81] Further, we acknowledge that household-level data on purchases cannot be directly compared to individual-level dietary intake data.

This rich dataset includes sociodemographic characteristics at the individual and household level, including age, gender, race/ethnicity, education, income, and household size and composition. This detailed information uniquely enables us to study important determinants of processed food purchasing and to identify population subgroups that purchase high amounts of processed products. Understanding these race/ethnic and sociodemographic disparities is often hindered by differential bias in self-reported dietary intakes, lack of cultural tailoring of dietary assessment, and food composition tables that are not specific to preferred foods or recipes used by different groups.[44,56,82] Therefore, food purchasing data recorded by barcode scanning may be valuable in examining dietary disparities. Further, race/ethnicity, education, and income may be associated with diet through interrelated pathways; therefore, the large sample size within the Homescan panel can facilitate understanding of the independent relationship between each factor and diet.[82]

Chapter 3. Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households?

Overview

Although excessive consumption of processed food is considered a risk factor for obesity, processed foods' contribution to US diet and overall nutrient content have not been accurately assessed. The objective was to develop a multi-dimensional classification system for processed food, determine 2000-2012 trends in the contribution of processed and convenience foods to US diet, and compare nutrient profiles across levels of processing and convenience. We analyzed food and beverage store purchases for 157,142 households from the 2000-2012 Homescan longitudinal panel. Explicit classification criteria were developed to categorize each product by level of processing and separately by convenience. We classified >1.2 million items using product-level information and ingredient lists. Survey-weighted nationally representative trends in the contribution of processed and convenience products to food, beverage, and food group purchases were determined. Median saturated fat, sugar, and sodium densities and the likelihood of purchases exceeding recommended maximums for these components were cross-sectionally compared across levels of processing and convenience using quantile and logistic regression. Over ¾ of calories purchased by US households came from processed (15.9%) and ultra-processed (61.0%) foods and beverages in 2012 (939 kcal/d per capita). By convenience, ready-to-eat (68.1%) and ready-to-heat (15.2%) products supplied the majority of household calories, with a significant upward trend in ready-to-heat foods between 2000 and 2012. The adjusted proportion of household-level food purchases exceeding recommended maximums for saturated fat, sugar, and sodium densities simultaneously was significantly higher for ultra-processed (60.4%) and ready-to-eat (27.1%) food purchases compared to purchases of less-processed foods (5.6%) or foods requiring cooking (4.9%). The unshifting dominance of ultra-processed and ready-to-eat foods as major calorie contributors to US diet in combination with their higher saturated fat, sugar, and sodium content support the need for future studies examining the relationship of these products with dietary and health outcomes.

Introduction

Excessive consumption of processed food is considered a key risk factor for poor dietary quality, obesity, and related chronic diseases by leading health organizations and nutrition researchers.[6,27,58-60] Increases in obesity prevalence have paralleled shifts away from traditional diets toward processed foods, driven by rapid advances in processing technology and emergence of transnational food manufacturers with vast marketing reach.[4-6,8,12,61] Processed foods, such as soda, candy, processed meat, or prepared meals, now account for ¾ of global food sales totaling $3.2 trillion.[3] However, limited research specific to the US has quantified the nutritional contribution of processed food to diet. A main reason for this research gap is a lack of clear consistent definition for “processed food.”[20,21] Various definitions assess the degree of processing used by the food industry to turn unprocessed whole foods into manufactured products, and foods are classified into levels along a spectrum, ranging from minimally to ultra-processed.[17,19-21,29] High energy density and a hyperpalatable combination of fat, sugar, and sodium are key mechanisms potentially linking processed foods to diet outcomes.[6,12,17,62]

In addition, many processed foods are manufactured to be ready-to-eat (RTE), requiring no preparation before quick, easy consumption.[1] Convenience foods are hypothesized to encourage rapid eating rate and eating while distracted (e.g., watching television) and thus may disrupt physiological satiation/satiety signaling.[30-35] However, not all processed foods are RTE; for example, boxed macaroni-and-cheese requires preparation and cooking.[1] Thus, scholars recommend that separate analysis of processing and convenience is needed.[1,35]

Only one study has estimated processed food intake in the US; using cross-sectional 2003-2008 data, processed foods collectively provided 57.3% of total energy intake.[19,37] However, this study defined processed food using a classification system created for consumer use, and a recent systematic review concluded this system was “incomplete and unclear.”[19,20,29] Processing and convenience were conflated rather than treated as separate dimensions. Thus, the amount of processed and convenience food in the US diet has not been accurately assessed.

Moreover, conclusions about the nutritional quality of processed foods are discrepant. US authors recently reported that processed foods are nutritionally important to American diets, and all categories defined by processing level contribute both nutrients to encourage and to limit.[19,37]

On the contrary, other studies found that processed and ultra-processed foods were collectively higher in added sugar, saturated fat, sodium, and energy density than less-processed products.[14,21] To understand these inconsistent findings, direct comparisons of the nutrient content of US foods by processing levels using product-specific data are needed.

To address these research gaps, this study aimed to develop a classification system that separates processing and convenience; to determine trends from 2000-2012 in the calorie contribution of processed and convenience foods in a nationally representative longitudinal panel of US households; and to compare nutrient densities across levels of processing or convenience.

Subjects and Methods

This study used data from the 2000-2012 Nielsen Homescan Panel, an ongoing longitudinal sample of US households who use barcode scanners to record all food and beverage purchases brought into the home.[83] Products purchased from supermarkets and grocery, drug, mass-merchandise, club, supercenter, and convenience stores were recorded for ≥10 months/year for up to 13 years (mean 4.2 y). Each year, 34,000 to 62,000 households were sampled from 76 markets and weighted to be nationally representative. Household size and demographic characteristics were collected by questionnaire. We excluded purchases during annual quarters deemed unreliable by study investigators and year-level observations including >1 unreliable quarter (2.2%) to ensure that purchases fully captured usual diet.[76,77] This study included 656,184 year level observations from 157,142 unique households (435,949 individuals). This de-identified secondary data analysis was exempt from institutional review board approval.

Dietary data and food grouping:

For each food or beverage, product weight (grams) and detailed product- and brand-specific attributes were provided, including characteristics such as flavor (plain or blueberry yogurt), product type (instant or regular oatmeal), or salt content (regular or low-sodium). Each barcode was linked to a corresponding Nutrition Facts Panel from sources including the Mintel Global New Products Database that provide calorie, saturated fat, total sugar, and sodium content as well as information appearing on the product's package and the product's ingredient list.[84] Methodology for this linking process has been described in detail elsewhere.[76,77]

Nielsen organized products into 623 "modules" that aggregate similar foods ("canned fruit – pears," "seafood – refrigerated") but also reflect placement of products within grocery stores ("fruit – dried or snacks," "fruit drinks & juices – cranberry"). Because most modules do not reflect nutritional content or processing level, all products were re-organized at the barcode-level (described below) into beverages and 10 basic food groups: grain products, dairy products, fruits, vegetables, starchy vegetables, nuts/legumes, meat/meat dishes/eggs, sweeteners/sweets, fats/oil, and other (**Supplemental Table 3.1**). A second specific food grouping system (45 groups) was created to reflect nutritional content and consumption patterns based on previous work.[85]

Processing and convenience classification system:

A classification system was developed for classifying foods and beverages into 4 categories of food processing (**Table 3.1**) and for separately classifying products into 3 categories of convenience (**Table 3.2**). Each category was explicitly defined, and criteria and decision rules for classification were established. A comprehensive list of examples within each category of processing and each category of convenience was created and organized by basic food group.

Processing:

To assess processing, 4 mutually exclusive categories were defined based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes (Table 3.1).[21] Agricultural methods, such as plant cultivation, and further processing by the consumer after purchase, such as cooking raw meat, were not considered. Our system was guided by work of Monteiro et al. but with important modifications.[27] Because that system was developed in Brazil for household expenditure surveys with <200 foods, we adapted category definitions and example foods for the complexity of the US food supply and enhanced detail of dietary recall or purchase data.[27] For example, because preservation (by canning) and flavoring are separate processing unit operations with separate purposes, we differentially classified fruit canned in natural juice vs in syrup and vegetables canned with or without added salt. Further, we distinguish brown vs white rice, whole-grain vs refined-grain flour, and bread products made with whole-grain flour and no added sweetener or fat vs refined bread products. Otherwise, our categories are consistent with those of Monteiro et al., a system that was top-rated among all global classification methods.[20]

“Minimally processed” is the lowest category and includes single ingredient foods and beverages that have undergone no or very slight modifications that do not change the inherent properties of the food as found in its raw or natural unprocessed form. These are generally single foods that may have components removed (e.g., skin from poultry or fat skimmed from milk), but nothing added. Examples include fresh fruits, vegetables, milk, eggs, and unseasoned meat.

“Moderately processed” products have been processed but remain as single foods. They are divided into 2 subcategories. “Moderately processed ingredients,” including sugar, oil, or whole-grain flour, are isolated food components extracted or purified from minimally processed foods by physical or chemical processes that change the inherent properties of the food.[27] Products “moderately processed for preservation or pre-cooking” are minimally processed foods modified by preservation methods such as canning, milling of grain to remove germ and thus reduce spoilage, concentrating fruit juice to aid storage and transport, fermentation of milk to produce yogurt, or pre-cooking grains. Examples are refined-grain flour or pasta, white or instant rice, and fruit or vegetables canned with no additional flavoring steps.

“Processed” products are divided into 2 subcategories. Products “processed for flavor” are defined as minimally or moderately processed foods with added moderately processed ingredients (sweeteners, salt, flavors, or fats), combined for the purpose of enhancing flavor but not changing the inherent properties of the food. They are primarily composed of minimally processed whole foods. Examples are salted nuts, fruit canned in syrup, or vegetables canned with added salt. “Processed grain products” were defined as whole-grain breads, tortillas, crackers, or breakfast cereals made from whole-grain flour with no added sweeteners or fat.

“Ultra-processed” products are multi-component mixtures of combined ingredients, processed to the extent that they no longer resemble their basic component foods as found in nature in unprocessed form. They are also separated into 2 subcategories. “Ultra-processed ingredients,” such as ketchup, margarine, mayonnaise, and jarred pasta sauce, are ultra-processed products typically consumed as condiments, dips, sauces, toppings, or ingredients in mixed dishes. “Ultra-processed products not consumed as additions” include white bread, sugar-sweetened beverages (SSBs), cookies, salty snacks, candy, and pre-prepared mixed dishes.

Convenience:

To separately measure convenience, 3 mutually exclusive categories were defined based on the amount of food preparation required by the consumer before a product can be eaten (Table 3.2). Convenience considers whether a product can consumed in its form as purchased (i.e., frozen, powdered mix), the length of active preparation time required, and the amount of culinary skill, energy, and attention the consumer must put forth to prepare a product for consumption.[1]

Products requiring “cooking and/or preparation” are least convenient and not typically consumed as purchased. These products require significant input of the consumer’s time, culinary skill, energy, or attention to cook or prepare before being eaten or drunk. This may include boiling dry pasta; cooking raw meat or eggs; chopping whole vegetables or fruit (heads of lettuce, onions, or whole melon); cooking fresh potatoes or dried beans; baking grain products (flour); or multi-step creation of mixed dishes (cake mixes or boxed pasta dinners).

Products classified as "ready-to-heat (RTH) or requiring minimal preparation" are also not consumed as purchased, but only a small amount of the consumer's time or effort and no culinary skill or attention are needed during their preparation (e.g., heating by microwave, oven, or toaster; thawing; or adding water). Examples include frozen dinners or pizza, frozen waffles, canned soup, hot dogs, instant oatmeal, canned or frozen vegetables, and powdered drink mixes.

"Ready-to-eat" products are highly convenient and can be consumed immediately with no preparation.[35] Examples include bread, pre-made cookies, salty snacks, candy, canned fruit, most fresh fruit, baby carrots, bagged salad, and ready-to-drink beverages. To ensure mutually exclusive classification of convenience, products that can be prepared in alternate ways were categorized based on the most minimal preparation typically required. For example, cheese was classified as RTE because it can be eaten as purchased, although it could be used in cooking.

Classification at the barcode-level:

Classification of each product into categories for processing, convenience, and food groups was conducted at the barcode-level using the Perl-based pattern matching syntax "regular expressions" and implemented within SAS 9.3 (SAS Institute Inc., Cary, NC). This technique was used to search ingredient lists, package information, and product attributes for keywords indicative of processing or convenience level. **Supplemental Material 3.1** provides a detailed description of this methodology. Programming code assigned each of 1,230,536 unique food or beverage barcodes to a single category for level of processing and separately to a single category for level of convenience. Accuracy of classification was manually reviewed for over 615,000 products. A detailed list of food and beverage products and their classification by processing, convenience, and food grouping is available from the authors upon request.

Statistical analyses:

Trends analysis was conducted using survey commands in Stata 13 (Stata Corp, College Station, TX) to generate nationally representative estimates incorporating Nielsen-provided sampling weights while accounting for repeated observations and market-level clustering. The contribution of each processing or convenience category was calculated as a percentage of total calories purchased, and additionally as a percentage of calories from foods, beverages, or basic food groups. Survey-weighted mean per capita and percent energy from each processing or convenience category were determined across all households by year. Regression models were used to test linear time trends. To identify top food contributors to each category of processing or convenience, specific food groups were ranked by mean per capita calories in 2000 and 2012.

To determine whether processing or convenience was associated with the nutritional content of food purchases in 2012, we focused on recommendations in the Dietary Guidelines for Americans, 2010 for food components to reduce because high saturated fat, sugar, and sodium is the primary mechanism hypothesized to link processing with health outcomes.[6,62,75] For a household's purchases within each category of processing, we calculated saturated fat (% kcal), total sugar (% kcal), and sodium (mg/1000 kcal) densities. We then determined whether household-level purchases in each category of processing exceeded the recommended 10% kcal from saturated fat, 15% kcal from sugar (the maximum allowance for calories from solid fat and added sugars), 2400 mg sodium per 2000 kcal, or exceeded all recommendations simultaneously.[75,86] Nutrient densities vary greatly for foods vs beverages, so we focus upon foods because recommendations specific for beverages were not available. Because moderately processed ingredients are food components not consumed alone but in combination with minimally or moderately processed foods, these categories were grouped as “less-processed.”[21] Median nutrient densities and the percentage of household-level purchases exceeding recommendations were compared across processing categories using Wald tests.

These comparisons may be confounded because less-processed food purchases include more fruits and vegetables than ultra-processed purchases. Therefore, regression models were used to control for this potential confounding. Using household-level purchases within each processing category as the unit of analysis, nutrient density was regressed on dummy variables for level of processing, while adjusting for the contribution of each basic food group (% kcal) to purchases in that processing category. Because nutrient density distributions were right-skewed, quantile regression and Stata’s margins command were used to find the weighted adjusted median nutrient density for purchases in each category of processing. To determine whether processing was associated with higher likelihood that household purchases exceeded recommendations for nutrient densities, survey-weighted logistic regression was used with the binary outcome of exceeding the recommended limit. Margins commands were used to predict the probability of exceeding recommended maximums for each level of processing. This approach was repeated for categories of convenience. For all analyses, significance was set at $P<0.001$ to adjust for multiple comparisons and take into account large sample size.

Results

Sociodemographic characteristics of our sample are presented in **Supplemental Table 3.2**. Over ¾ of calories purchased by US households from retail stores in 2012 came from processed (15.9%) and ultra-processed (61.0%) foods and beverages (939 kcal/d per capita, **Figure 3.1A**). Top calorie sources among ultra-processed products included refined breads; grain-based desserts; SSBs; processed salty snacks; candy; RTE cereal; ice cream; and mayonnaise, salad dressing, pasta sauce, ketchup, margarine, and shortening (**Supplemental Table 3.3**). Peanut butter and salted nuts; potato chips and popcorn; cheese; and salted butter were the largest calorie contributors among products processed for flavor. The percent of total calories from minimally and moderately processed products among barcoded store purchases was <25%. Top minimally processed products were plain milk, eggs, fresh potatoes, and fresh or plain dried fruit.

Considering foods and beverages separately, the contribution of ultra-processed products was greater for foods (62.5% of food calories) than for beverages (47.4% of beverage calories). By volume, the pattern was similar (**Supplemental Figure 3.1A**). Although purchases of ultra-processed foods remained stable between 2000 and 2012, decreases in refined breads, grain-based desserts, candy, and ice cream were balanced by increases in frozen grain-, pasta-, or rice-based dishes and processed meat. The significant trend toward increases in minimally processed food purchases across this time period was largely attributable to fresh fruit. Increased purchases of cheese and sweetened/flavored yogurt drove a significant rise in the contribution of foods processed for flavor. Moderately processed foods (mainly sugar and refined-grain flour) and ultra-processed ingredients (margarine and shortening) declined. Calories from minimally processed beverage purchases decreased significantly between 2000 and 2012, mainly due to large declines in calories from plain milk. Shifts away from unsweetened fruit juice from-concentrate (moderately processed) and toward pre-sweetened teas and fruit juices (processed) were significant. Although calories from ultra-processed beverages dropped across time (-22 kcal/d) as SSB purchases declined, their relative contribution did not change significantly.

Alternately, classification by convenience determined that RTE foods and beverages contributed over $^{2}/_{3}$ of calories purchased in 2012 (**Figure 3.1B**). Top RTE calorie contributors were salty snacks, breads, grain-based desserts, milk, sugar and syrups, SSBs, and candy (**Supplemental Table 3.4**). Among RTH products, main calorie sources included frozen grain-based dishes; RTH pancakes, biscuits, or rolls; soup; pre-prepared or instant pasta/rice dishes; and pre-cooked hot dogs and sausages. Cooking oil and shortening, flour, dry pasta, eggs, grain-based dessert mixes, fresh potatoes, pancake or biscuit mixes, and boxed macaroni-and-cheese were top calorie contributors requiring cooking or preparation. Among foods, RTH products significantly increased between 2000 (14.1%) and 2012 (16.5%), while RTE foods declined. Among beverages, ready-to-drink products provided almost all calories (>90%).

By food group, the majority of grain product purchases were ultra-processed (**Figure 3.2A**). Purchases of minimally processed (brown rice and plain whole-grain hot cereals) and processed grain products (whole-grain breads or cereals with no added sweeteners or fats) were low (≤2%). Most grain products were purchased RTE (60%), but significant shifts toward RTH products occurred (**Figure 3.2B**). Ultra-processed products provided the majority of calories among dairy products across the 13-year period, despite significant declines in ice cream and significant upward trends in moderately processed foods (cheese and sweetened yogurt). Almost all dairy products were RTE. Among fats and oils, ultra-processed ingredients (margarine, mayonnaise, salad dressing, and shortening) were the main calorie contributors, but declined across time as moderately processed (oil) and processed products (salted butter) increased. About $^{2}/_{3}$ of fats/oils were purchased in RTE form. Contributions of minimally processed products were greater among fruits, vegetables, starchy vegetables, and meat than for other food groups (**Supplemental Figures 3.2A** and **3.3A**). RTE foods made smaller contributions to meat, vegetables, and starchy vegetables than to other food groups (**Supplemental Figures 3.2B** and **3.3B**).

In 2012, median saturated fat, total sugar, and sodium densities were higher for ultra-processed food purchases compared to less-processed food purchases and higher for RTE food purchases compared to foods requiring cooking and/or preparation, holding constant the contributions of fruit, vegetables, and all food groups to calories purchased (**Table 3.3**). After adjustment, recommended limits for saturated fat, sugar, or sodium densities were exceeded by 94.7%, 94.5%, and 96.3% of household-level ultra-processed food purchases, respectively (**Figure 3.3**). Independent of the smaller amount of fruits and vegetables among ultra-processed food purchases, the percent of household-level ultra-processed food purchases that exceeded all 3 recommendations (60.4%) was significantly higher than the percent of less-processed food purchases with the combination of high fat, sugar, and salt (5.6%). By convenience, 84.5%, 67.9%, and 92.4% of household-level RTE food purchases exceeded limits for saturated fat, sugar, and sodium, respectively. The adjusted proportion of household-level food purchases that exceeded all limits simultaneously was significantly higher for RTE foods (27.1%) compared to foods requiring cooking/preparation (4.9%). Conclusions did not differ in sensitivity analysis examining different recommended cutpoints for sugar (10% or 25% kcal) or total purchases.

Discussion

To the best of our knowledge, this study is the first to determine trends in the calorie contribution of processed and convenience foods to US household purchases and to compare the saturated fat, sugar, and sodium content of purchases by level of processing and convenience. In this nationally representative longitudinal sample of US households, processed and ultra-processed foods dominated purchasing patterns by collectively providing over ¾ of calories. By level of convenience, over 80% of calories purchased were RTE or RTH products. These patterns were remarkably resistant to change between 2000 and 2012. Moreover, household-level ultra-processed food purchases and RTE food purchases were significantly more likely to simultaneously exceed recommended maximums for saturated fat, sugar, and sodium densities compared to purchases of less-processed foods or foods requiring cooking. Using these criteria, our results suggest that ultra-processed foods collectively have a poor nutritional profile.

In our study, the calorie contributions of processed (15.9%) and ultra-processed (61.0%) food and beverage purchases were substantial. Our results are consistent with recent findings that processed and ultra-processed products collectively dominate diets in Canada (61.7%) and the UK (63.4%); importantly, these studies classified level of processing using definitions similar to ours.[14,15] Only one prior study was US-based; using 2003-2008 NHANES data, processed foods as defined by the International Food Information Council Foundation collectively provided 80.2% of calories in store-bought foods (57.3% total energy).[19] However, direct comparison with our results is difficult because of differences in how processed foods were defined. Their overall estimate includes foods we classified as minimally (frozen vegetables or dried fruit) or moderately processed (sugar), but an overall estimate of ultra-processed foods was not provided. Their study used a classification system rated as low in quality by a recent systematic review, which noted a major limitation that many foods were omitted.[19,20] Of note, oil and butter, large sources of energy (~67 kcal/d) in our study, were not assigned to a level of processing.[19] Even so, our studies agree that processed foods provide the majority of calories in the US diet.

The amount of convenience food in the US diet is largely unknown, as convenience is rarely considered separately from processing.[1] We revealed that the majority of purchases by US households were RTE (68.1%) and RTH (15.2%) products. Our results are in line with the minimal time Americans spend in home food preparation (<1 hr/d) and increases in eating while distracted by television or work, which may promote overconsumption of RTE food.[34,87]

Trends analysis found remarkable stability in the calorie contribution of ultra-processed foods from 2000 to 2012. Similar patterns of ultra-processed food purchases plateauing at high levels were reported in Canada and other high-income countries.[12,16,18] By examining trends within food groups and by convenience, we uniquely revealed shifts occurring *within* the ultra-processed group. Significant upward trends in overall RTH food purchases were driven by increases in ultra-processed RTH grain-, pasta-, or rice-based dishes. In view of recent declines in fast food and food away-from-home, our findings suggest that ultra-processed RTH prepared meals may be convenient at-home replacements for dining out.[88,89] Encouraging decreases in ultra-processed RTE grain-based desserts, candy, ice cream, and margarine were also found.

Using barcode-specific nutrition information for >1 million products, we found that household purchases of ultra-processed and RTE foods had higher adjusted median saturated fat, sugar, and sodium densities and were significantly more likely to exceed recommended limits for all 3 components in combination compared to less-processed or less-convenient foods. These conclusions were robust to adjustment for potential confounding by food group distribution, suggesting that the more favorable nutrient content of minimally processed foods occurs not simply because this category includes more fruits and vegetables. Our US findings are consistent with studies abroad showing that a standardized food basket with identical proportions of fruit, vegetables, and other food groups was higher in saturated fat, added sugar, and sodium when composed of only processed and ultra-processed foods vs only less-processed foods.[14,21]

However, the US study cited above and a recent report concluded that processing is *not* a major determinant of a food's nutrient contributions to diet.[19,37] The study suggests that no processing category contains foods that are uniformly "healthy" or "unhealthy;" for example, minimally processed foods, including eggs and meat, contributed greatly to dietary cholesterol.[19] Yet, this category did *not* contribute disproportionately to saturated fat and made small contributions to added sugar and sodium.[19] Processed foods collectively made greater relative contributions to added sugar and sodium intakes.[19,37] Despite its conclusion, this study is consistent with our finding that ultra-processed foods are high in food components to limit.

Mozaffarian et al. propose that processing should be considered as a potentially relevant dietary metric that may be associated with obesity.[64,65] Scholars suggest that the shortage of research on this topic arises because current dietary assessment methods collect insufficient details for categorizing foods based on processing level.[14,17] Our classification system provides criteria for defining processed foods that could help future studies target data collection to relevant food details in key food groups; for example, increases in ultra-processed RTH foods suggest that a key detail to assess may be whether mixed dishes are homemade vs pre-prepared.

A main limitation of our data is that participants do not record whether all purchases were consumed; however, food waste is likely greater for perishable minimally processed items and may lead to underestimation of ultra-processed products' contribution.[90] Products without barcodes or Nutrition Facts Panels, including minimally processed items (unpackaged fresh fruit, vegetables, or meat) as well as ultra-processed items (deli meat, bakery items, and store-prepared RTE/RTH foods), were not captured. Further, food away-from-home was not reported. Thus, our findings pertain only to purchases of packaged goods, not total diet. Added sugar content is not required on nutrition labels, so total sugar was used; however, studies found this substitution is reasonable for nutrient profiling.[91] We could not examine specific saturated fatty acids, which may have differential effects on cardiometabolic risk, or *trans* fat; but, to take into consideration that saturated fats have varying effects depending upon the replacement nutrient, we evaluated compliance with saturated fat and sugar recommendations simultaneously.[92-94] Classification does not reflect benefits of processed foods to food or nutrition security, and refinement may be needed to isolate ultra-processed foods detrimental to health.[37] Estimates were weighted to be nationally representative, but participants may differ in unobservable characteristics not incorporated into sampling weights.[95] Validation studies found the accuracy of the Homescan data was comparable to other widely used economic datasets, but misreporting is possible.[81]

A major strength of our study is use of product-specific ingredients and nutrient content, which may improve accuracy and classification.[17,78,79] Scanning of barcodes linked to ingredient lists enabled us to classify products without requiring participants' recall or awareness of product ingredients. Purchases were collected year-round, better reflecting usual diet. We uniquely report results for foods separately from beverages and within food groups.

In conclusion, we provide novel evidence that ultra-processed and RTE foods dominated US purchasing patterns over the past 15 years and have a combination of high saturated fat, sugar, and sodium consistent with hypothesized mechanisms linking these products to excess energy intake.[6,12,62] Our findings support the need for future studies to determine whether increased intake of ultra-processed RTE foods is associated with poor health outcomes. The classification system presented here may provide the framework needed to facilitate such studies.

Supplemental Material 3.1. Classification at the Barcode Level

Classification of each product into categories for processing, convenience, and food groups was conducted at the barcode-level using the Perl-based pattern matching syntax “regular expressions” and implemented within SAS (SAS version 9.3, SAS Institute Inc, Cary, NC). This technique was used to search ingredient lists, package information, and product attributes for keywords indicative of processing or convenience level. For example, SAS macros were developed to search ingredient lists for terms indicating the presence of added sweeteners, salt, flavors, fats, or oils; within Nielsen food group “modules” such as “canned fruit – pears,” these macros were used to identify sweetened and/or flavored canned pears and assign processing and convenience level accordingly. This technique was also used to disaggregate modules containing heterogeneous products; for example, “fruit – dried or snacks” was separated into unsweetened dried fruit, sweetened dried fruit, or fruit snacks using searches of ingredient lists and product descriptions for terms distinguishing these disparate products. Such macros were also developed to identify the main ingredient of mixed dishes (i.e., pasta, vegetable, starchy vegetable) and classify barcodes into food groups accordingly. Programming code was used to assign each of 1,230,536 unique food or beverage barcodes to a single category for level of processing and separately to a single category for level of convenience. Additionally, each barcode was assigned to a single basic food group and to a single specific food group. Accuracy of classification was manually reviewed for >615,000 products. A detailed list of product classification into processing, convenience, and food groupings is available from the authors upon request.

Tables and Figures

Table 3.1. Classification system for categorizing foods and beverages based on extent and purpose of processing[1]

Category	Definition	Food groups[2]	Examples
<u>MINIMAL</u>			
Minimally processed	Single ingredient foods with no or very slight modifications that do not change inherent properties of the food as found in its natural form	Beverages	Milk (fresh plain[3]), coffee (whole/ground beans), water (bottled plain), tea (leaves/bags)
		Fruit, vegetables, legumes	Fresh, frozen, or dried plain fruit, vegetables, or legumes; plain nuts
		Meat/meat dishes/eggs	Eggs; unseasoned[4] meat (refrigerated or frozen)
		Grain products	Whole-grain plain hot cereal, brown rice, popcorn kernels
		Dairy products	Cream
		Fats/oils, sweets, other	Honey, herbs, spices, pepper
<u>MODERATE</u>			
Moderately processed ingredients	Isolated food components obtained by extraction or purification using physical or chemical processes that change inherent properties of the food	Beverages	Unsweetened[5] fruit juice not-from-concentrate
		Fruit, vegetables, legumes	N/A
		Meat/meat dishes/eggs	Egg whites
		Grain products	Whole-grain[6] flour, whole-grain pasta
		Dairy products	N/A
		Fats/oils, sweets, other	Oil, unsalted butter, sugar, pure maple syrup, salt
Moderately processed for preservation or pre-cooking	Minimally processed foods modified by physical or chemical processes for the purpose of preservation or pre-cooking but remaining as single ingredients	Beverages	Unsweetened fruit juice from-concentrate or frozen concentrate, dry milk, instant coffee
		Fruit, vegetables, legumes	Unsweetened/unflavored canned fruit, vegetables, or legumes; unsweetened/unsalted peanut butter
		Meat/meat dishes/eggs	Unseasoned canned meat
		Grain products	Refined-grain pasta, refined-grain flour, white rice, instant rice, plain refined-grain hot cereal
		Dairy products	Sour cream, plain yogurt, evaporated milk
		Fats/oils, sweets, other	N/A
<u>PROCESSED</u>			
Processed for flavor	Minimally or moderately processed foods with added moderately processed ingredients, combined for the purpose of enhancing flavor but not changing the inherent	Beverages	Sweetened/flavored[7] fruit or vegetable juice, tea, or soy milk; chocolate milk; cocoa mix
		Fruit, vegetables, legumes	Sweetened/flavored canned, dried, refrigerated, or frozen fruit, vegetables, or legumes; jam; potato chips; frozen French fries; salted peanut butter; nuts with salt or oil
		Meat/meat dishes/eggs	Seasoned refrigerated, frozen, or canned meat; smoked or cured bacon, ham, or

Category	Definition	Food groups[2]	Examples
	properties of the food		seafood
		Grain products	Sweetened/flavored hot cereal, flavored pasta, flavored popcorn (microwaveable or pre-popped)
		Dairy products	Cheese, sweetened/flavored yogurt, sweetened condensed milk, whipped cream
		Fats/oils, sweets, other	Salted butter, flavored oil, seasoning salts
Processed grain products	Grain products made from whole-grain flour with water, salt, and/or yeast	Grain products	Whole-grain bread, tortillas, crackers, or RTE cereals with no added sugar or fat
ULTRA-PROCESSED			
Ultra-processed ingredients	Multi-component mixtures of combined ingredients not resembling their basic components and consumed as additions (condiments, dips, sauces, toppings, or ingredients in mixed dishes)	Beverages	N/A
		Fruit, vegetables, legumes	Tomato sauce, salsa, hummus, jelly
		Meat/meat dishes/eggs	N/A
		Grain products	Bread crumbs/breading with refined grains or added sugar/fat
		Dairy products	Creamer, whipped topping, dairy-based chip/veggie dip, cheese dip/queso, alfredo sauce
		Fats/oils, sweets, other	Margarine; mayonnaise; salad dressing; shortening; pancake syrup; artificial sweetener; baking chocolate; icing; ketchup, barbecue sauce, marinades, and other condiments; sauce/seasoning mixes
Ultra-processed products not consumed as additions	Multi-component mixtures of combined ingredients not resembling their basic components and not typically consumed as additions	Beverages	Soda, alcohol, fruit drinks[8], sports drinks, energy drinks, flavored waters, coffee beverages
		Fruit, vegetables, legumes	Fruit snacks; gelatin fruit salads; chocolate- or yogurt-covered dried fruit or nuts; vegetable-based soups; frozen vegetables in sauce; onion rings; entrée garden salads; re-structured potato chips; tater tots, hash brown patties, re-formed French fries; RTH or instant potato dishes (mashed potatoes, stuffed baked potatoes); RTE potato salad; canned baked beans or beans with pork
		Meat/meat dishes/eggs	Sausage; hot dogs; pressed/formed lunchmeats (bologna, salami, some turkey) or ham; Spam; RTH meat dishes (meat loaf, crab cakes, buffalo wings, pot roast, barbecue); meat-based frozen meals (Salisbury steak); breaded meat (chicken nuggets, fish sticks); meat-based soups
		Grain products	Bread, tortillas, rolls, bagels, or RTE breakfast cereals with refined grains or added sugar/fat; pancakes, waffles, or biscuits (RTH, ready-to-bake, mixes); grain-based desserts (cookies, cake, pie, pastries; RTE, ready-to-bake, mixes); processed salty snacks (crackers, pretzels, tortilla chips, cheese puffs); frozen pizza; RTH or RTE grain-based dishes (burritos, sandwiches, pot pies); frozen or canned pasta dishes (lasagna, ravioli, spaghetti and meatballs); pasta- or rice-based frozen meals; boxed macaroni-and-cheese; instant rice/pasta dish mixes;

Category	Definition	Food groups[2]	Examples
			noodle- or rice-based soups; stuffing mix
		Dairy products	Ice cream, frozen yogurt, pudding (RTE and mixes), processed cheese, cheesecake
		Fats/oils, sweets, other	Candy, chocolate, popsicles, sorbet, gelatin (RTE and mixes), broth, bouillon

[1] Mutually exclusive categories of processing were defined based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes. Food processing was considered separately from product convenience. RTE, ready-to-eat; RTH, ready-to-heat.

[2] Food groups were defined broadly to classify all products into beverages or 10 mutually exclusive food groups. "Fruit, vegetables, and legumes" includes fruit/fruit products, vegetables/vegetable products, starchy vegetables/starchy vegetable products, and nuts/legumes. "Meat" includes beef, pork, poultry, and seafood.

[3, 4, 5] "Plain," "unseasoned," and "unsweetened" indicate that the product contains no added sweeteners (natural or artificial), salt, flavors, fats, or oils.

[6] Whole-grain products were defined by the 2010 Dietary Guidelines for Americans criteria of including bran, germ, and endosperm and primarily containing "whole-grain" wheat, rye, oats, corn, barley, or other grains labeled as "whole"; brown rice; buckwheat; bulgur; millet; oatmeal; popcorn; quinoa; or rolled oats.

[7] "Sweetened/flavored" indicates that the product contains added sweeteners (natural or artificial), salt, flavors, fats and/or oils.

[8] Fruit drinks are defined as beverages primarily composed of sugar or sweetener (as 1st or 2nd ingredients) with fruit juice or fruit juice concentrate as a lesser ingredient.

Table 3.2. Classification system for categorizing foods and beverages based on convenience and the amount of preparation required by the consumer prior to food consumption[1]

Category	Definition	Food groups[2]	Examples
Cooking and/or preparation	Requires significant input of consumer's time, culinary skill, energy, or attention to cook/prepare before consumption; not typically consumed as purchased	Beverages	Coffee (whole/ground beans), tea (leaves/bags)
		Fruit, vegetables, legumes	Fresh fruit or vegetables requiring preparation (heads of lettuce, onions, broccoli, whole melon) or cooking (potatoes); canned tomatoes; dried beans
		Meat/meat dishes/eggs	Eggs, uncooked meat, uncooked sausage or bacon
		Grain products	Flour, dry pasta or rice, pasta/rice dish mixes (boxed macaroni-and-cheese), grain-based dessert mixes, pancake or biscuit mixes
		Dairy products	Whipping cream, evaporated milk, pudding mixes, sweetened condensed milk
		Fats/oils, sweets, other	Oil, shortening, baking chocolate, gelatin mixes, cooking sauces, herbs and spices, sauce/seasoning mixes
Ready-to-heat (RTH) or minimal preparation	Requires a small amount of consumer's time or effort and no culinary skill or attention (such as heating, microwaving, thawing, or adding water); not typically consumed as purchased	Beverages	Powdered mixes for sports drinks or flavored waters; instant tea mixes; frozen fruit juice concentrate; cocoa or coffee beverage mixes; dry milk; instant coffee
		Fruit, vegetables, legumes	Frozen or canned vegetables or legumes; frozen fruit; frozen French fries, tater tots, or hash brown patties; frozen potato dishes (mashed potatoes, stuffed baked potatoes); frozen meals with potatoes as main ingredient; instant mashed potatoes or potato mixes; vegetable, potato, or corn-based soups; frozen vegetables, potatoes, or corn in sauce; onion rings; tomato sauce; canned baked beans or beans with pork or hot dogs
		Meat/meat dishes/eggs	Pre-cooked sausage; hot dogs; frozen or refrigerated meat dishes (meat loaf, crab cakes, pot roast, barbecue); meat-based frozen meals (Salisbury steak); breaded meat (chicken nuggets, fish sticks); meat-based soups
		Grain products	Frozen pizza; frozen grain-based dishes (burritos, sandwiches, pot pies); frozen pasta dishes (lasagna, ravioli) or frozen meals (spaghetti and meatballs, macaroni and cheese); frozen pasta- or rice-based dinners; noodle- or rice-based soups; frozen pancakes or waffles; microwaveable popcorn; hot cereals; frozen cakes or pies; ready-to-bake cookies, biscuits, or rolls; instant rice or pasta dish mixes; canned ravioli or other pasta dishes; instant rice; stuffing mixes
		Dairy products	Frozen whipped topping, alfredo sauce, cheese dip/queso
		Fats/oils, sweets, other	Ready-to-spread icing; broth and bouillon; pre-made gravy or sauces
Ready-to-eat (RTE)	Can be consumed immediately with no preparation	Beverages	Milk, soda, alcohol, fruit drinks, fruit or vegetable juice, ready-to-drink tea, sports drinks, energy drinks, flavored waters, bottled water, soy milk, ready-to-drink coffee beverages
		Fruit, vegetables, legumes	Fresh, canned, or dried fruit; fruit snacks; jam; jelly; fresh/refrigerated RTE vegetables (pre-cut bagged salad, baby carrots); entrée garden salads; olives, pickles; salsa; potato chips; potato salad; peanut butter; nuts
		Meat/meat dishes/eggs	Lunch meat; canned meat or processed meat (Spam); summer sausage; beef jerky;

Category	Definition	Food groups[2]	Examples
			seafood or chicken salad
		Grain products	RTE cookies, doughnuts, pastries, and other grain-based desserts; salty snacks (potato chips, crackers, pretzels, tortilla chips, corn chips, pre-popped popcorn); RTE bread, tortillas, rolls, bagels; RTE cereal
		Dairy products	Cheese, ice cream, yogurt, creamer, cream, sour cream, dairy-based dip, RTE pudding, whipped cream
		Fats/oils, sweets, other	Margarine, mayonnaise, butter, salad dressing, candy, sugar, pancake syrup, honey, popsicles, sorbet, dessert syrups, artificial sweeteners, RTE gelatin, ketchup, barbecue sauce, and other condiments

[1] Mutually exclusive categories of convenience were defined based on the amount of food preparation required of the consumer before a product can be eaten. Products that can be prepared in alternate ways were categorized on the most minimal preparation typically required. Convenience was considered separately from food processing. RTE, ready-to-eat; RTH, ready-to-heat.

[2] Food groups were defined broadly to classify all products into beverages or 10 mutually exclusive food groups. “Fruit, vegetables, and legumes” includes fruit/fruit products, vegetables/vegetable products, starchy vegetables/starchy vegetable products, and nuts/legumes. “Meat” includes beef, pork, poultry, and seafood.

Table 3.3. Median nutrient density of household-level food purchases by level of processing and convenience, Homescan 2012[1]

	Processing[2]			Convenience[3]		
	Less-processed (minimal/moderate)	Processed	Ultra-processed	Requires cooking/ preparation	Ready-to-heat (RTH)	Ready-to-eat (RTE)
Saturated fat (% kcal) [4]						
Median (IQR)	8.0 (5.4, 11.4)	17.8 (13.4, 23.6)*	11.9 (10.3, 13.5)*	9.7 (7.5, 12.2)	11.6 (9.3, 13.5)*	13.3 (11.0, 15.9)*
Adjusted median (IQR)[5]	8.0 (6.0, 10.6)	16.3 (13.0, 20.2)*	14.0 (11.8, 16.4)*	8.5 (6.5, 10.6)	13.3 (11.0, 15.5)*	13.0 (11.2, 14.8)*
Total sugar (% kcal)						
Median (IQR)	21.1 (11.9, 33.0)	11.1 (7.1, 16.6)*	19.5 (16.4, 22.9)*	8.4 (5.0, 12.9)	10.0 (7.8, 12.6)*	24.6 (20.1, 29.6)*
Adjusted median (IQR)	17.4 (12.9, 23.9)	13.5 (10.7, 18.6)*	21.4 (17.3, 26.2)*	12.2 (9.3, 16.2)	12.7 (10.7, 15.5)*	18.6 (15.6, 21.7)*
Sodium (mg/1000 kcal)						
Median (IQR)	1150 (237, 3253)	1950 (1535, 2624)*	1920 (1663, 2204)*	1683 (1097, 2712)	2836 (2459, 3284)*	1578 (1272, 2090)*
Adjusted median (IQR)	1175 (313, 3248)	2079 (1674, 2582)*	1811 (1640, 2113)*	1463 (901, 2502)	2743 (2355, 3234)*	1911 (1658, 2420)*

* Median significantly different from referent group ("less-processed" or "requires cooking/preparation"), Wald test with $P<0.001$ to account for multiple comparisons and large sample size.

[1] Data from the 2012 Homescan longitudinal panel of household purchases of consumer packaged goods. All values are weighted to be nationally representative and include only foods (not beverages). Number of household-level purchases: all foods: n=59,286; less processed: n=59,175; processed: n=59,267; ultra-processed: n=59,284; requires cooking/preparation: n=59,043; ready-to-heat: n=59,240; ready-to-eat: n=59,283. IQR, interquartile range; RTE, ready-to-eat; RTH, ready-to-heat.

[2] Each bar-coded food was classified into a mutually exclusive category for processing based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes. "Less processed" includes minimally processed foods, moderately processed ingredients, and foods moderately processed for preservation or pre-cooking. "Processed" includes foods processed for flavor and processed grain products. "Ultra-processed" includes ultra-processed ingredients and ultra-processed products not consumed as additions.

[3] Each bar-coded food was separately classified into a mutually exclusive category for convenience based on the amount of food preparation required of the consumer before a product can be eaten. "Ready-to-heat" includes products requiring minimal preparation.

[4] Nutrient densities were calculated at the household-level for all food purchases within a category of processing or convenience. Values are median densities across all household-level purchases.

[5] Determined by survey weighted quantile regression, regressing nutrient density on processing or convenience level (dummy variables) with adjustment for % kcal from food groups (quartiles for fruit/fruit products, vegetables/vegetable products, starchy vegetables/starchy vegetable products, grain products, dairy products, fats/oils, nuts/legumes, meat/meat dishes/eggs, sweeteners/sweets, and other foods). Stata's "margins" command was used to determine the adjusted nutrient density at the 25th, 50th (median), and 75th percentile for purchases in each category of processing or convenience.

Supplemental Table 3.1. Food grouping system for Homescan barcode-level data[1]

Basic Food Group[2]	Specific Food Group[3]	Foods or beverages included
Grain products	**Cereal**	RTE breakfast cereals, granola, oatmeal, grits, cream of wheat, and other hot cereals
	Baking products	Flour (whole-grain and refined grain), masa, corn meal, semolina; breading/batter mixes
	Breads and quick breads	Breads: Bread, tortillas, taco shells, rolls, hot dog/hamburger buns, sandwich rolls, sandwich wraps, bagels, English muffins, bread sticks, garlic bread, pita bread, pizza crusts, canned brown bread, bread crumbs, croutons; quick breads: pancakes, waffles, French toast, biscuits, corn bread, zucchini or fruit breads; includes RTE products, frozen/refrigerated dough, frozen/refrigerated ready-to-bake products, mixes
	Rice and grains	White rice, wild rice, brown rice, quinoa, bulgur wheat, barley, and grain mixtures; includes regular, parboiled, instant, and pre-cooked
	Rice dishes	Instant/microwaveable rice dish mixes (e.g, rice with sauce, pilaf), rice dish meal kits (e.g., kits for jambalaya, fried rice, dirty rice, “helper”-type kits), prepared RTH rice dishes (e.g., rice with vegetables and sauce, rice pilaf, risotto, fried rice), frozen rice-based dinners (e.g., rice with sauce and vegetables or meat)
	Pasta	Fresh or dried, whole-grain or refined grain pasta; flavored pasta (e.g., spinach pasta); egg noodles; couscous
	Pasta dishes	Frozen pasta dishes or dinners (e.g., lasagna, ravioli, manicotti, spaghetti with meatballs, macaroni and cheese); frozen pasta and vegetable side dishes; pasta dish meal kits (e.g., boxed macaroni-and-cheese, “helper”-type kits); canned pasta dishes (e.g., ravioli, spaghetti with sauce); instant pasta dish mixes (e.g., microwaveable macaroni and cheese, pasta with sauce, Asian noodle bowls); uncooked ravioli or tortellini; RTE macaroni salad
	Salty snacks	Crackers, snack crackers, corn chips, pretzels, tortilla chips, cheese-flavored tortilla chips, cheese puffs, pita chips, popcorn (unpopped kernels, microwaveable, or pre-popped), sandwich crackers, rice cakes, snack mixes with crackers
	Grain-based mixed dishes	Frozen pizza; frozen grain-based dishes (e.g., burritos, sandwiches, breakfast sandwiches, pancake breakfast meals, pot pies, sandwich pockets, rice/gluten-based vegetarian products); refrigerated grain-based dishes (e.g., breakfast sandwiches, RTE sandwiches, Lunchables); grain-based meal kits (e.g., taco shell or nacho kits); stuffing mix
	Soups and stews	Noodle- or rice-based soups (e.g., chicken noodle, chicken and rice)
	Grain-based desserts	Cookies, brownies, cake/cupcakes, pie, cobbler, turnovers, snack cakes (e.g., Twinkies), muffins, doughnuts, sweet rolls, danish, sticky buns, coffee cake, toaster pastries, scones, pie crusts, pastry shells, granola bars,

Basic Food Group[2]	Specific Food Group[3]	Foods or beverages included
		protein bars, meal replacement bars, ice cream cones, eclairs, tarts, cream puffs, animal crackers, graham crackers
Fruit and fruit products	**Fruit**	Fresh fruit, refrigerated cut fresh fruit, apple slices with dip, refrigerated sweetened fruit, frozen fruit, dried fruit, canned/shelf-stable fruit, cinnamon apples, fruit topping, pie filling, candied fruit (i.e., citron)
	Candy and sweet snacks	Fruit snacks, fruit leather, fruit bars, fried apple or banana chips, yogurt- or chocolate-covered fruit, maraschino cherries, caramel apples, candied apples, fruit salads with marshmallow (e.g., ambrosia), fruit salads with gelatin
	Sweeteners and toppings	Jams, preserves, marmalade, fruit or pumpkin butter, jelly, lemon curd
Vegetables and vegetable products	**Vegetables**	Fresh vegetables, bagged salad, baby carrots, refrigerated pre-chopped vegetables in microwaveable/steaming packages, vegetable trays with dip, celery or carrot sticks with dip, frozen vegetables, canned vegetables, olives, pickles, pickled vegetables, sauerkraut, tomato puree/paste, dried vegetables (e.g., sun-dried tomatoes)
	Vegetable-based mixed dishes	Vegetable-based mixed dishes (e.g., broccoli with cheese sauce, green bean casserole, creamed spinach, glazed carrots, vegetables with sauce, eggplant parmesan, stuffed mushrooms, vegetable-based burgers); fried breaded vegetables (e.g., onion rings, fried okra); canned vegetables in sauce (greens with meat, vegetables in tomato sauce); stuffed olives; pre-made salad bowls (e.g., chef salad, Caesar salad); RTE coleslaw
	Soups and stews	Vegetable-based soups (e.g., vegetable soup, tomato soup, French onion soup, gazpacho)
	Sauces, condiments, and dips	Jarred tomato-based pasta sauce, salsa, guacamole, spinach dip
Starchy vegetables and starchy vegetable products	**Starchy vegetables**	Starchy vegetables include potatoes, sweet potatoes, corn, and green peas. Fresh starchy vegetables (e.g., potatoes, sweet potatoes); refrigerated potatoes or ears of corn in microwaveable/steaming packages; frozen starchy vegetables; dried starchy vegetables (e.g., dehydrated potatoes or potato flakes); canned starchy vegetables
	Fried potatoes	Frozen French fries, sweet potato fries, hash browns, hash brown patties, tater tots, potato pancakes, home fries
	Salty snacks	Potato chips, potato crisps, sweet potato chips, corn nuts, crispy green peas
	Starchy vegetable-based mixed dishes	Prepared starchy vegetable-based dishes (mashed potatoes, stuffed baked potatoes, potato skins, au gratin potatoes, sweet potato casserole, candied yams, hash brown casserole, creamed corn, corn soufflé, starchy

Basic Food Group[2]	Specific Food Group[3]	Foods or beverages included
		vegetables in sauce); starchy-vegetable based frozen dinners (starchy vegetable as primary ingredient); instant potato mixes (e.g., mashed potatoes, potatoes au gratin); RTE potato salad
	Soups and stews	Starchy-vegetable based soups (e.g., potato soup, corn chowder, cream of potato)
Nuts and legumes	**Legumes**	Legumes include beans, black-eyed peas, split peas, edamame, and lentils. Dried, frozen, or canned legumes; tofu
	Salty snacks	Chocolate- or yogurt-covered soynuts
	Legume-based mixed dishes	Prepared legume-based dishes (e.g., lima beans or other legumes in sauce, soy- or bean-based vegetarian burgers, bean chili); canned legume-based side dishes (baked beans; beans in tomato sauce; beans with pork, hot dogs; refried beans; black-eyed peas with stewed tomatoes); RTE three-bean salad
	Soups and stews	Legume-based soups (e.g., split pea, lentil, black bean, bean-based chili)
	Sauces, condiments, and dips	Black bean dip, hummus
	Nuts and nut products	Raw, blanched, dry-roasted, or oil-roasted nuts or seeds; nut butters (e.g., peanut butter, almond butter, soynut butter), nut-based bars; nut-based trail mix; nut-based dessert toppings; almond or nut-based pastry filling
	Candy and sweet snacks	Chocolate- or yogurt-covered nuts or seeds; candy-coated nuts or seeds
Meat, meat mixed dishes, and eggs	**Meat**	Meat includes beef, pork, poultry, and seafood. Fresh or frozen meat (plain, seasoned, or marinated); canned meat (e.g. tuna, salmon, chicken); breaded meat (chicken nuggets, tenders, or patties; fried chicken; fish sticks; breaded shrimp or clam strips; fish patties; veal patties; pork patties); sliced or shaved lunch meat not containing nitrates, nitrates, mechanically separated meat, or fillers and not cured or smoked
	Processed meat	Bacon, sausage, bratwurst, hot dogs, Canadian bacon, smoked or cured meats (e.g., ham, pork chops, smoked turkey, corned beef, smoked salmon); smoked or cured lunch meat (e.g., turkey, ham, roast beef, pastrami); pressed, chopped, or formed lunch meat (bologna, salami, pepperoni, luncheon loaf, some ham or turkey); canned processed meat (Spam, Vienna sausage); summer sausage; beef jerky
	Salty snacks	Pork rinds
	Meat-based mixed	Includes beef, pork, poultry, seafood, and processed meat dishes. Prepared meat-based dishes (stuffed chicken

Basic Food Group[2]	Specific Food Group[3]	Foods or beverages included
	dishes	breasts, buffalo wings, fried breaded patties with gravy, meat loaf, ribs, meatballs, BBQ, crab cakes, stuffed fish or seafood, meat with sauce); meat-based frozen meals (Salisbury steak, turkey and gravy); canned meat-based dishes (e.g., corned beef hash, seafood in sauce); RTE seafood, chicken, tuna, or ham salad
	Soups and stews	Meat-based soups (e.g., meat-based chili, beef stew, beef vegetable soup, seafood chowder)
	Sauces, condiments, and dips	Crab dip, smoked salmon dip, white or red clam sauce
	Eggs and egg dishes	Fresh eggs, egg whites, egg substitutes, RTE egg salad or deviled eggs, prepared egg-based mixed dishes (quiche, omelets, egg soufflés, frozen meals with eggs and meat)
Fats and oils	**Fats and oils**	Oil, cooking spray, flavored oil, butter, margarine, shortening, lard
	Sauces, condiments, and dips	Salad dressing, mayonnaise, pesto sauce, béarnaise sauce, butter sauce, oil-based creamy horseradish sauce
Sweeteners and sweets	**Sweeteners and toppings**	Granulated sugar, brown sugar, powdered sugar, molasses, sorghum syrup, flavored granulated sugar, honey, pure maple syrup, agave nectar, artificial sweeteners, stevia, corn syrup, pancake syrup, flavored syrups for coffee drinks or Italian soda, fruit syrups, chocolate or fruit-flavored dessert or milk syrup, dessert topping (e.g., caramel, butterscotch, hot fudge, strawberry sauce, marshmallow cream), icing
	Candy and sweet snacks	Candy, chocolate, candy bars, marshmallows, fudge, toffee, baking chocolate, morsels, gum, mints, candy dessert toppings, popsicles, sorbet, ices, gelatin, candy-making kits
	Sauces, condiments, and dips	Chocolate dipping sauce or fondue, caramel dip, hazelnut spread, RTH dessert sauces (e.g., caramel, butterscotch)
Dairy products	**Yogurt**	Yogurt (plain or sweetened/flavored)
	Other dairy products	Sour cream, cream, whipping cream, creamer (liquid or powdered), whipped cream, whipped topping, evaporated milk, sweetened condensed milk
	Cheese	Cheddar, Swiss, mozzarella, Parmesan, Romano, feta, ricotta, blue cheese, cottage cheese, American cheese, cream cheese, cheese spreads, spray cheese, non-dairy/imitation cheese
	Dairy-based desserts	Ice cream; sherbet; ice milk; frozen yogurt; ice cream bars, cones, sandwiches; pudding; cheesecake; tiramisu; mousse

Basic Food Group[2]	Specific Food Group[3]	Foods or beverages included
	Dairy-based mixed dishes	Fried cheese sticks, cheese soufflé
	Soups and stews	Dairy-based soups (e.g., cheddar cheese soup, broccoli cheese, clam chowder, cream of mushroom)
	Sauces, condiments, and dips	RTH cheese dip or salsa con queso, alfredo sauce, cheese sauce, dairy-based chip or vegetable dip (e.g., French onion, ranch, dill)
Other	**Baking products**	Salt, pepper, herbs, spices, seasoning products (e.g., seasoned salt, garlic salt, lemon pepper, hamburger seasoning), sauce and seasoning mixes (e.g., for meatloaf, tacos, chili, spaghetti sauce, marinades), flavor extracts, yeast, baking soda, baking powder, corn starch, cocoa powder, pectin, fruit protectors, canning or pickling products, food coloring, egg replacers, capers, marzipan, pastry filling
	Soups and stews	Broth, stock, bouillon
	Sauces, condiments, and dips	Ketchup, barbecue sauce, tartar sauce, cocktail sauce, mustard, taco sauce, soy sauce, steak sauce, hot sauce, pickle relish, fruit relish, vinegar, cooking wine, Worcestershire sauce, teriyaki sauce, fish sauce, marinades, stir fry sauce, prepared gravy, dip mix
Beverages	**Milk**	Fresh or shelf-stable milk (plain, chocolate, or flavored); dry milk; hot chocolate/cocoa mix; instant breakfast; powder for flavored milk; milk drinks (e.g., containing oil, thickeners, or mostly water, such as Yoohoo); milk drink mixes (e.g., hot chocolate mixes with non-dairy creamer)
	Milk beverages	Buttermilk, egg nog, milk substitutes (e.g., plain or flavored soy, almond, rice, oat, or hemp milk), milk substitute drinks (e.g., plain or flavored soy, almond, rice, oat, or hemp milk with added oils), coconut milk
	Yogurt	Yogurt drinks, shakes, or smoothies; kefir
	Fruit juice	Fruit juice, including 100% or <100%, not from-concentrate or from-concentrate, and with or without sweeteners or flavors; frozen fruit juice concentrate; sparkling fruit juice
	Vegetable juice	Vegetable juice, including 100% or <100%, not from-concentrate or from-concentrate, and with or without sweeteners or flavors
	Water	Plain bottled water; carbonated water (e.g., seltzer, club soda, mineral water, sparkling water); ice
	Sugar-sweetened	Caloric and low-calorie cola, root beer, ginger ale, other soft drinks, energy drinks, tonic, flavored seltzer or

Basic Food Group[2]	Specific Food Group[3]	Foods or beverages included
	beverages	carbonated water, sports drinks, flavored waters, fruit drinks[4], vegetable drinks
	Coffee	Whole or ground coffee beans; pods or discs for single-cup brewers; coffee substitute; instant coffee; coffee beverages (coffee with milk or creamer, such as latte or cappuccino, including ready-to-drink or instant mixes)
	Tea	Tea leaves or bags, ready-to-drink sweetened or flavored tea, instant tea mixes, tea drinks (tea with milk or creamer, such as chai tea latte, including ready-to-drink or instant milks)
	Beer	Beer, ale, malt liquor, stout, porter, malt beverage
	Wine	Regular wine, sparkling wine, dessert wine, sake, sangria, vermouth, de-alcoholized wine
	Liquor	Whiskey, bourbon, brandy, gin, liqueurs, bitters, rum, scotch, tequila, vodka
	Mixed alcoholic beverages	Premade alcoholic cocktails and coolers

[1] Grouping of foods and beverages occurred at 2 levels. Each food or beverage is assigned to a basic food group (beverages and 10 food groups) and separately to a specific food group (45 food and beverage groups). Classification and food group assignment occurred at the Universal Product Code (barcode)-level. Perl-based "regular expressions" were used to search ingredient lists, package information, and product attributes for relevant details differentiating food groups. Program code was used to assign each barcode to a single specific food group and to a single basic food group. RTE, ready-to-eat; RTH, ready-to-heat.

[2] Foods and beverages were grouped into 11 categories (beverages and 10 food groups). Processing level does not vary within many specific food groups (e.g., grain-based desserts, SSBs, candy), so the basic food grouping system was developed to group foods more broadly with processing variation in each group. Basic groups considered the main component of each product, and groupings differ from nutritionally and consumption based food groups. Mixed dishes and soups were classified as grain-, meat-, vegetable-, starchy vegetable-, legume-, or dairy-based using the first main ingredient in the ingredient list and the product description.

[3] Foods and beverage were additionally grouped into specific food groups (45 groups). These mutually exclusive, nutritionally meaningful groups were based on nutrient composition, dietary behaviors, and consumption patterns. Beverages are classified into separate categories based on their differential effects on satiety. Many specific food groups do not correspond to a single basic food group (e.g., the specific food group "soup and stews" contains items in the basic food groups vegetables/vegetable products, starchy vegetables/starchy vegetable products, nuts/legumes, meat/meat dishes/eggs, and grain products).

[4] Fruit drinks are defined as beverages primarily composed of sugar or sweetener (as 1st or 2nd ingredients) with fruit juice or fruit juice concentrate as a lesser ingredient.

Supplemental Table 3.2. Sociodemographic characteristics of US households participating in the 2000-2012 Homescan panel, select years shown[1]

	Year			
	2000	**2004**	**2008**	**2012**
Individual characteristics, n individuals (%)				
Total individuals, n	82,004	90,307	140,057	140,100
Age groups				
Children	17,193 (21.0%)	17,456 (19.3%)	26,512 (18.9%)	23,843 (17.0%)
2-5 y	3,078 (3.8%)	3,022 (3.3%)	5,202 (3.7%)	4,374 (3.1%)
6-11 y	6,145 (7.5%)	5,967 (6.6%)	9,037 (6.5%)	8,137 (5.8%)
12-18 y	7,970 (9.7%)	8,467 (9.4%)	12,273 (8.8%)	11,332 (8.1%)
Adults	64,811 (79.0%)	72,851 (80.7%)	113,545 (81.1%)	116,257 (83.0%)
19-39 y	15,934 (19.4%)	15,260 (16.9%)	22,718 (16.2%)	22,617 (16.1%)
40-59 y	29,140 (35.5%)	33,466 (37.1%)	53,958 (38.5%)	50,480 (36.0%)
≥60 y	19,737 (24.1%)	24,125 (26.7%)	36,869 (26.3%)	43,160 (30.8%)
Gender				
Male	38,300 (46.7%)	41,949 (46.5%)	65,846 (47.0%)	65,591 (46.8%)
Female	43,704 (53.3%)	48,358 (53.5%)	74,211 (53.0%)	74,509 (53.2%)
Household characteristics, n households (weighted %)[2]				
Total households, n	34,278	38,821	60,138	59,288
Household composition				
Single adults, no children	8,816 (25.7%)	10,867 (26.6%)	15,819 (26.7%)	15,099 (26.4%)
Single adults, with children	936 (6.0%)	990 (5.1%)	1,363 (6.0%)	944 (4.0%)
Multiple adults, no children	15,848 (39.4%)	18,158 (39.6%)	29,437 (38.1%)	30,804 (40.1%)
Multiple adults, with children	8,678 (28.9%)	8,806 (28.7%)	13,519 (29.2%)	12,441 (29.5%)
Race/ethnicity[3]				
Non-Hispanic white	28,886 (78.9%)	31,343 (75.4%)	49,474 (73.2%)	47,835 (71.3%)
Non-Hispanic black	2,750 (10.9%)	3,581 (10.8%)	5,157 (11.0%)	5,485 (11.2%)
Hispanic	1,828 (8.8%)	2,442 (9.9%)	3,030 (10.9%)	3,069 (12.0%)
Non-Hispanic other race/ethnicity	814 (1.4%)	1,455 (3.8%)	2,477 (4.9%)	2,899 (5.5%)
Household education[4]				
Less than high school	755 (3.6%)	739 (2.9%)	836 (2.8%)	725 (2.7%)
High school or some college	17,749 (63.1%)	20,046 (62.0%)	28,865 (60.5%)	26,914 (59.7%)
College degree or higher	15,774 (33.3%)	18,036 (35.2%)	30,437 (36.8%)	31,649 (37.6%)

	Year			
	2000	**2004**	**2008**	**2012**
Household income				
<$25,000	7,027 (32.1%)	8,398 (25.4%)	9,962 (22.7%)	9,739 (23.6%)
$25,000-$49,999	12,685 (30.5%)	13,623 (27.4%)	18,817 (26.1%)	18,161 (26.6%)
$50,000-$74,999	6,927 (17.4%)	7,387 (15.6%)	11,532 (16.0%)	10,735 (15.9%)
≥$75,000	7,639 (19.9%)	9,413 (31.6%)	19,827 (35.2%)	20,653 (33.9%)

[1] Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods. Total sample includes 656,184 household-year level observations from 157,142 unique households (435,949 individuals).

[2] Percentages of households weighted to be nationally representative.

[3] Race/ethnicity self-reported by head of household.

[4] Highest level of education reported by male or female head of household.

Supplemental Table 3.3. Top food and beverage contributors to per capita daily calories purchased by US households within each category of food processing, Homescan 2000 and 2012[1]

	Per capita kcal/d ± SE		
	2000	2012	Change
Minimally processed			
Total	**133 ± 0.9**	**127 ± 0.7**	**-7 ± 1***
Milk, unsweetened/unflavored (fresh)	72 ± 0.6	48 ± 0.4	-24 ± 1*
Eggs	17 ± 0.2	17 ± 0.1	0 ± 0
Starchy vegetables, unsweetened/unflavored (fresh, refrigerated, or frozen)	11 ± 0.1	13 ± 0.1	1 ± 0*
Nuts, unsweetened/unflavored	6 ± 0.2	7 ± 0.2	0 ± 0
Fruit, unsweetened/unflavored (fresh or dried)	5 ± 0.1	13 ± 0.2	9 ± 0*
Hot cereal, whole-grain unsweetened/unflavored	4 ± 0.1	5 ± 0.1	1 ± 0*
Vegetables, unsweetened/unflavored (fresh, refrigerated, or frozen)	4 ± 0.0	5 ± 0.0	1 ± 0*
Cream, unsweetened/unflavored (regular or whipping)	4 ± 0.1	6 ± 0.1	2 ± 0*
Legumes, unsweetened/unflavored (dried)	2 ± 0.1	2 ± 0.0	0 ± 0*
Water, unsweetened/unflavored	2 ± 0.2	0 ± 0.0	-2 ± 0*
Honey	2 ± 0.1	1 ± 0.0	0 ± 0*
Meat, unsweetened/unflavored uncooked (refrigerated or frozen)	1 ± 0.0	5 ± 0.1	4 ± 0*
Popcorn kernels, unsweetened/unflavored	1 ± 0.1	2 ± 0.1	0 ± 0*
Whole-grain rice	1 ± 0.0	2 ± 0.1	1 ± 0*
Moderately processed ingredients			
Total	**112 ± 1.1**	**101 ± 0.8**	**-12 ± 1***
Sugar (regular, brown, and powdered)	58 ± 0.7	43 ± 0.5	-15 ± 1*
Oil and unsalted butter	48 ± 0.6	50 ± 0.5	2 ± 1*
Fruit juice, unsweetened/unflavored not from-concentrate	5 ± 0.1	4 ± 0.1	-1 ± 0*
Whole-grain flour	1 ± 0.1	2 ± 0.0	1 ± 0*
Whole-grain pasta	0 ± 0.0	2 ± 0.0	2 ± 0*
Moderately processed for preservation or pre-cooking			
Total	**80 ± 0.7**	**56 ± 0.5**	**-23 ± 1***
Refined-grain flour	25 ± 0.4	15 ± 0.2	-10 ± 0*
Refined-grain pasta	19 ± 0.2	15 ± 0.2	-4 ± 0*
Fruit juice, unsweetened/unflavored from-concentrate (shelf-stable or refrigerated juice, frozen concentrate)	14 ± 0.2	6 ± 0.1	-7 ± 0*
Rice, white or instant	10 ± 0.3	10 ± 0.3	0 ± 0
Other dairy products (sour cream and evaporated milk)	4 ± 0.1	4 ± 0.0	0 ± 0
Hot cereal, refined-grain unsweetened/unflavored	2 ± 0.1	1 ± 0.0	0 ± 0*
Dry milk	1 ± 0.1	0 ± 0.0	-1 ± 0*

	Per capita kcal/d ± SE		
	2000	2012	Change
Starchy vegetables, unsweetened/unflavored canned or jarred	1 ± 0.0	1 ± 0.0	0 ± 0*
Fruit, unsweetened/unflavored canned or jarred	1 ± 0.0	1 ± 0.0	0 ± 0*
Buttermilk	1 ± 0.0	0 ± 0.0	0 ± 0*
Instant coffee, unsweetened/unflavored	1 ± 0.0	0 ± 0.0	0 ± 0*
Vegetables, unsweetened/unflavored canned or jarred	1 ± 0.0	1 ± 0.0	0 ± 0*
Peanut butter, unsweetened/unflavored	0 ± 0.0	0 ± 0.0	0 ± 0*
Yogurt, unsweetened/unflavored	0 ± 0.0	1 ± 0.0	0 ± 0*
Processed for flavor			
Total	**173 ± 1.0**	**191 ± 0.9**	**18 ± 1***
Nuts and nut butters, sweetened/flavored	35 ± 0.4	35 ± 0.3	0 ± 1
Moderately processed salty snacks (sliced potato chips and sweetened/flavored popcorn)	31 ± 0.4	28 ± 0.2	-3 ± 0*
Cheese	22 ± 0.2	32 ± 0.2	10 ± 0*
Salted butter	16 ± 0.3	17 ± 0.2	1 ± 0*
Fruit, sweetened/flavored (canned/jarred or dried)	7 ± 0.1	6 ± 0.1	-1 ± 0*
Fruit juice, sweetened/flavored (shelf-stable or refrigerated juice)	6 ± 0.1	6 ± 0.1	-1 ± 0*
Bacon, smoked meat, sliced ham, or cured sliced lunch meats	6 ± 0.1	8 ± 0.1	2 ± 0*
Meat, sweetened/flavored (refrigerated or frozen uncooked, canned, or frozen RTH)	5 ± 0.1	9 ± 0.1	4 ± 0*
Starchy vegetables, sweetened/flavored (canned or frozen)	5 ± 0.3	4 ± 0.1	-1 ± 0*
Vegetables, sweetened/flavored (canned or jarred; pickles or pickled vegetables; olives)	5 ± 0.1	4 ± 0.0	-1 ± 0*
Jam and preserves	5 ± 0.1	3 ± 0.0	-2 ± 0*
Tea, sweetened/flavored (ready-to-drink or instant mix)	5 ± 0.2	5 ± 0.1	1 ± 0*
Yogurt, sweetened/flavored	5 ± 0.1	12 ± 0.4	8 ± 0*
Milk, sweetened/flavored (chocolate milk or cocoa mix)	4 ± 0.1	4 ± 0.1	0 ± 0*
Fried sliced potatoes	4 ± 0.1	3 ± 0.1	-1 ± 0*
Hot cereal, sweetened/flavored	3 ± 0.1	3 ± 0.1	0 ± 0
Legumes, sweetened/flavored (canned)	3 ± 0.0	3 ± 0.0	0 ± 0*
Flavored pasta and egg noodles	2 ± 0.1	2 ± 0.0	0 ± 0*
Other sweetened/flavored dairy products (coffee cream, sweetened condensed milk, whipped cream)	1 ± 0.0	3 ± 0.1	2 ± 0*
Vegetable juice, sweetened/flavored	1 ± 0.0	1 ± 0.0	0 ± 0*
Milk substitutes, sweetened/flavored (soy milk and almond milk)	1 ± 0.1	1 ± 0.1	1 ± 0*
Processed grain products			
Total	**2 ± 0.1**	**1 ± 0.0**	**0 ± 0***
Whole-grain unsweetened/unflavored RTE cereal	1 ± 0.0	1 ± 0.0	-1 ± 0*
Whole-grain breads and tortillas with no added sweetener or fat	0 ± 0.0	1 ± 0.0	0 ± 0*

	Per capita kcal/d ± SE		
	2000	2012	Change
Ultra-processed ingredients			
Total	**124 ± 0.9**	**107 ± 0.6**	**-17 ± 1***
Mayonnaise, salad dressing, ketchup, BBQ sauce, tomato sauce, cooking sauces, and other condiments	52 ± 0.4	50 ± 0.3	-2 ± 1*
Margarine and shortening	39 ± 0.6	24 ± 0.2	-15 ± 1*
Pancake syrup, dessert syrups, icing, jelly, corn syrup, and artificial sweetener	13 ± 0.2	10 ± 0.1	-3 ± 0*
Creamer and whipped topping	13 ± 0.3	15 ± 0.2	3 ± 0*
Baking chocolate	4 ± 0.1	5 ± 0.1	0 ± 0
Sauces and seasoning mixes	1 ± 0.0	1 ± 0.0	0 ± 0*
Bread crumbs	1 ± 0.0	1 ± 0.0	0 ± 0*
Ultra-processed products not consumed as additions			
Total	**666 ± 3.4**	**639 ± 3.3**	**-27 ± 5***
Breads, tortillas, rolls, bagels, pancakes, muffins, or biscuits from refined grain or with added sweetener or fat (RTE, mixes, ready-to-bake)	107 ± 0.6	94 ± 0.5	-13 ± 1*
Grain-based desserts (RTE, frozen, mixes, ready-to-bake)	105 ± 0.8	93 ± 0.6	-12 ± 1*
SSBs (sweetened/flavored carbonated beverages, fruit drinks, sports drinks, flavored waters)	76 ± 1.1	57 ± 0.6	-19 ± 1*
Processed salty snacks (crackers from refined grain or with added fat, tortilla or corn chips, cheese puffs, pretzels, caramel corn, restructured potato chips)	70 ± 0.6	68 ± 0.4	-3 ± 1*
Candy, gum, fruit snacks, popsicles and sorbet, gelatin, chocolate/yogurt-covered fruit or nuts	67 ± 0.9	59 ± 0.6	-8 ± 1*
RTE cereal from refined grains or with added sweeteners or fats	47 ± 0.4	43 ± 0.3	-4 ± 1*
Ice cream, pudding, and other dairy-based desserts	40 ± 0.4	33 ± 0.3	-7 ± 0*
Grain-based dishes (pizza, burritos, sandwiches, pot pies, stuffing mix)	22 ± 0.3	29 ± 0.3	7 ± 0*
Pasta dishes (frozen lasagna, spaghetti and meatballs, mac and cheese, or pasta-based frozen meals; boxed macaroni and cheese; instant pasta dish mixes; canned ravioli or spaghetti and meatballs)	20 ± 0.2	28 ± 0.9	8 ± 1*
Processed meat (sausages; hot dogs; bologna, salami, or other pressed/formed lunch meats; chopped/formed ham; canned Spam or sausages)	18 ± 0.2	28 ± 0.2	10 ± 0*
Processed cheese	15 ± 0.2	14 ± 0.1	-1 ± 0*
Beer	14 ± 0.6	12 ± 0.4	-2 ± 1*
Soup	13 ± 0.1	15 ± 0.2	3 ± 0*
Liquor	10 ± 0.4	9 ± 0.3	-1 ± 1
Wine	9 ± 0.3	8 ± 0.2	0 ± 0
Meat dishes (meat balls, buffalo wings, meat loaf, crab cakes, meat-based frozen meals, RTH pot roast or other meats with sauce)	6 ± 0.1	8 ± 0.1	2 ± 0*
Starchy vegetable dishes (mashed potatoes, stuffed baked potatoes, potato skins, potato-based frozen meal, instant mashed potatoes or potatoes au gratin, RTE potato salad)	6 ± 0.1	6 ± 0.1	0 ± 0*
Legume dishes (canned baked beans or beans with pork)	5 ± 0.1	5 ± 0.1	0 ± 0
Rice dishes (rice-based frozen meals, instant rice dish mixes)	5 ± 0.1	13 ± 1.5	8 ± 2*

	Per capita kcal/d ± SE		
	2000	**2012**	**Change**
Chicken nuggets, fish sticks, fried chicken, or other breaded meat	3 ± 0.1	5 ± 0.1	2 ± 0*
Hot cocoa with creamer/added oils	3 ± 0.1	2 ± 0.0	-1 ± 0*
Restructured fried potatoes, tater tots, and hash brown patties	2 ± 0.0	3 ± 0.1	1 ± 0*
Vegetable dishes (frozen onion rings or other breaded vegetables; entrée garden salads)	1 ± 0.0	2 ± 0.0	1 ± 0*
Coffee beverages (instant mixes or ready-to-drink)	1 ± 0.1	2 ± 0.1	1 ± 0*
Sweetened/flavored milk substitute with added oils (soy milk) and eggnog	1 ± 0.0	2 ± 0.0	1 ± 0*
Nut-based bars and trail mix with candy or chocolate	1 ± 0.0	2 ± 0.1	1 ± 0*

* Significant difference in per capita kcal/day between 2000 and 2012 assessed by *t* tests, *P*<0.05.

[1] Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods. Total sample includes 656,184 household-year level observations from 157,142 unique households (435,949 individuals). Specific food groups were ranked by per capita kcal/day. RTE, ready-to-eat; RTH, ready-to-heat.

[2] Mean ± SE (all such values) determined by dividing total calories purchased during a given year within a processing category by the number of days recorded during the year and household size. All values are weighted to be nationally representative.

Supplemental Table 3.4. Top food and beverage contributors to per capita daily calories purchased among US households by level of convenience, Homescan 2000 and 2012[1]

	Per capita kcal/day ± SE[2]		
	2000	**2012**	**Change**
Requires cooking and/or preparation			
Total	**210 ± 1.6**	**206 ± 1.2**	**-3 ± 2**
Oil and shortening	54 ± 0.8	49 ± 0.5	-5 ± 1*
Baking products (flour, sauce/seasoning mixes, and corn starch)	28 ± 0.4	18 ± 0.2	-10 ± 0*
Pasta	21 ± 0.2	19 ± 0.2	-2 ± 0*
Eggs	17 ± 0.2	18 ± 0.1	1 ± 0*
Grain-based dessert mixes (cakes, brownies, cookies, muffins); prepared/ready-to-bake pie crusts or pastry dough	13 ± 0.2	14 ± 0.1	0 ± 0
Fresh or refrigerated potatoes, corn, or other starchy vegetables	11 ± 0.1	12 ± 0.1	1 ± 0*
Mixes for pancakes, biscuits, bread/rolls, white flour tortillas, or fruit breads; bread crumbs	11 ± 0.1	10 ± 0.1	-1 ± 0*
Boxed macaroni and cheese mixes; other pasta dish meal kits; uncooked fresh/frozen tortellini or ravioli	10 ± 0.1	8 ± 0.1	-1 ± 0*
Rice (non-instant), quinoa, and barley	9 ± 0.3	10 ± 0.3	1 ± 0*
Uncooked sausages, bacon, ham, or other processed meats	8 ± 0.1	12 ± 0.1	4 ± 0*
Baking chocolate, morsels, chocolate chips, and gelatin mixes	6 ± 0.1	5 ± 0.1	0 ± 0*
Powdered sugar, molasses, and corn syrup	4 ± 0.1	3 ± 0.1	-1 ± 0*
Evaporated milk, sweetened condensed milk, and whipping cream	3 ± 0.1	3 ± 0.1	0 ± 0
Fresh or refrigerated vegetables requiring cooking/preparation (whole carrots, celery stalks, heads of lettuce, cauliflower heads, mushrooms, onions; bagged stir-fry mixtures); canned tomatoes or tomato paste/sauce	3 ± 0.0	4 ± 0.0	1 ± 0*
Refrigerated or frozen uncooked meat (ground beef, seasoned pork tenderloins, chicken breasts or pieces, pork roasts, fish fillets, shrimp, beef or turkey burger patties, steaks)	2 ± 0.1	10 ± 0.1	8 ± 0*
Dried beans, lentils, or split peas	2 ± 0.1	2 ± 0.0	-1 ± 0*
Pudding mixes	2 ± 0.0	1 ± 0.0	-1 ± 0*
Sauces/condiments used in cooking (vinegar, cooking wine, Worcestershire sauce, teriyaki sauce, marinades, basting sauces, pizza sauce, stir fry sauces, gravy mixes)	1 ± 0.0	2 ± 0.0	1 ± 0*
Un-popped popcorn kernels	1 ± 0.1	2 ± 0.1	0 ± 0*
Meal kits for making stuffing casseroles, pizza, tacos, or nachos	1 ± 0.0	1 ± 0.0	0 ± 0*
Buttermilk	1 ± 0.0	1 ± 0.0	0 ± 0*
Meal kits for rice mixed dishes (jambalaya, paella, fried rice, dirty rice)	0 ± 0.0	0 ± 0.0	0 ± 0*
Meal kits for potato-based mixed dishes (mashed potato casseroles, hash brown casseroles, potato dumplings or latkes)	0 ± 0.0	0 ± 0.0	0 ± 0*
Fresh fruit requiring preparation (lemons, coconuts, avocado, whole melon, whole pineapple)	0 ± 0.0	1 ± 0.1	1 ± 0*
Ready-to-heat (RTH) or requires minimal preparation			
Total	164 ± 1.0	189 ± 2.1	25 ± 2*

	Per capita kcal/day ± SE[2]		
	2000	**2012**	**Change**
Frozen grain-based mixed dishes (pizza, breakfast sandwiches, pancake meals, burritos, taco/enchilada dinners, pot pies, sandwiches, sandwich pockets); instant stuffing mixes; refrigerated grain-based mixed dishes (breakfast sandwiches, hot sandwiches/melts)	20 ± 0.2	27 ± 0.3	7 ± 0*
Frozen waffles, pancakes, French toast, or biscuits; ready-to-bake biscuits, rolls, bread, breadsticks	13 ± 0.2	13 ± 0.1	0 ± 0
Canned soup, instant soup mixes, bouillon cubes/powder, refrigerated or frozen pre-prepared soups	13 ± 0.1	15 ± 0.2	3 ± 0*
Frozen pasta dishes (lasagna) or pasta-based frozen meals (macaroni and cheese, spaghetti and meatballs, ravioli); instant or microwaveable macaroni cheese or Asian noodle bowls; canned ravioli or spaghetti with sauce	10 ± 0.1	19 ± 0.9	9 ± 1*
Pre-cooked processed meat (hot dogs, sausages, microwaveable bacon, Canadian bacon, ham steaks)	9 ± 0.1	13 ± 0.1	3 ± 0*
Instant/microwaveable hot cereals (plain or flavored oatmeal, grits, cream of wheat)	9 ± 0.2	9 ± 0.1	0 ± 0
Frozen pre-prepared grain-based desserts (cakes, pies, turnovers, honey buns, toaster pastries); refrigerated ready-to-bake cookies, brownies, sweet rolls)	9 ± 0.1	9 ± 0.1	0 ± 0
Canned or frozen starchy vegetables (potatoes, yams, corn, or peas alone or mixed with non-starchy vegetables)	7 ± 0.3	6 ± 0.1	-1 ± 0*
Frozen fried potatoes (French fries, sweet potato fries, hash brown patties, tater tots, fried potato pancakes)	6 ± 0.1	6 ± 0.1	0 ± 0
Frozen or refrigerated pre-prepared meat-based mixed dishes (meat loaf, BBQed meats, meat with gravy or sauce, crab cakes, stuffed chicken breasts or seafood, pot roasts) and meat-based frozen meals (Salisbury steak, meat loaf, or turkey and gravy dinners)	6 ± 0.1	7 ± 0.1	1 ± 0*
Microwaveable popcorn	6 ± 0.1	6 ± 0.1	0 ± 0
Hot chocolate/cocoa mixes; chocolate or strawberry powder for flavored milk; dry milk	6 ± 0.2	3 ± 0.1	-3 ± 0*
Powdered SSB mixes (sports drinks, fruit-flavored drinks, fruit drinks) and frozen fruit drink concentrates	5 ± 0.1	5 ± 0.2	0 ± 0
Frozen starchy vegetable-based mixed dishes (stuffed baked potatoes, mashed potatoes, potato skins, scalloped potatoes, starchy vegetables with sauce), potato-based frozen dinners, instant mashed potato mixes, canned starchy vegetables in sauce (cream-style corn, candied yams)	5 ± 0.1	5 ± 0.1	0 ± 0
Sauces, condiments, and dips (jarred pasta sauce, gravy, cheese sauce/dip)	5 ± 0.1	5 ± 0.0	0 ± 0*
Canned legume-based dishes (baked beans, beans with pork/hot dogs, beans in tomato/barbecue sauce, refried beans)	5 ± 0.1	5 ± 0.1	0 ± 0
Frozen rice-based mixed dishes or frozen meals (fried rice, rice with sauce and vegetables/meat); rice dish mixes	4 ± 0.1	13 ± 1.5	8 ± 2*
Frozen fruit juice concentrate	4 ± 0.1	1 ± 0.0	-3 ± 0*
Frozen breaded meat (chicken nuggets or patties, fried chicken, fish sticks or patties); frozen pre-cooked meat (steamed shrimp, grilled fish fillets, hamburger patties, roasted chicken strips)	4 ± 0.1	6 ± 0.1	3 ± 0*
Instant tea mixes	3 ± 0.2	2 ± 0.1	-1 ± 0*
Canned beans, lentils, or black-eyed peas	3 ± 0.0	3 ± 0.0	0 ± 0*
Frozen or canned vegetables; refrigerated pre-cut vegetables in microwaveable steaming packages	2 ± 0.0	2 ± 0.0	0 ± 0*
Instant or pre-cooked rice	2 ± 0.1	2 ± 0.0	0 ± 0*
Icing	2 ± 0.1	3 ± 0.0	1 ± 0*
Frozen whipped topping	2 ± 0.0	1 ± 0.0	-1 ± 0*

	Per capita kcal/day ± SE[2]		
	2000	2012	Change
Powdered mixes for coffee beverages (latte, mocha); instant coffee	2 ± 0.1	1 ± 0.0	0 ± 0*
Frozen vegetable-based mixed dishes or frozen meals (eggplant parmesan, green bean casserole, vegetables with cheese or sauce); fried breaded vegetables (onion rings, fried okra)	1 ± 0.0	1 ± 0.0	0 ± 0*
Ready-to-eat (RTE)			
Total	**916 ± 4.2**	**827 ± 3.3**	**-90 ± 5***
Crackers, potato chips, potato crisps, corn chips, tortilla chips, pretzels, pre-popped popcorn, rice cakes	95 ± 0.7	90 ± 0.5	-5 ± 1*
Bread, buns, rolls, bagels, wraps, English muffins, tortillas, taco shells, croutons	85 ± 0.5	73 ± 0.4	-12 ± 1*
Pre-made cookies, snack cakes, doughnuts, muffins, brownies, toaster pastries, animal crackers, graham crackers, pastries, coffee cake, sweet rolls, cereal/snack bars, granola bars, protein bars	83 ± 0.8	71 ± 0.5	-12 ± 1*
Fresh milk (plain or flavored)	75 ± 0.7	51 ± 0.4	-24 ± 1*
Granulated sugar, brown sugar, pancake syrup, chocolate/fruit syrups for desserts or milk, jam, preserves, jelly, honey, dessert toppings, pure maple syrup, artificial sweeteners	71 ± 0.7	51 ± 0.5	-20 ± 1*
Regular or diet soda, fruit drinks, energy drinks, sports drinks, flavored waters	70 ± 1.1	52 ± 0.6	-19 ± 1*
Chocolate bars, candy bars, non-chocolate candy, fruit snacks/leather, chocolate/yogurt-covered fruit or nuts, caramel apples, gelatin, popsicles, sorbet	66 ± 0.9	59 ± 0.6	-7 ± 1*
Butter and margarine	49 ± 0.4	42 ± 0.3	-7 ± 0*
RTE breakfast cereals and granola	48 ± 0.4	43 ± 0.3	-5 ± 1*
Mayonnaise, salad dressing, ketchup, barbecue sauce, mustard, other condiments, relishes, caramel dip, chip/veggie dip, salsa, bean dip, hummus	46 ± 0.4	43 ± 0.3	-2 ± 0*
Peanut butter, nuts, seeds, nut trail mixes	43 ± 0.5	45 ± 0.4	2 ± 1*
Ice cream, frozen yogurt, sherbert, ice cream cones/bars, pudding	38 ± 0.4	32 ± 0.3	-6 ± 0*
Cheese (natural and processed)	37 ± 0.3	45 ± 0.3	9 ± 0*
Fruit juice	21 ± 0.2	15 ± 0.2	-6 ± 0*
Cream, creamer, sour cream, whipped cream	17 ± 0.3	24 ± 0.3	7 ± 0*
Beer and ale	14 ± 0.6	12 ± 0.4	-2 ± 1*
Fresh RTE fruit (apples, oranges, cherries, grapes, berries), canned fruit, apple sauce, dried fruit, cut refrigerated fruit	13 ± 0.1	19 ± 0.2	6 ± 0*
Liquor	10 ± 0.4	9 ± 0.3	-1 ± 1
Wine	9 ± 0.3	8 ± 0.2	0 ± 0
Processed lunch meat, canned processed meat such as spam or ham, summer sausage, smoked salmon, beef jerky	7 ± 0.1	11 ± 0.1	4 ± 0*
Yogurt	5 ± 0.1	13 ± 0.4	8 ± 0*
RTE vegetables (bagged pre-cut salad, baby carrots, carrot or celery sticks, tomatoes, sprouts)	4 ± 0.0	4 ± 0.0	0 ± 0*
Canned meat (tuna, salmon, chicken, seafood)	4 ± 0.1	3 ± 0.0	-1 ± 0*
Bottled water, seltzer, club soda	2 ± 0.2	0 ± 0.0	-2 ± 0*
Ready-to-drink pre-sweetened tea	1 ± 0.1	4 ± 0.1	2 ± 0*
Milk substitutes (soy, almond, rice milk), egg nog	1 ± 0.1	3 ± 0.1	2 ± 0*

	Per capita kcal/day ± SE[2]		
	2000	2012	Change
Tomato juice and other vegetable juices	1 ± 0.0	1 ± 0.0	0 ± 0*
Combination lunch kits (Lunchables, sandwich wrap kits), pre-made RTE sandwiches	1 ± 0.0	1 ± 0.0	0 ± 0*
Pre-made potato salad	1 ± 0.0	1 ± 0.0	1 ± 0*

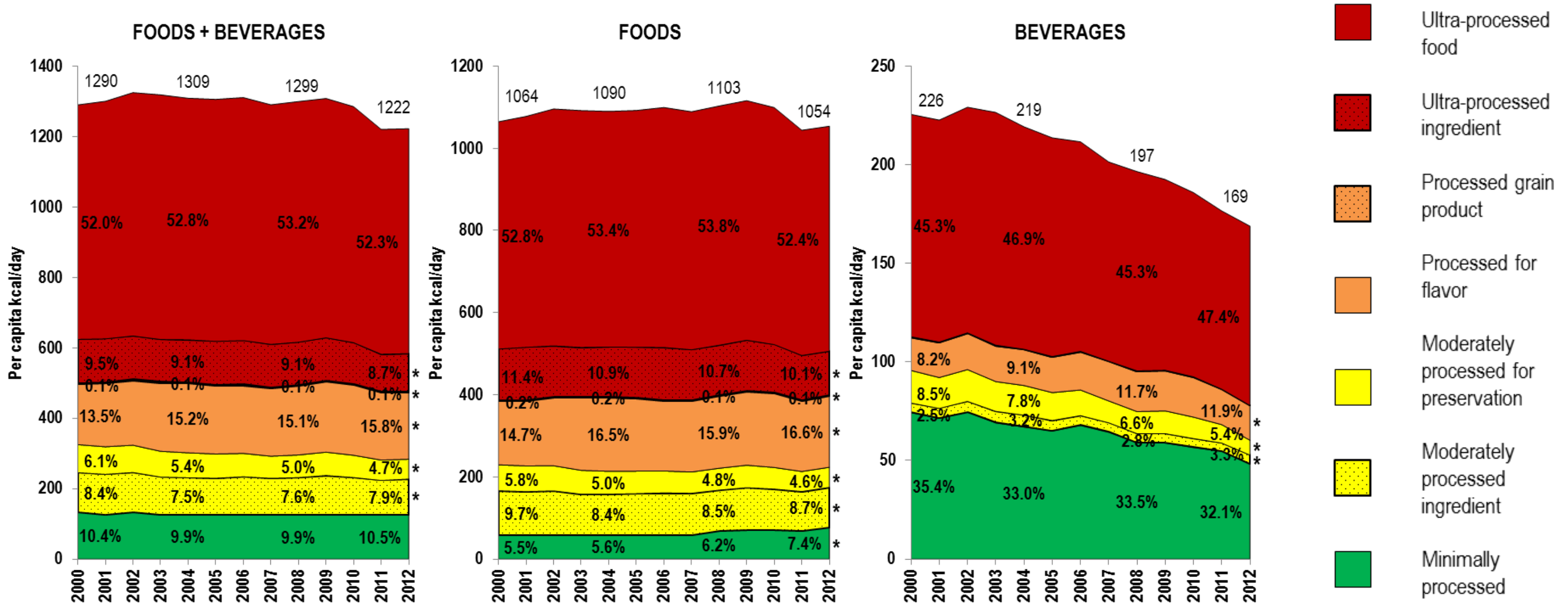
* Significant difference in per capita kcal/day between 2000 and 2012 assessed by *t* tests, $P<0.05$.

[1] Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods. Total sample includes 656,184 household-year level observations from 157,142 unique households (435,949 individuals).

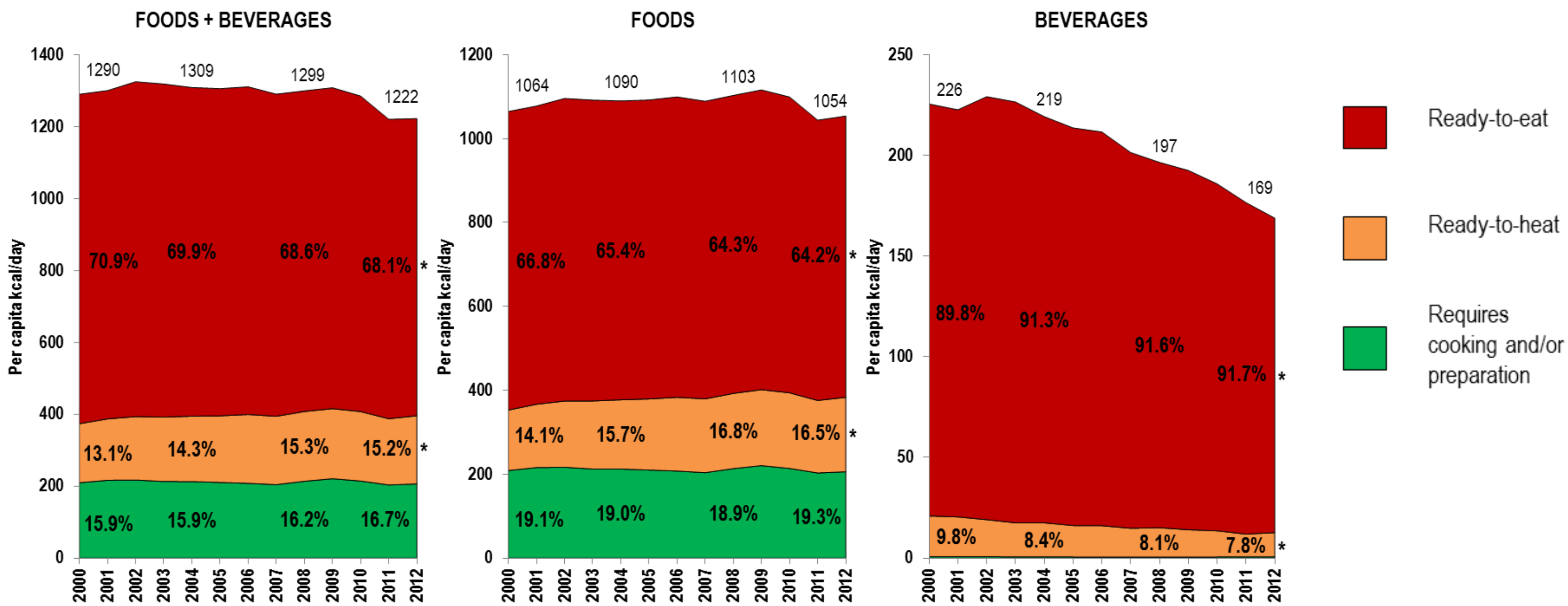
[2] Mean ± SE (all such values) determined by dividing total calories purchased during a given year within a convenience category by the number of days recorded during the year and household size. All values are weighted to be nationally representative.

Figure 3.1. Trends in the contribution of processed foods and convenience foods to calories purchased among US households, Homescan 2000-2012[1]

A. Processing



B. Convenience

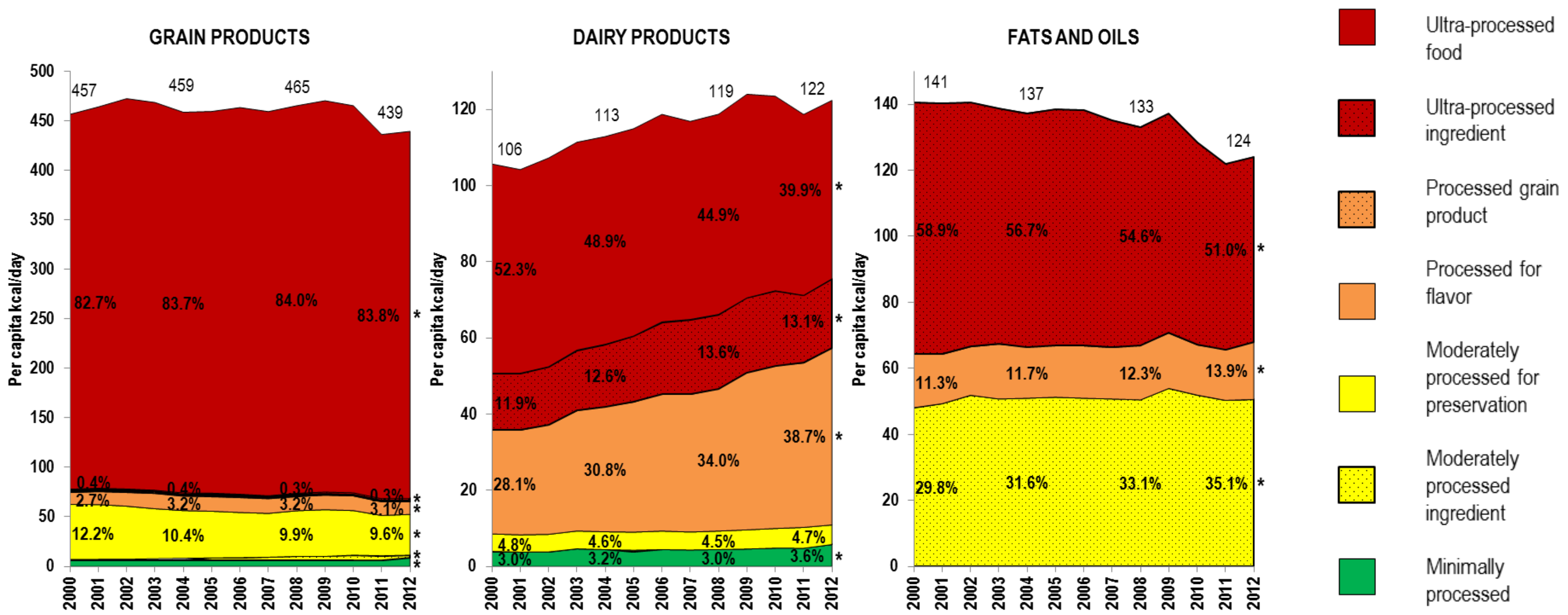


* Significant linear trend in % kcal/d from given category of processing or convenience, determined using survey weighted linear regression models. *P*<0.001 to account for multiple comparisons and sample size.

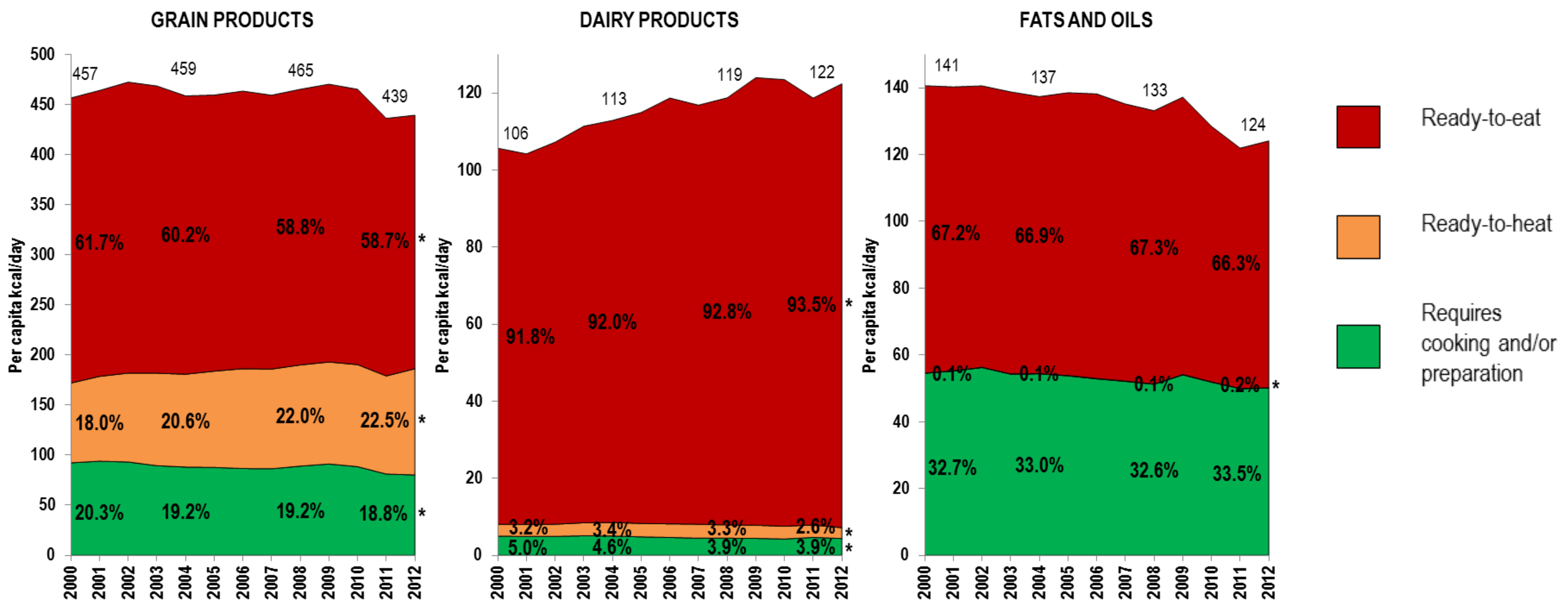
[1] Mean per capita kcal/d and % kcal/d purchased from each category of A) processing and B) convenience by year. Each uniquely barcoded food or beverage was classified into a mutually exclusive category for A) processing based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes and B) convenience based on the amount of food preparation required by the consumer before a product can be eaten. Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods. All values are weighted to be nationally representative. Number of year-level observations and households: foods and beverages: n=656,184 (157,142 households); foods: n=656,172 (157,139 households); beverages: n=655,833 (157,114 households).

Figure 3.2. Trends in the contribution of processed foods and convenience foods to calories purchased within food groups among US households, Homescan 2000-2012[1]

A. Processing



B. Convenience

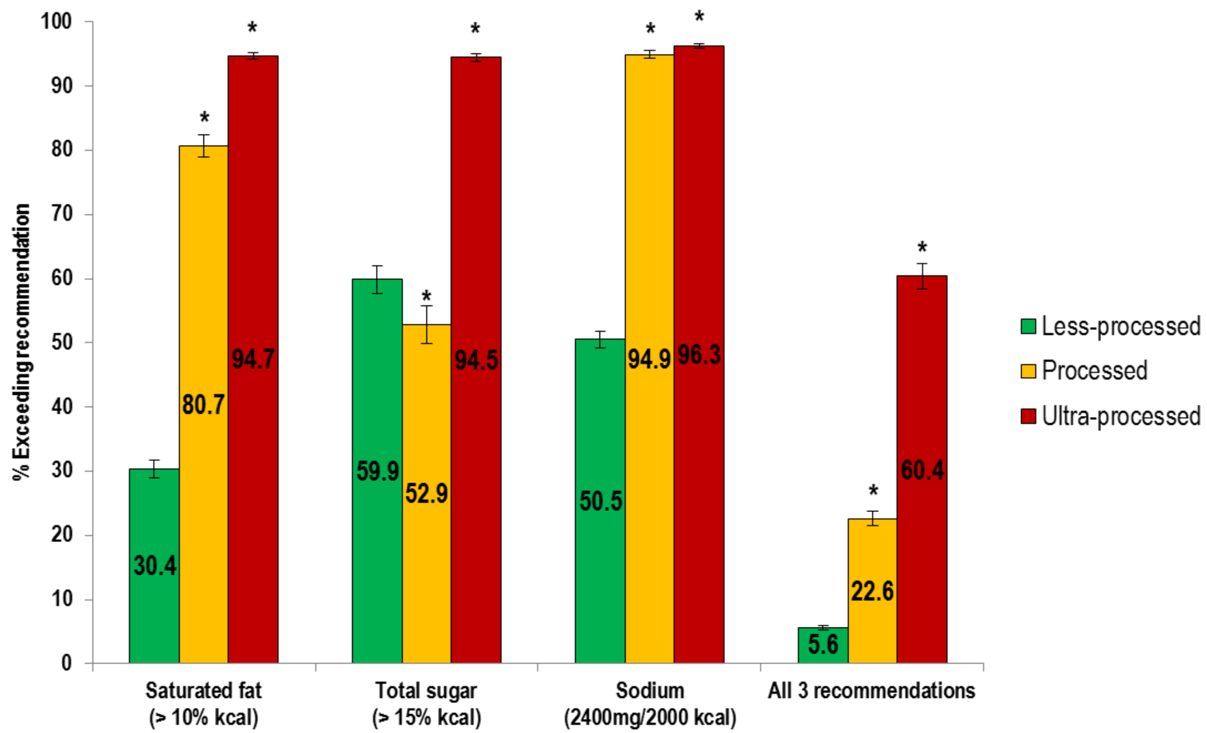


* Significant linear trend in % kcal/d from given category of processing or convenience, determined using survey weighted linear regression models. *P*<0.001 to account for multiple comparisons and sample size.

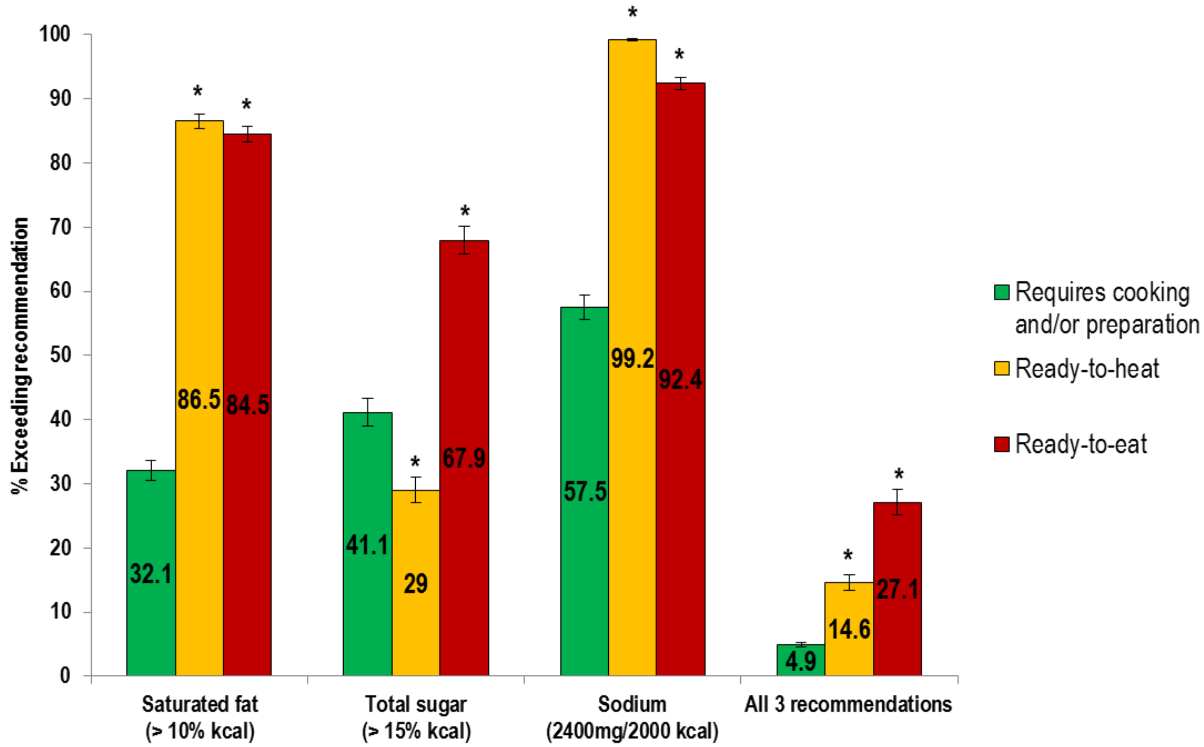
[1] Mean per capita kcal/d and % kcal/d of grain products, dairy products, and fats/oils purchased from each category of A) processing and B) convenience by year. Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods. All values are weighted to be nationally representative. Grain products include breads, flour, rice, pasta, cereal, grain-based desserts, crackers, pretzels, popcorn, tortilla chips, other grain-based salty snacks, and grain/pasta/rice-based mixed dishes. Dairy products include cheese, ice cream, dairy-based desserts, yogurt, cream, creamer, sour cream, dairy-based dips or sauces, and dairy-based mixed dishes or soups. Fats and oils include cooking oils, butter, margarine, shortening, mayonnaise, and salad dressing. Number of year-level observations and households purchasing any products within a food group during a given year: grain products: n=656,113 (157,132 households); dairy products: n=654,883 (157,048 households); fats and oils: n=650,451 (156,638 households).

Figure 3.3. Adjusted proportion of household-level food purchases exceeding saturated fat, sugar, and sodium density recommendations by level of processing and convenience, Homescan 2012[1]

A. Processing[2]



B. Convenience[3]



* Significantly different from less-processed foods (Figure 3.3A) or foods requiring cooking and/or preparation (Figure 3.3B), Wald test with *P*<0.001 to account for multiple comparisons and sample size.

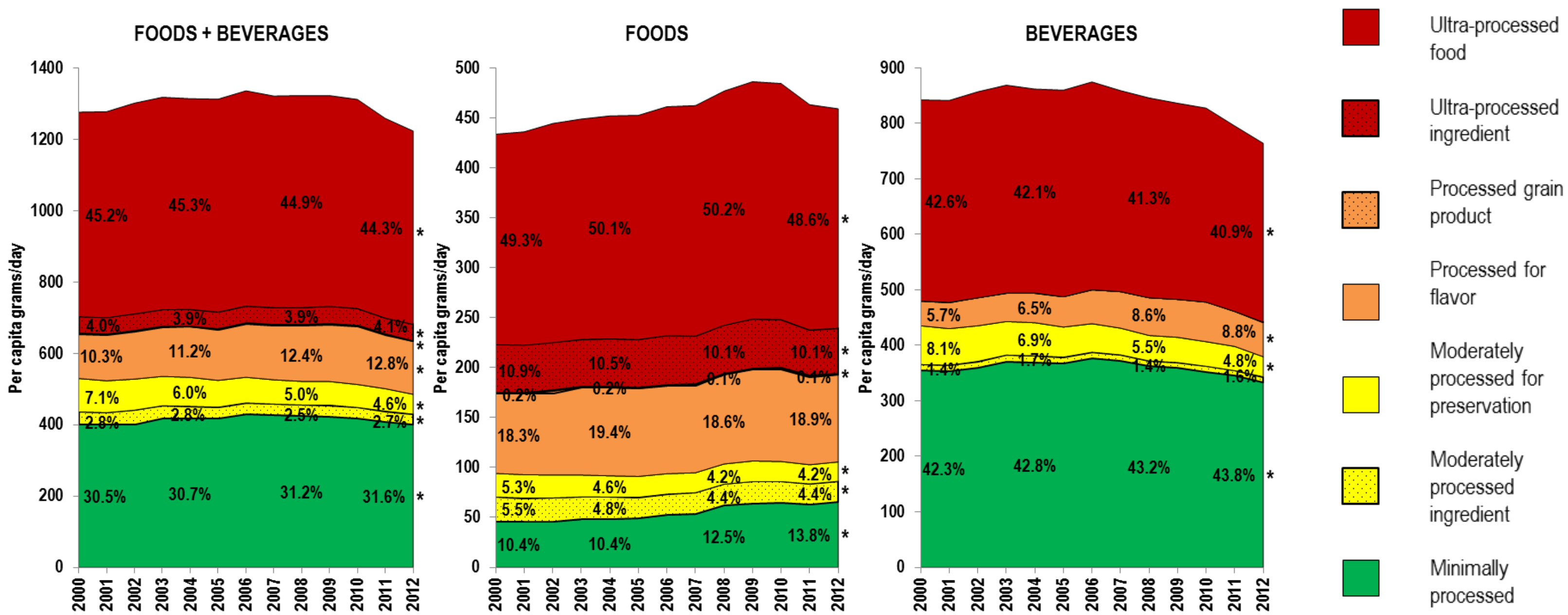
[1] Adjusted percentage of household-level food purchases within a category of A) processing or B) convenience that have > 10% kcal saturated fat, >15% kcal sugar, >2400 mg sodium/2000 kcal, or exceed all 3 recommended maximum nutrient densities. Nutrient densities were calculated at the household-level for all food purchases within a category of processing or convenience. Determined from survey weighted logistic regression models regressing the binary outcome of exceeding recommendations on processing or convenience level (dummy variables), with adjustment for the % kcal from food groups (quartiles) and with market-level clustering. Stata's "margins" command was used to determine the predicted probability of exceeding recommended maximums for purchases in each category. Data from the 2012 Homescan panel of household purchases of consumer packaged goods. Number of household-level purchases: less processed: n=59,175; processed: n=59,267; ultra-processed: n=59,284; requires cooking and/or preparation: n=59,043; ready-to-heat: n=59,240; ready-to-eat: n=59,283.

[2] "Less-processed" includes minimally processed and moderately processed.

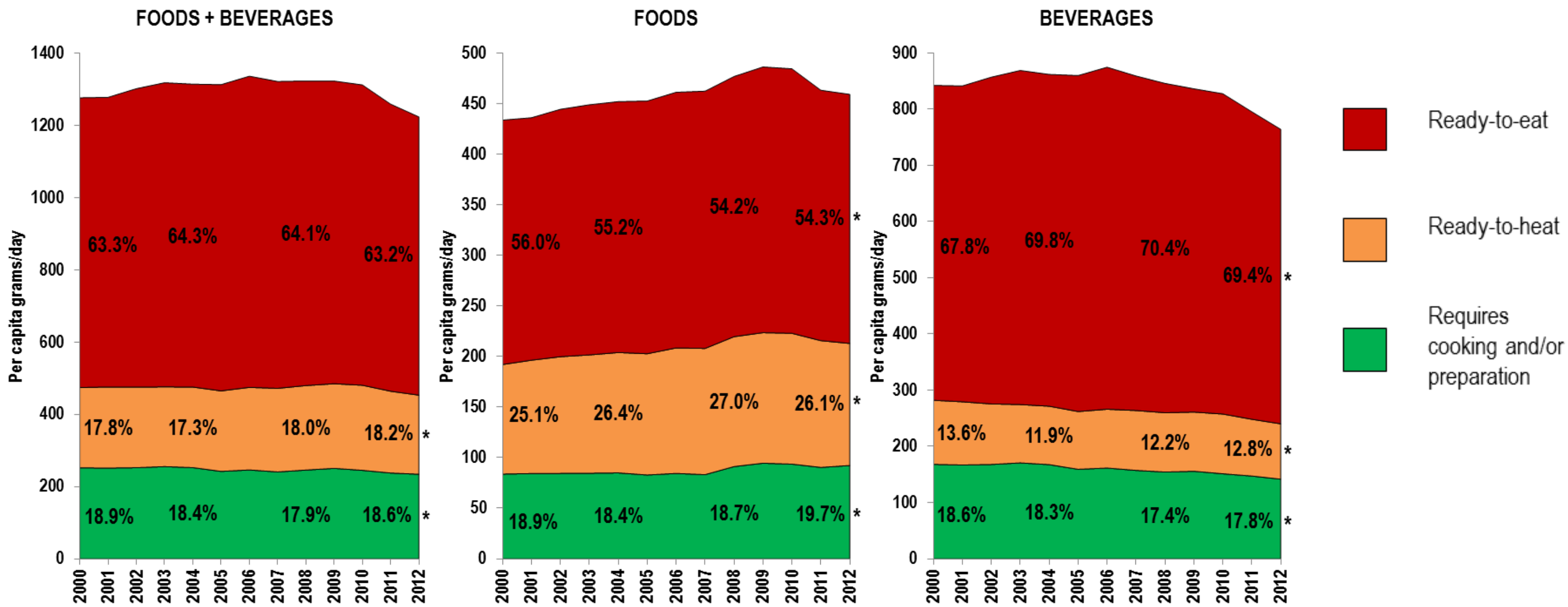
[3] "Ready-to-heat" includes products requiring minimal preparation.

Supplemental Figure 3.1. Trends in the contribution of processed foods and convenience foods to grams purchased among US households, Homescan 2000-2012[1]

A. Processing



B. Convenience

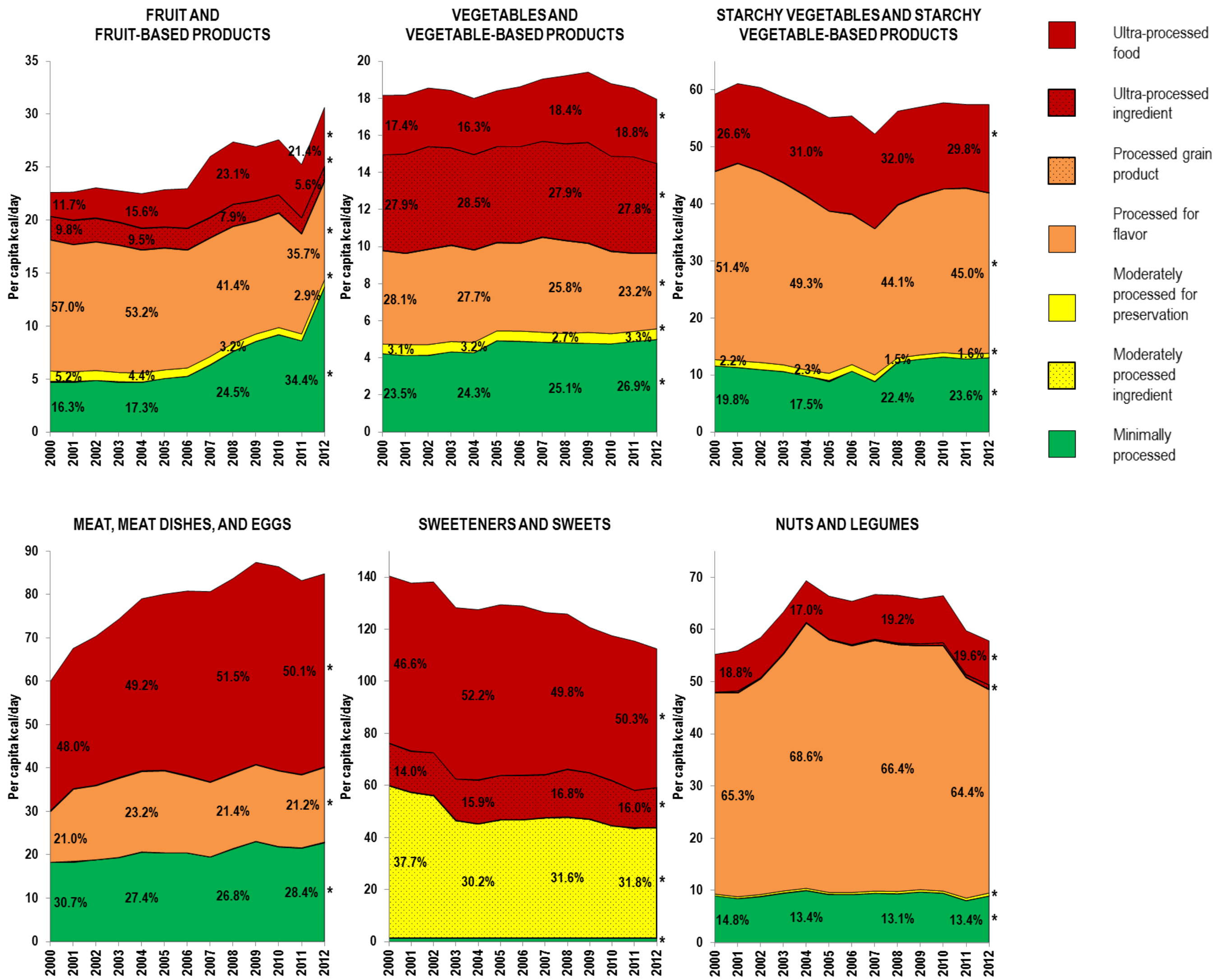


* Significant linear trend in % grams/d from given category of processing or convenience, determined using survey weighted linear regression models. *P*<0.001 to account for multiple comparisons and sample size.

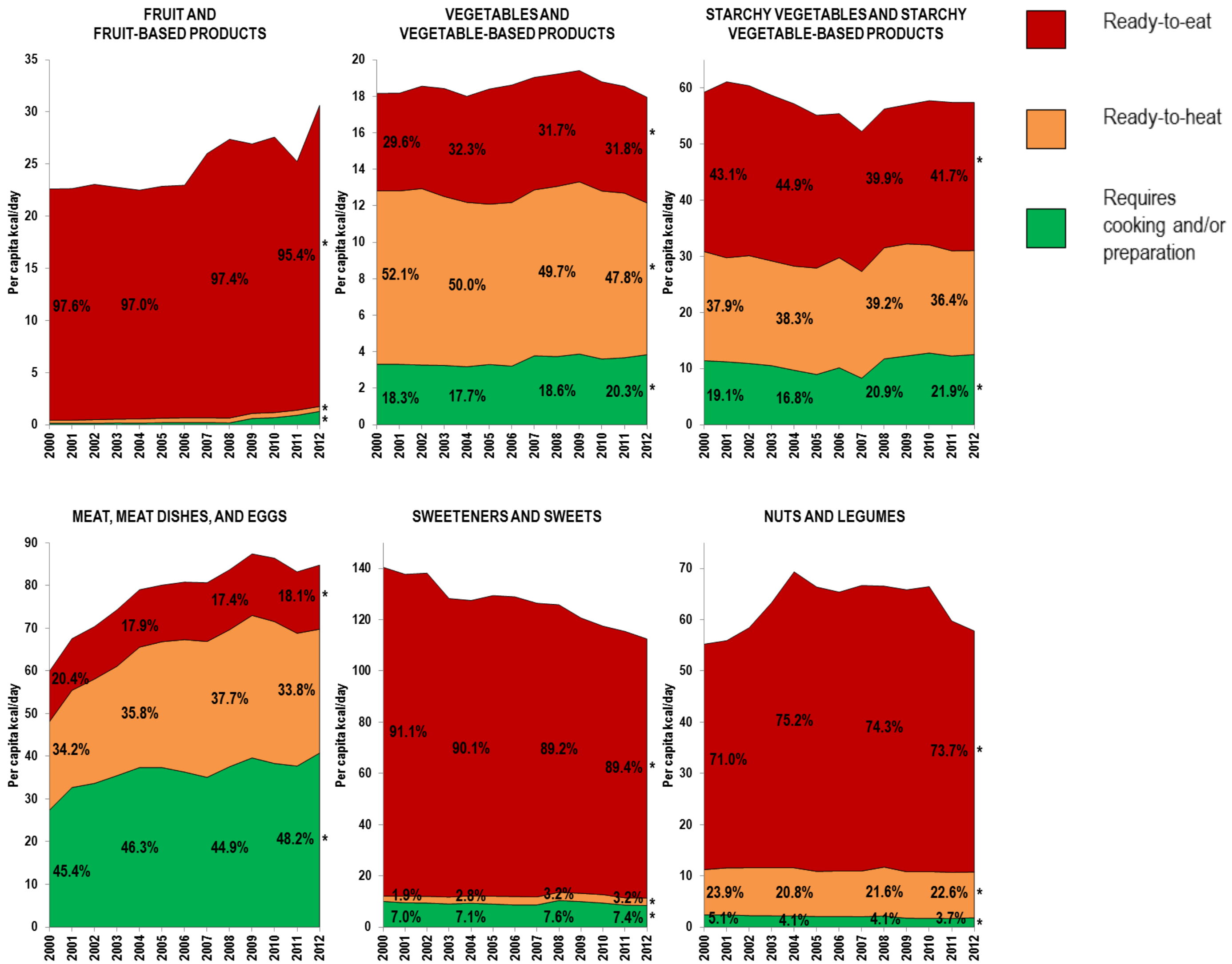
[1] Mean per capita g/d and % g/d purchased from each category of A) processing and B) convenience by year. Each uniquely barcoded food or beverage was classified into a mutually exclusive category for A) processing based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes and B) convenience based on the amount of food preparation required by the consumer before a product can be eaten. To ensure comparability across products, the volume of beverage concentrates (powdered mixes, coffee beans, and tea leaves) was adjusted to as-consumed form. Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods. All values are weighted to be nationally representative. Number of year-level observations and households: foods and beverages: n=656,184 (157,142 households); foods: n=656,172 (157,139 households); beverages: n=656,113 (157,139 households).

Supplemental Figure 3.2. Trends in the contribution of processed foods and convenience foods to calories purchased within food groups among US households, Homescan 2000-2012[1]

A. Processing



B. Convenience

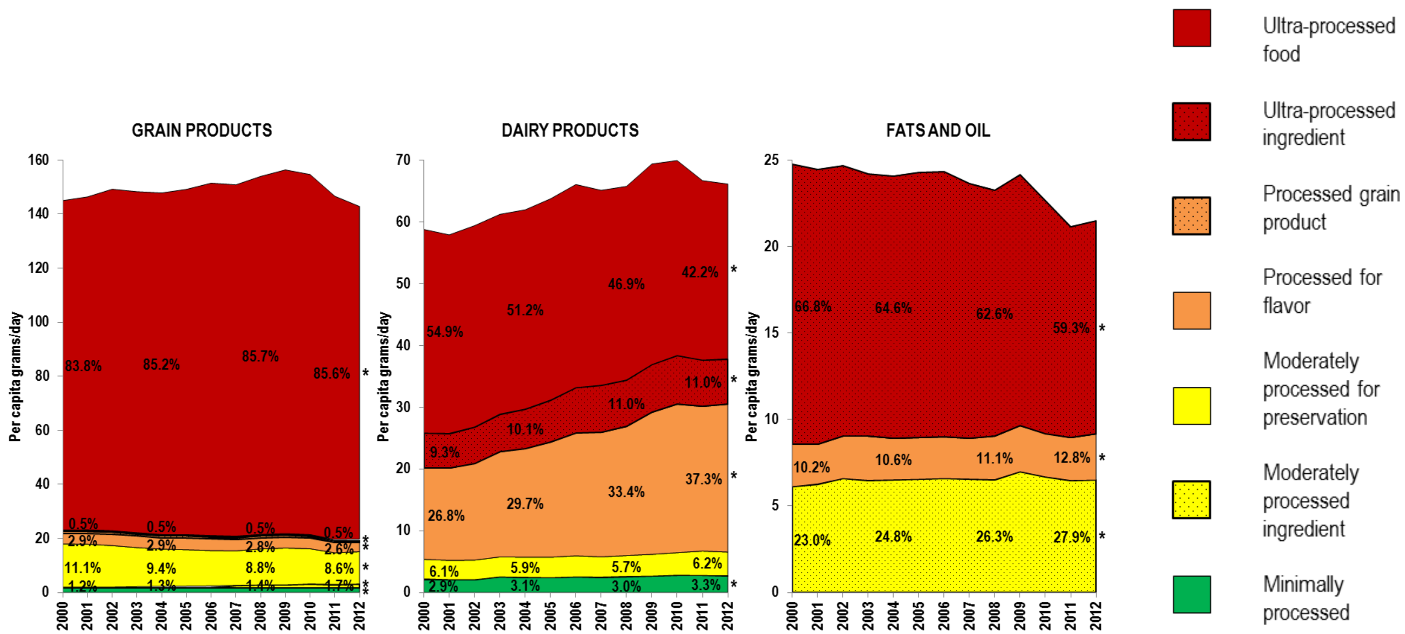


* Significant linear trend in % kcal/d from given category of processing or convenience, determined using survey weighted linear regression models. *P*<0.001 to account for multiple comparisons and sample size.

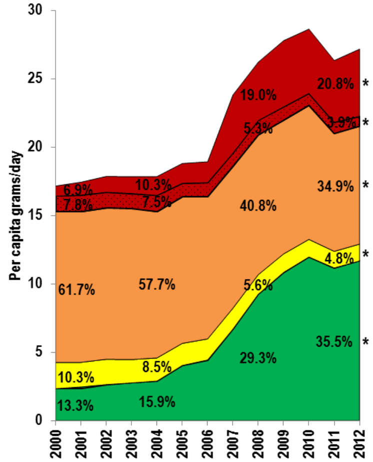
[1] Mean per capita kcal/d and % kcal/d of fruit/fruit products, vegetables/vegetable products, starchy vegetables/starchy vegetable products, meat/meat dishes/eggs, sweeteners/sweets, and nuts/legumes purchased from each category of A) processing and B) convenience. Each uniquely barcoded food or beverage was classified into a mutually exclusive category for A) processing based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes and B) convenience based on the amount of food preparation required by the consumer before a product can be eaten. Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods. All values are weighted to be nationally representative. Number of year-level observations and households purchasing any products within a food group during a given year: fruit and fruit products n=643,092 (155,789 households); vegetables and vegetable products: n=652,476 (156,805 households); starchy vegetables and starchy vegetable products: n=651,770 (156,754 households); meat, meat dishes, and eggs: n=654,244 (156,935 households); sweeteners and sweets: n=653,595 (156,931 households); nuts and legumes: n=648,472 (156,281 households).

Supplemental Figure 3.3. Trends in the contribution of processed foods and convenience foods to grams purchased within food groups among US households, Homescan 2000-2012[1]

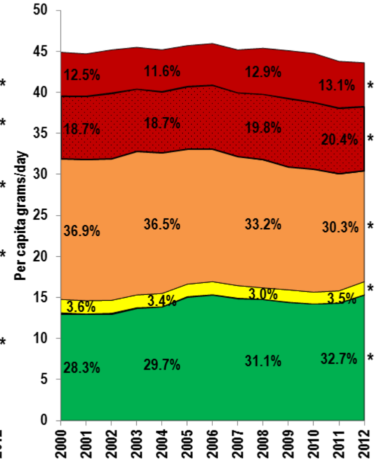
A. Processing



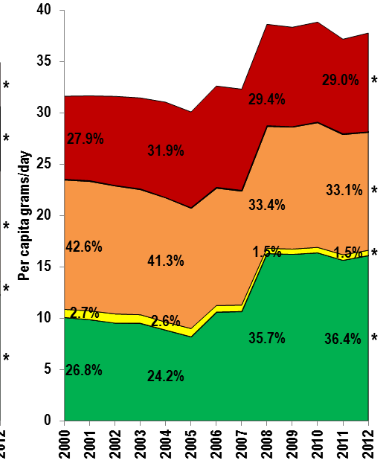
FRUIT AND
FRUIT-BASED PRODUCTS



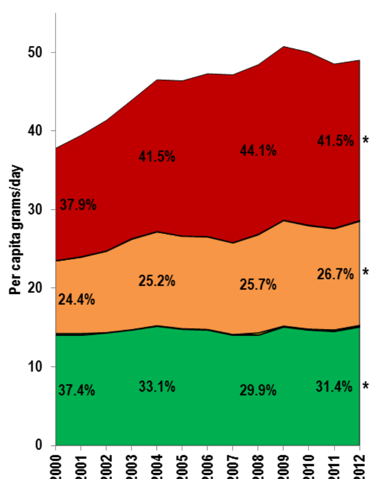
VEGETABLES AND
VEGETABLE-BASED PRODUCTS



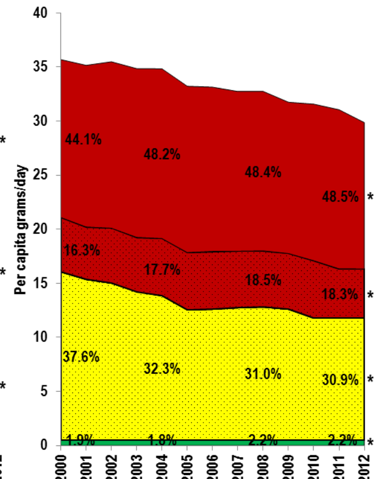
STARCHY VEGETABLES AND STARCHY
VEGETABLE-BASED PRODUCTS



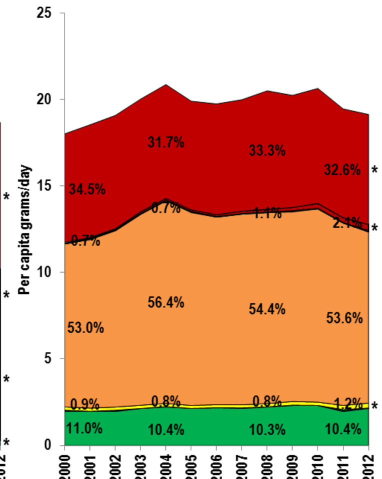
MEAT, MEAT DISHES, AND EGGS



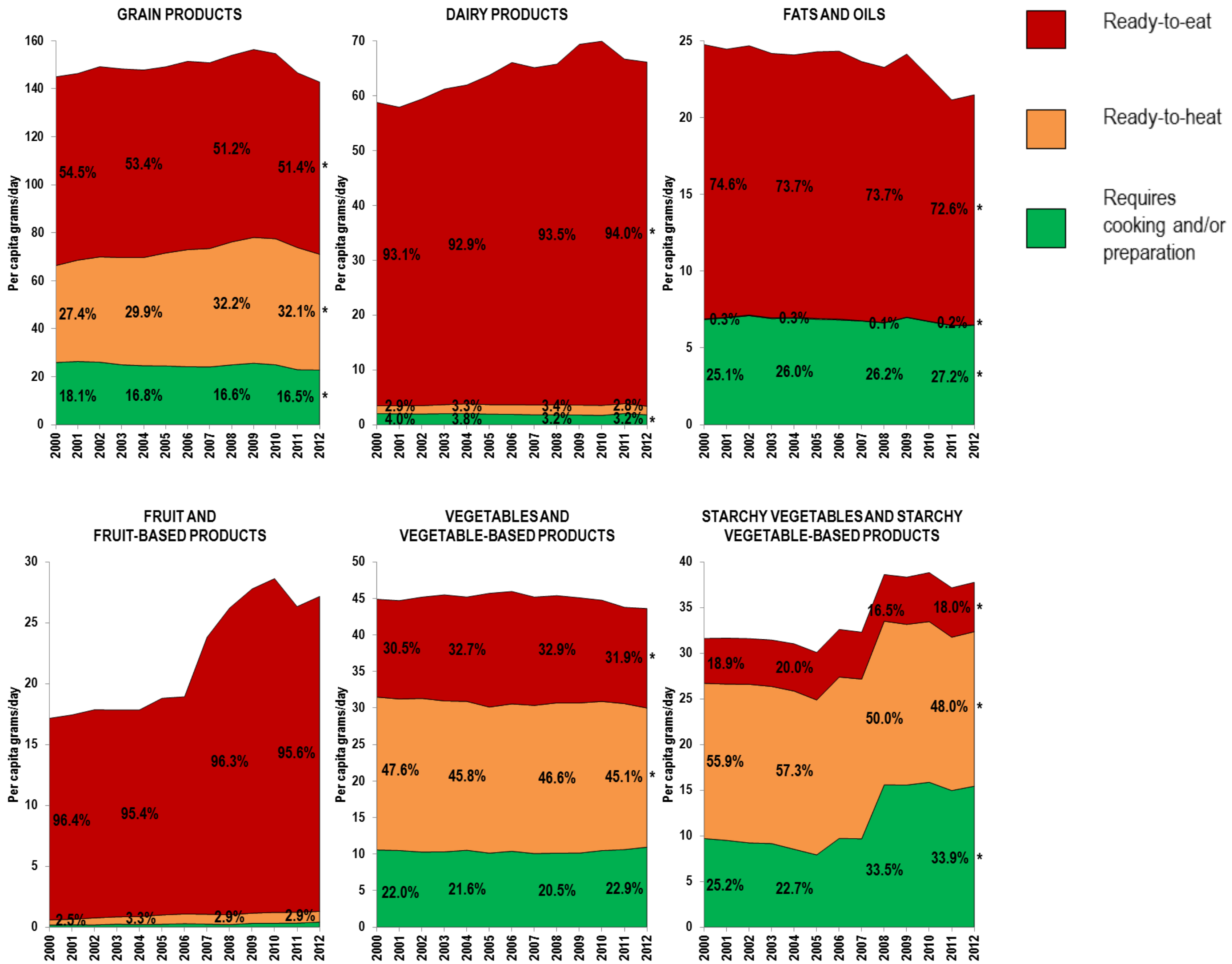
SWEETENERS AND SWEETS

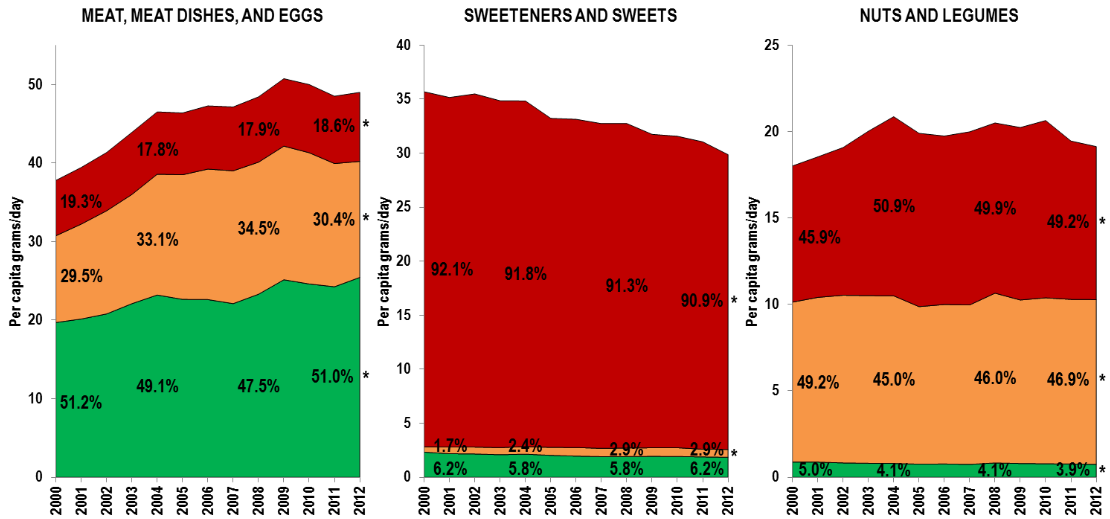


NUTS AND LEGUMES



B. Convenience





* Significant linear trend in % grams/d from given category of processing or convenience, determined using survey weighted linear regression models. *P*<0.001 to account for multiple comparisons and sample size.

[1] Mean per capita g/d and % g/d of grain products, dairy products, fats/oils, fruit/fruit products, vegetables/vegetable products, starchy vegetables/starchy vegetable products, meat/meat dishes/eggs, sweeteners/sweets, and nuts/legumes purchased from each category of A) processing and B) convenience. Each uniquely barcoded food or beverage was classified into a mutually exclusive category for A) processing based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes and B) convenience based on the amount of food preparation required by the consumer before a product can be eaten. To ensure comparability across products, the volume of beverage concentrates (powdered mixes, coffee beans, and tea leaves) was adjusted to as-consumed form. Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods. All values are weighted to be nationally representative. Number of year-level observations and households purchasing any products within a food group during a given year: grain products: n=656,113 (157,132 households); dairy products: n=654,883 (157,048 households); fats and oils: n=650,982 (156,679 households); fruit and fruit products: n=643,097 (155,790 households); vegetables and vegetable products: n=652,617 (156,817 households); starchy vegetables and starchy vegetable products: n=651,770 (156,754 households); meat, meat dishes, and eggs: n=654,286 (156,942 households); sweeteners and sweets: n=653,913 (156,949 households); nuts and legumes: n=648,508 (156,287 households).

Chapter 4. Ultra-processed and ready-to-eat food and beverage purchases differ by race/ethnicity, education, and income in a longitudinal study of US households

Overview

Sociodemographic disparities in dietary quality persist among Americans, but it is not clear whether processed foods contribute to differences in diet across vulnerable subpopulations. We examined whether education, income, and race/ethnicity are independently associated with ultra-processed or ready-to-eat food and beverage purchases among US households and how these associations shifted within the past 15 years. We analyzed data from the 2000-2012 Homescan panel (n=157,142 households). Over 1.2 million barcoded products were classified by level of food processing and by level of convenience. Longitudinal random effects multivariable-adjusted regression models were used to examine time-varying associations of education, income, and race/ethnicity with the contribution of ultra-processed and ready-to-eat products to purchases. Multinomial logistic regression was used to compare the predicted probability of being in the highest quartile of processed food purchases across race/ethnic groups. The calorie contribution of ultra-processed products to food purchases was ≥58% for all subpopulations. Inverse associations of ultra-processed food purchases with education and income emerged across time as households of higher, but not lower, socioeconomic status shifted away from these foods. Compared to non-Hispanic white households, non-Hispanic black households had significantly higher ultra-processed beverage purchases yet lower ultra-processed food purchases. Blacks were significantly more likely than whites to be in the highest quartile for purchases of moderately processed foods (predicted probability: 45.8% vs 21.0%) and foods requiring cooking (41.3% vs 21.7%) and purchased more cooking oils and table sugar. Black and Hispanic race/ethnicities and lower education were associated with lower ready-to-eat convenience food purchases. Findings suggest that purchases of ultra-processed foods among less-educated and lower-income households and ultra-processed beverages among blacks may contribute to US diet disparities. Further research is needed to explore the implications of lower ultra-processed food purchases and higher purchases of moderately processed foods used in cooking among blacks.

Introduction

Sociodemographic disparities in obesity and nutrition-related chronic diseases among US children and adults have been well-documented.[38-41] Studies suggest that differences in dietary intake across race, ethnic, and socioeconomic groups may mediate these inequalities in health outcomes.[42-44] Of note, non-Hispanic black race/ethnicity, lower education, and lower income have been associated with worse adherence to dietary guidelines and lower diet quality;[43-46] further, evidence suggests these gaps remained unchanged or widened in recent years.[47-49]

Between-group differences in processed food intake may contribute to these disparities in diet, but have not been previously explored. Concurrent with the widening gap in dietary quality across sociodemographic subpopulations, traditional dietary patterns have been steadily replaced by industrially processed foods, such as soda, candy, cookies, salty snacks, and prepared meals.[7,12,96] This nutrition transition was driven by transnational food and beverage manufacturers who have harnessed rapid advancements in food processing technology to mass-produce and distribute processed products.[4,6,7,12] Leading health organizations and nutrition researchers conclude that excessive consumption of these processed foods may promote poor dietary quality, obesity, and related co-morbidities.[6,27,58-60]

Researchers define food processing by the extent and purpose of the processes used to convert whole unprocessed foods into manufactured food products.[20,21] Based on their level of processing, products are classified into categories ranging from minimally processed to ultra-processed.[17,19-21] Some, but not all, processed foods are manufactured to be ready-to-eat and may independently promote overconsumption by encouraging eating patterns that impair physiological satiation/satiety responses; thus, researchers may additionally separate dimensions of processing and convenience.[1,31,32,34,35] We recently reported that ultra-processed foods and beverages provided 61.0% of calories purchased by US households in a large nationally representative sample; furthermore, the majority of products (68.1%) were purchased in ready-to-eat form (Poti, Popkin, et al. unpublished observations). In line with our estimate, analysis of 2003-2008 NHANES data found that 57.3% of energy intake came from processed foods.[19]

However, it remains unknown whether race/ethnicity and socioeconomic status (SES) are associated with ultra-processed or ready-to-eat food purchases. Previous studies examining disparities in dietary intake have focused upon subpopulation differences in macronutrient or micronutrient intakes and diet quality, but many note that understanding the types of foods contributing to these disparities is needed to inform dietary guidelines, interventions, or policy efforts.[45,56,97] Examination of race/ethnic and socioeconomic variation in diet is often hindered by differential bias in self-reported dietary intakes and lack of race/ethnic appropriate food composition databases; therefore, food purchasing data recorded by barcode scanning may provide valuable insight.[43,44,56] Further, it is unclear how associations may have changed across time, so adjusted time trends may yield better understanding of increasing disparities.

To address these gaps in the research literature, we aimed to determine the longitudinal association of sociodemographic and economic characteristics with the contribution of ultra-processed and ready-to-eat products to food and beverages purchases among a large nationally representative sample of US households.

Subjects and Methods

Study population:

This analysis used data from the 2000-2012 Nielsen Homescan Panel, an unbalanced longitudinal cohort of US households who use barcode scanners to record all food and beverage purchases brought into the home.[83] Purchases from grocery, drug, mass-merchandise, club, supercenter, and convenience stores and supermarkets were recorded for ≥10 months/year for up to 13 years (mean 4.2 y). Each year, approximately 30,000 to 65,000 households were sampled from 76 geographic markets (52 metropolitan and 24 nonmetropolitan areas). Household characteristics were assessed by questionnaire and included race-ethnicity, education level of the male and female head of household, income, and each participant's age and gender. We excluded purchases during quarters deemed unreliable by study investigators and year-level observations for households reporting >1 unreliable quarter during a given year (2.2%) to best capture shopping habits and usual diet.[76,77] The final analytic sample included 656,184 household-year level observations (157,142 unique households with 435,949 individuals) from 2000-2012. As secondary data analysis, this study was exempt from institutional review board approval.

Dietary data:

Households scan the barcode of each food or beverage purchased, which is linked to detailed product- and brand-specific attributes, including flavor (plain or cinnamon spice oatmeal), formula (low-fat or regular cheese), type (whole-wheat vs enriched wheat flour), product (green peas vs black-eyed peas), or salt content (regular or low-sodium). As reported previously, each barcode was linked to a corresponding Nutrition Facts Panel using data from sources including the Mintel Global New Products Database to obtain the product's calorie content and ingredient list as well as all information appearing on its package.[76,77,84] For each year, ~300,000 barcoded products were linked in this way to their nutrient content.

Nielsen organized similar products into 623 "modules" that primarily reflect placement of products within grocery stores (e.g., "fruit – dried or snacks," "dinners – frozen"). Thus, we re-organized all products at the barcode-level into 45 food and beverage groups reflecting nutritional content and consumption patterns using product attributes and ingredient lists (Poti, Popkin, et al., unpublished observations).

Processing and convenience classification system:

In previous work, we developed a multidimensional classification system for categorizing foods and beverages by degree of food processing and separately by level of convenience; a detailed description of this system is available elsewhere and described in brief below (Poti, Popkin, et al., unpublished observations).

Processing:

Each scanned barcoded item was assigned to one of four mutually exclusive categories of food processing based upon the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes (**Supplemental Table 4.1**).[21] Additional processing steps by the consumer after purchase, such as cooking raw meat or baking, were not considered. Our classification system for food processing was based upon previous work by Monteiro and colleagues in Brazil, but with modifications to adapt category definitions and example foods for the complexity of the US food supply and enhanced detail provided by dietary recall or purchase data.[20,27]

"Minimally processed" products are defined as single ingredient foods and beverages that have undergone no or slight modifications that do not change the properties of the food as found in its natural unprocessed form. Milk, fresh fruits and vegetables, eggs, and unseasoned meat are key examples.

"Moderately processed" products have undergone physical or chemical processing but remain as single foods and are divided into two subcategories. "Moderately processed ingredients" are isolated food components extracted or purified from minimally processed foods; examples include sugar, oil, or whole-grain flour.[27] Products "moderately processed for preservation or pre-cooking" are minimally processed foods modified by preservation methods, such as canning or non-alcoholic fermentation, or by partial cooking. Fruits or vegetables canned with no additional flavoring steps, plain yogurt, refined-grain flour or pasta, and white or instant rice are included.

"Processed" products are separated into two subcategories. Products "processed for flavor" are primarily composed of minimally or moderately processed foods with added moderately processed ingredients, combined for the purpose of enhancing flavor but not changing the inherent properties of the food. Their main ingredient is a whole unprocessed food. Salted nuts, fruit canned in syrup, and cheese are examples. "Processed grain products" were defined as breads, tortillas, breakfast cereals, and crackers made from whole-grain flour without addition of sweeteners or fats.

"Ultra-processed" products are multi-component mixtures of combined ingredients so extensively processed that they no longer resemble the unprocessed form of their component foods. Two subcategories were defined. “Ultra-processed ingredients” are ultra-processed products typically consumed as condiments, sauces, or ingredients in mixed dishes; examples are mayonnaise, margarine, ketchup, and pasta sauce. “Ultra-processed products not consumed as additions” include white bread, cookies, sugar-sweetened beverages (SSBs), candy, ice cream, and pre-prepared mixed dishes.

Convenience:

To separately classify foods and beverages by convenience, each product was assigned to one of three mutually exclusive categories based on the amount of food preparation required by the consumer before the product can be eaten or drunk (**Supplemental Table 4.2**). The length of active preparation time and the amount of the consumer’s culinary skill, energy, and attention needed to prepare a product for consumption were considered.[1]

Products requiring “cooking and/or preparation” are not typically consumed as purchased, but first require significant input of the consumer’s time, culinary skill, energy, or attention to cook or prepare before consumption. Examples include eggs, raw meat, fresh potatoes, dried beans, dry pasta, flour, cake mixes, or boxed macaroni-and-cheese mixes.

Products “ready-to-heat or requiring minimal preparation” cannot be consumed as purchased, but their preparation requires only a small amount of the consumer’s time or effort and no culinary skill or attention. Examples include frozen dinners or pizza, frozen waffles, canned soup, hot dogs, instant oatmeal, canned or frozen vegetables, and powdered drink mixes.

“Ready-to-eat” products can be consumed immediately with no preparation,[35] and this category includes bread, salty snacks, pre-made cookies, candy, fruit, and ready-to-drink beverages. Products that can be consumed as-purchased or used in cooking, such as sugar or butter, were categorized based on the most minimal preparation typically required.

Classification at the barcode-level:

Each of 1,230,536 unique barcoded food or beverage products purchased over the 2000-2012 period was classified into a single category for level of processing and separately to a single category for level of convenience. Classification was facilitated by using the Perl-based pattern matching syntax “regular expressions” within SAS version 9.3 (SAS Institute) to search ingredient lists, product attributes, and package information for keywords pertinent to processing or convenience level. Over 615,000 products were manually reviewed to ensure accuracy of classification.

Statistical analyses:

All statistical analyses were performed using Stata 13 (Stata Corp). To examine the association of ultra-processed or ready-to-eat food and beverage purchases with sociodemographic and economic household characteristics, we used multivariable-adjusted longitudinal random effects linear regression models. Outcomes were expressed as a percentage of purchases to control for differences in absolute calories purchased among households with different sociodemographic characteristics. Models regressed the percentage of calories purchased from a given food category on indicator variables for education (determined by the highest level of education attained by either the male or female head of household and categorized as less than high school, high school diploma, and college degree or higher), income (<$25,000; $25,000-$49,999; $50,000-$74,999; and ≥$75,000), and race/ethnicity (non-Hispanic white [white], non-Hispanic black [black], Hispanic, and non-Hispanic other races). Separate models were run for each category of processing and convenience, separately for foods (expressed as a percentage of food calories purchased) and beverages (as a percentage of beverage calories purchased). To determine whether associations between purchases and sociodemographic factors varied across time, we used Wald chunk tests for the joint significance of interaction product terms with significance set at $\alpha=0.05$. Significant interactions were detected between time and education, income, and race/ethnicity with $P<0.001$ for all models, except for the time by education interaction for the outcome ready-to-eat foods ($P=0.11$). Therefore, all interaction terms were retained in the final models. We used Stata's margins command to determine the adjusted outcome value (% kcal from processed or convenience foods) for each sociodemographic group. The association between processed or convenience food purchases and sociodemographic characteristics was assessed using conditional marginal effects in 2000 and in 2012 from the fully interacted model. Time trends from 2000 to 2012 were assessed by determining the marginal effect of year (2012 vs 2000) for each sociodemographic group and compared across subpopulations using postestimation Wald tests.

Additional analyses are presented only for race/ethnicity because this factor predicted substantial differences in processed and convenience food purchasing. To assess how race/ethnicity was associated with purchases of processed or convenience products in the extremes of the distribution during the most recent time point (2012), we used multinomial logistic regression models regressing quartile of processed or convenience food purchases (% kcal) on indicator variables for race/ethnicity. Beta coefficients from the fully adjusted model were used to determine the predicted probability of being in the highest quartile of processed or convenience food purchases (Stata's margins command) for each race/ethnic group, and pairwise group comparisons were made using Wald tests.

To identify key processed or convenience foods that varied across sociodemographic subpopulations, initial descriptive analysis used Stata's survey commands to provide unadjusted weighted estimates of food group purchases (per capita kcal/d) for all 45 food groups within each processing or convenience category for each sociodemographic group (results not shown). For each food group contributing to differences across sociodemographic groups (>15 kcal/d for foods and >5 kcal/d for beverages), multivariable-adjusted linear regression models were used to determine the adjusted mean purchases within each subpopulation in 2012. If >15% of households had zero purchases of a food group, a two-part regression model was used; the first part modeled the probability of purchasing any products within the food group using a probit binary choice model, and the second part modeled the distribution of the amount purchased among consumers using linear regression.

All models included education, income, and race/ethnicity simultaneously to estimate associations for each sociodemographic characteristic controlling for the other factors. All models were adjusted for household composition (single adult with no children, single adult with children, multiple adults with no children, and multiple adults with children), the interaction of household composition and time ($P<0.001$), household size, the age and gender of each household member, geographic market, and market-level unemployment rate. For all analyses, statistically significant differences were tested using a two-sided P value of 0.001 to account for multiple comparisons and large sample size.

Results

Characteristics of the study population and subgroup sample sizes are presented in **Supplemental Table 4.3**. In 2000, lower household education and income were associated with lower contributions of ultra-processed products to food purchases (**Figure 4.1A and 4.1B**). However, college-educated and higher-income households significantly decreased their ultra-processed food purchases between 2000 and 2012, while less-educated and lower-income households did not. Thus, the direction of these associations reversed; in 2012, the percent contribution of ultra-processed foods to purchases was significantly greater among less-educated and lower-income households compared to more-educated and higher-income households, respectively. Greater calorie contributions of refined breads and quick breads, grain-based desserts, margarine and shortening, and processed meat contributed to these associations (**Supplemental Tables 4.4 and 4.5**). By convenience level, lower household education was significantly associated with a lower contribution of ready-to-eat foods to calories purchased (**Figure 4.2A**), primarily because of a greater relative contribution of foods requiring or used in cooking (such as oil and shortening) and ready-to-heat foods among these households compared to college-educated households (**Supplemental Table 4.6**). Differences in ready-to-eat foods by income level were minor (**Figure 4.2B**). Associations of education and income with ultra-processed or ready-to-eat food purchases were small in magnitude, yet meaningful; for example, because of dissimilarities in total calories purchased, the small percent difference in ultra-processed food purchases between less-educated and college-educated households translated to a 155 kcal/d disparity.

Adjusting for other sociodemographic factors, race/ethnicity was significantly associated with ultra-processed food purchases (**Figure 4.1C**). In 2012, the calorie contribution of ultra-processed foods to purchases was 4.1 percentage points lower (95% CI: -4.4, -3.8) among black compared to white households, despite small but significant declines between 2000 and 2012 among whites but not blacks. In contrast, moderately processed food purchases were 5.4 percentage points higher (95% CI: 5.2, 5.6) among black households (**Supplemental Figure 4.1**). The predicted probability of being in the highest quartile of moderately processed food purchases was significantly higher among black (45.8%) and Hispanic (31.6%) households compared to white households (21.0%) in 2012 (**Table 4.1**). Top food group contributors to these differences among race/ethnic groups are presented in **Table 4.2**. Lower purchases of grain-based desserts, candy, salty snacks, and dairy-based desserts among black and Hispanic households contributed to differences in ultra-processed food purchasing. Moderately processed food purchases differed primarily because of greater purchases of cooking oil and rice among black and Hispanic households; higher purchases of table sugar among blacks also contributed.

By level of convenience, race/ethnicity was significantly associated with the contribution of ready-to-eat foods to household purchases (**Figure 4.2C**). In particular, ready-to-eat food purchases were lower among black households (-4.9 percentage points; 95% CI: -5.1, -4.7) compared to white households in 2012. For both black and Hispanic households, lower purchases of candy, nuts and peanut butter, and grain-based desserts contributed to differences in the share of ready-to-eat foods compared to whites; additionally, black households bought less cheese and salty snacks while Hispanic households bought less butter and margarine (**Table 4.3**). Conversely, black (41.3%) and Hispanic (34.0%) households were significantly more likely to be in the highest quartile of foods requiring cooking and/or preparation compared to whites (21.7%, Table 4.1). Of note, black households purchased 4.5 percentage points (95% CI: 4.3, 4.7) more of their food calories from products requiring cooking or preparation compared to white households (**Supplemental Figure 4.2**); greater purchases of cooking oil and shortening, uncooked processed meat (among blacks), and rice (especially among Hispanics) largely explained these differences.

For beverages, black households had a significantly higher mean contribution of ultra-processed drinks to beverage calories (7.1 percentage points in 2012; 95% CI: 6.6, 7.7) compared to whites, although a significant decrease occurred between 2000 and 2012 for black but not for white households (**Figure 4.3D**). Further, the caloric share of minimally processed beverages was 11.3% lower (95% CI: -11.8, -10.8) among black households compared to white households (**Figure 4.3A**), following significantly greater declines in minimally processed beverages for black compared to white households from 2000-2012. The predicted probability of being in the highest quartile of minimally processed beverage purchases was significantly lower for black vs white households (8.6% vs 27.3%) in 2012 (Table 4.1). Higher SSB and lower plain milk purchases among blacks were the primary contributors to caloric differences in beverage purchases among race/ethnic subpopulations (Table 4.2).

Discussion

Using data from a large longitudinal panel of US households and product-specific nutrition information for over 1.2 million items, this study provides novel evidence that ultra-processed food and beverage purchases may contribute to sociodemographic disparities in diets of Americans. For every education, income, and race/ethnic group, ultra-processed foods provided the majority (~60%+) of calories purchased. Inverse associations of ultra-processed food purchases with education and income emerged across time as households of higher SES shifted away from these foods. Among black households, we observed a striking contrast in purchasing patterns of foods vs beverages, including higher ultra-processed beverages yet lower ultra-processed foods compared to whites. A distinct finding was that, compared to whites, black and Hispanic race/ethnicities were significantly associated with *lower* contributions of ultra-processed and ready-to-eat products to food purchases, yet greater contributions of foods that were moderately processed (such as cooking oils and table sugar) and foods requiring cooking. Black and Hispanic race/ethnicities and less education were associated with lower contributions of ready-to-eat convenience foods to purchases, suggesting a greater role of food preparation and cooking in these groups.

In our nationally representative US sample, the mean proportion of calories purchased from ultra-processed foods was >50% for every population subgroup. Studies found ultra-processed products collectively were higher in saturated fat, added sugar, sodium, and energy density compared to less-processed foods.[14,21] Thus, our finding seems consistent with low adherence to dietary guidelines reported among all Americans, regardless of SES.[45-47] Excessive consumption of ultra-processed foods may promote poor health outcomes as a consequence of their unfavorable nutrient content as well as their hyperpalatability, which has been linked to neurobiological and behavioral features of addiction.[6,12,62] Recent studies reported that a higher contribution of ultra-processed foods in the diet was associated with obesity and metabolic syndrome.[22,66,67]

We found that lower education and income were associated with higher ultra-processed food purchases. No prior estimates are available for comparison, but our results are compatible with lower dietary quality index scores, higher added sugar intakes, and lower fruit and vegetable consumption reported among individuals with low SES.[44-47,97] In our study, although differences across groups were small, trends analysis indicated that households with higher SES continued to decrease ultra-processed food purchasing across time, whereas no improvements were observed among less-educated and lower-income households. This finding is consistent with recent work reporting significant improvements in dietary quality between 1999-2010 among high-, but not low-, SES groups; consequently, disparities between these groups widened.[47] Another study found associations of SES with energy density and caloric beverage intake reversed across time among US children, resulting in inverse associations in 2008.[49] SES differentials in dietary intakes may reflect differences in economic constraints or access to healthful foods.[42,44]

Previous research reported poor adherence to dietary guidelines among blacks; however, the types of foods contributing to race/ethnic differences were not examined.[46,48,56] Unexpectedly, in our sample, controlling for education and income, black households had lower purchases of ultra-processed and ready-to-eat foods, including grain-based desserts, candy, and salty snacks, and higher purchases of moderately processed cooking oils and table sugar, compared to whites. Moubarac et al. suggest that, although moderately processed foods are energy dense, they are consumed in combination with minimally processed foods in dietary patterns that have more favorable nutrient profiles compared to diets high in ultra-processed products.[14] Conversely, other researchers suggest that variation in dietary traditions and cultural methods of preparation, particularly frying or seasoning vegetables with fat, may mediate racial disparities in diet quality.[43,98-100] We consistently found higher purchases of fats, such as cooking oil or shortening, and sugar among black, less-educated, and lower-income households, despite differing ultra-processed food purchase levels. Further research is necessary to replicate our findings and explore interactions of ultra-processed foods with moderately processed food patterns indicative of home food preparation.

Higher ultra-processed beverage purchases among blacks in our study are consistent with higher consumption of SSBs and consequent higher added sugar intakes previously reported among black children and adults.[52,53,101,102] In addition, we found lower purchases of minimally processed beverages, primarily plain milk, among black compared to white households. In agreement, nationally representative studies reported significantly lower calcium intakes and prevalence of meeting milk recommendations among blacks vs whites, which may arise from cultural preferences or lactose intolerance.[45,46,48] Higher SSB consumption and lower milk intake have each been separately associated with increased weight gain.[103,104] Additional studies are needed to determine whether an overall beverage pattern defined by processing level, reflecting both higher SSB and lower milk intakes, contributes to diet and health disparities among blacks.

In our sample, Hispanic ethnicity was associated with lower contributions of ultra-processed foods to purchases and no difference in ultra-processed beverages compared to whites. These findings are consistent with higher dietary quality index scores, more favorable biomarkers of micronutrient status, and greater compliance with fruit and vegetable recommendations reported among this population.[43,45-47] However, this profile is not observed among all subgroups of Hispanics, and scholars suggest that combining this heterogeneous group of individuals into a single category may obscure important differences in diet that contribute to differential health outcomes.[57] Further research is needed to understand how diet may be related to higher obesity prevalence in Hispanics, and this work may be facilitated by recognizing the variation in diet across Hispanic or Latino backgrounds.[57]

Independent from processing, ready-to-eat convenience foods may encourage rapid eating rate and eating while attention is distracted, such as while watching television; these eating behaviors may lessen neurophysiological satiating effects and impair satiety responses, respectively.[1,31,32,34,35] Although evidence is limited, higher convenience food intake has been associated with overweight.[72,73] However, we found that lower education and black race/ethnicity were associated with a lower contribution of ready-to-eat foods to purchases. Consistent with our results, studies have found adults with lower income or education are more likely to cook, while higher SES was associated with higher consumption of convenience and ready-to-eat foods.[44,105-108]

A key limitation of this study is that households do not report whether all purchases were consumed. However, studies found greater waste among perishable minimally processed foods and beverages that may lead to underestimation of the caloric share of ultra-processed products; nonetheless, the amount of food waste may vary across household size, race/ethnicity, and income level.[21,109] Foods without barcodes or nutrition labels could not be scanned, but this includes both minimally processed items (random-weight fresh produce or meat) and ultra-processed items (deli meats and cheeses, bakery products, and store-prepared ready-to-eat/ready-to-heat foods). Additionally, households do not report food away-from-home, which has been associated with race/ethnicity and SES.[110] Therefore, our findings apply only to purchases of packaged goods and may not be generalizable to total diet. Findings from this nationwide sample may not translate to the general US population because of potential selection bias related to participant burden.[95] Although misreporting is possible, the accuracy of the Homescan data is comparable to other commonly used economic datasets.[81]

A major strength of our study is use of objective scanning of product barcodes, which may be advantageous for monitoring sociodemographic differences in diet because race/ethnicity and SES are likely associated with underreporting.[42-44,56] Use of item-specific nutrition information likely improves accuracy by capturing ethnic variation in preferred products.[43,56] Year-level purchases may better reflect seasonal variation and usual diet.

In conclusion, this study provides new evidence suggesting that higher ultra-processed food purchases among less-educated and lower-income households and higher ultra-processed beverage purchases among blacks may contribute to sociodemographic disparities in diets of Americans. Higher moderately processed foods and foods requiring cooking, coupled with lower ultra-processed and ready-to-eat foods, represent novel patterns among black households that suggest dietary traditions, culture, and food preparation methods may mediate between-group differences. Further investigation is warranted to examine how these patterns may contribute to disparities in dietary quality and health of vulnerable populations.

Tables and Figures

Table 4.1. Multivariable adjusted predicted probability (95% CI) of being in the highest quartile of purchases within each category of processed or convenience foods by race/ethnicity, Homescan 2012[1]

		Predicted probability (95% CI) of being in Q4 of purchases[2]		
	Q4 range (median)	**Non-Hispanic white**	**Non-Hispanic black**	**Hispanic**
Processing[3]				
Foods[4]				
Minimally processed	≥10.1% kcal (13.6% kcal)	23.7 (12.9, 34.4)[b]	24.7 (13.5, 35.8)[b]	28.8 (16.4, 41.2)[a]
Moderately processed	≥17.5% kcal (23.4% kcal)	21.0 (13.0, 29.1)[c]	45.8 (33.4, 58.1)[a]	31.6 (20.9, 42.3)[b]
Processed	≥21.4% kcal (25.5% kcal)	25.4 (11.2, 39.6)[a]	19.0 (7.5, 30.4)[b]	18.8 (7.3, 30.3)[b]
Ultra-processed	≥70.5% kcal (75.9% kcal)	26.7 (20.0, 33.3)[a]	15.2 (10.7, 19.8)[c]	19.8 (14.2, 25.4)[b]
Beverages[5]				
Minimally processed	≥50.6% kcal (66.0% kcal)	27.3 (11.5, 43.2)[a]	8.6 (2.3, 14.8)[c]	23.2 (8.9, 37.4)[b]
Moderately processed	≥12.0% kcal (21.2% kcal)	24.0 (10.6, 37.4)[b]	30.9 (15.5, 46.3)[a]	25.0 (11.3, 38.7)[b]
Processed	≥16.3% kcal (26.9% kcal)	23.2 (16.5, 29.9)[c]	34.4 (25.8, 43.0)[a]	28.3 (20.5, 36.2)[b]
Ultra-processed	≥66.9% kcal (80.4% kcal)	24.1 (6.4, 41.8)[ab]	32.7 (11.7, 53.7)[a]	21.2 (5.1, 37.3)[b]
Convenience[6]				
Foods				
Requires cooking/preparation	≥24.7% kcal (30.0% kcal)	21.7 (13.2, 30.3)[c]	41.3 (28.8, 53.7)[a]	34.0 (22.5, 45.5)[b]
Ready-to-heat/minimal preparation	≥19.5% kcal (23.9% kcal)	24.9 (17.1, 32.7)[a]	26.5 (18.2, 34.7)[a]	21.9 (14.6, 29.3)[b]
Ready-to-eat	≥72.4% kcal (77.3% kcal)	26.0 (18.6, 33.4)[a]	14.8 (9.9, 19.7)[c]	20.4 (14.0, 26.8)[b]

[a,b,c] By row, values not sharing a common letter are statistically significantly differences across race/ethnicity, Wald test with $P<0.001$ to adjust for multiple comparisons and large sample size.

[1] Data from n=59,286 households participating in the 2012 Homescan panel of household purchases of consumer packaged goods.

[2] Values are the multivariable adjusted predicted probability (95% CI) of being in highest quartile of processed (minimally processed, moderately processed, processed, or ultra-processed) or convenience (requiring cooking, ready-to-heat, or ready-to-eat) food or beverage purchases among households in each race/ethnic group. Determined from multivariable multinomial logistic regression models regressing quartiles of the contribution (% kcal) of each category of processing or convenience to purchases on race/ethnicity, with adjustment for education, income, household composition, household size (number of household members in each age and gender category), and geographic market/market-level unemployment rate.

[3] Each bar-coded food was classified into a mutually exclusive category for processing based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes.

[4] For each category, households were divided into quartiles based on the percent contribution (% kcal) of foods classified into that category to total food purchases.

[5] For each category, households were divided into quartiles based on the percent contribution (% kcal) of beverages classified into that category to total beverage purchases.

[6] Each bar-coded food was separately classified into a mutually exclusive category for convenience based on the amount of food preparation required of the consumer before a product can be eaten. Beverages not shown since >90% kcal are ready-to-eat.

Table 4.2. Daily per capita purchases for top food group contributors to differences in processed food purchasing by race/ethnicity, Homescan 2012[1]

	Daily per capita purchases[2] Adjusted mean ± SE			Marginal effect of race[3] β (95% CI)		
	NH white	**NH black**	**Hispanic**	**NH white**	**NH black**	**Hispanic**
Total (Foods + Beverages)	**1297 ± 3.2**	**1230 ± 9.8***	**1205 ± 13.1***	**Ref**	**-67 (-88, -47)**	**-92 (-119, -66)**
Foods	**1128 ± 3.0**	**1064 ± 9.0***	**1046 ± 12.0***	**Ref**	**-64 (-83, -45)**	**-82 (-107, -58)**
Minimally Processed	**88 ± 0.4**	**86 ± 1.2**	**89 ± 1.6**	**Ref**	**-2 (-5, 0)**	**1 (-2, 4)**
Eggs	18 ± 0.1	20 ± 0.3*	20 ± 0.4*	Ref	2 (1, 2)	2 (1, 3)
Moderately Processed	**139 ± 0.7**	**202 ± 2.2***	**163 ± 2.9***	**Ref**	**63 (58, 68)**	**24 (18, 30)**
Fats/oils (oil, unsalted butter)	46 ± 0.3	85 ± 1.1*	60 ± 1.4*	Ref	39 (37, 42)	14 (11, 17)
Sweeteners (table sugar)	43 ± 0.3	60 ± 1.1*	42 ± 1.3	Ref	17 (15, 19)	-1 (-4, 2)
Rice (white or instant)	7 ± 0.1	13 ± 0.4*	20 ± 0.6*	Ref	7 (6, 7)	13 (12, 15)
Processed	**200 ± 0.7**	**170 ± 2.0***	**174 ± 2.7***	**Ref**	**-30 (-34, -25)**	**-26 (-31, -20)**
Nuts (salted/nut butters)	43 ± 0.2	31 ± 0.7*	34 ± 1.0*	Ref	-12 (-14, -11)	-9 (-11, -7)
Cheese	36 ± 0.2	22 ± 0.5*	32 ± 0.6*	Ref	-14 (-15, -13)	-5 (-6, -4)
Ultra-processed	**701 ± 2.1**	**606 ± 6.4***	**619 ± 8.6***	**Ref**	**-95 (-108, -82)**	**-82 (-99, -64)**
Grain-based desserts	101 ± 0.4	84 ± 1.3*	88 ± 1.7*	Ref	-17 (-20, -15)	-13 (-16, -9)
Breads/quick breads	98 ± 0.4	94 ± 1.1*	100 ± 1.5	Ref	-4 (-7, -2)	2 (-1, 5)
Candy/sweet snacks	75 ± 0.4	58 ± 1.2*	61 ± 1.6*	Ref	-17 (-20, -15)	-14 (-17, -11)
Salty snacks	74 ± 0.3	59 ± 0.9*	67 ± 1.1*	Ref	-15 (-17, -13)	-7 (-9, -5)
Dairy-based desserts	38 ± 0.2	29 ± 0.6*	30 ± 0.9*	Ref	-9 (-10, -8)	-9 (-10, -7)
Pasta dishes	28 ± 0.5	18 ± 1.5*	21 ± 2.0*	Ref	-10 (-13, -7)	-7 (-11, -3)
Processed meat	27 ± 0.1	34 ± 0.4*	26 ± 0.6	Ref	7 (6, 8)	-1 (-2, 0)
Beverages	**169 ± 0.7**	**166 ± 2.2**	**159 ± 3.0**	**Ref**	**-3 (-8, 1)**	**-10 (-16, -4)**
Minimally Processed	**52 ± 0.3**	**30 ± 0.8***	**48 ± 1.1***	**Ref**	**-23 (-24, -21)**	**-4 (-7, -2)**
Milk	52 ± 0.3	29 ± 0.8*	48 ± 1.1*	Ref	-23 (-24, -21)	-4 (-7, -2)
Moderately Processed	**13 ± 0.1**	**15 ± 0.3***	**13 ± 0.4**	**Ref**	**2 (2, 3)**	**0 (0, 1)**
Fruit juice (unsweetened)	11 ± 0.1	14 ± 0.3*	12 ± 0.4	Ref	3 (2, 3)	1 (0, 1)
Processed	**16 ± 0.1**	**22 ± 0.4***	**19 ± 0.6***	**Ref**	**6 (5, 7)**	**3 (2, 4)**
Tea (sweetened/flavored)	4 ± 0.1	8 ± 0.3*	6 ± 0.3*	Ref	4 (3, 4)	2 (1, 3)
Ultra-processed	**88 ± 0.6**	**99 ± 1.9***	**79 ± 2.5***	**Ref**	**11 (7, 15)**	**-9 (-14, -4)**
SSBs	48 ± 0.4	67 ± 1.3*	51 ± 1.7	Ref	19 (16, 22)	3 (-1, 6)

	Daily per capita purchases[2] Adjusted mean ± SE			Marginal effect of race[3] β (95% CI)		
	NH white	**NH black**	**Hispanic**	**NH white**	**NH black**	**Hispanic**
Beer	12 ± 0.3	10 ± 0.8	12 ± 1.1	Ref	-2 (-3, 0)	0 (-2, 3)
Wine	11 ± 0.2	6 ± 0.6*	6 ± 0.8*	Ref	-5 (-6, -4)	-5 (-7, -3)
Liquor	9 ± 0.2	8 ± 0.7	6 ± 0.8*	Ref	-1 (-2, 1)	-3 (-5, -2)

* Significantly different than non-Hispanic white, Wald test with *P*<0.001 to adjust for multiple comparisons and large sample size.

[1] Data from n=59,286 households participating in the 2012 Homescan panel of household purchases of consumer packaged goods. Categories of processing are based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes. Food groups selected from preliminary unadjusted analysis as groups differing by ≥15 kcal (foods) or ≥5 kcal (beverages) across race/ethnic groups, as well as the top food group contributor to calories in each category. NH, Non-Hispanic; SSB, sugar-sweetened beverage.

[2] Values are the adjusted mean ± SE daily per capita household purchases of selected food groups within categories of processing. For food groups with <15% non-consumers, values are determined from multivariable adjusted linear regression models, regressing purchases (kcal/d) on race/ethnicity; for food groups with >15% zero non-consumers, values are determined from a 2-part model including 1) a probit model of the probability of purchasing and 2) linear regression of the amount purchased. All models are adjusted for education, income, household composition, household size (number of household members in each age and gender category), and geographic market/market-level unemployment rate. Stata's margins command was used to determine the adjusted mean outcome.

[3] Values are the difference in per capita household purchases between specified race/ethnic group and non-Hispanic white households. Determined from the fully adjusted model using Stata's margins command with the "dydx" option.

Table 4.3. Daily per capita purchases for top food group contributors to differences in convenience food purchasing by race/ethnicity, Homescan 2012[1]

	Daily per capita purchases[2] Adjusted mean ± SE			Marginal effect of race[3] β (95% CI)		
	NH white	**NH black**	**Hispanic**	**NH white**	**NH black**	**Hispanic**
Total (Foods + Beverages)	**1297 ± 3.2**	**1230 ± 9.8***	**1205 ± 13.1***	**Ref**	**-67 (-88, -47)**	**-92 (-119, -66)**
Foods	**1128 ± 3.0**	**1064 ± 9.0***	**1046 ± 12.0***	**Ref**	**-64 (-83, -45)**	**-82 (-107, -58)**
Requires cooking/preparation	**208 ± 0.8**	**254 ± 2.5***	**230 ± 3.4***	**Ref**	**46 (41, 52)**	**23 (16, 29)**
Fats/oils (oil, shortening)	45 ± 0.3	84 ± 1.1*	59 ± 1.4*	Ref	39 (37, 41)	14 (11, 17)
Processed meat (uncooked bacon and sausage)	12 ± 0.1	20 ± 0.3*	12 ± 0.3	Ref	8 (7, 8)	-1 (-1, 0)
Rice (dried uncooked)	6 ± 0.1	13 ± 0.5*	20 ± 0.7*	Ref	7 (6, 8)	14 (13, 16)
Ready-to-heat/minimal preparation	**180 ± 1.4**	**167 ± 4.1**	**156 ± 5.5***	**Ref**	**-13 (-22, -5)**	**-24 (-35, -13)**
RTH grain-based mixed dishes	26 ± 0.2	20 ± 0.5*	23 ± 0.7*	Ref	-6 (-7, -5)	-3 (-5, -2)
Ready-to-eat	**740 ± 1.8**	**644 ± 5.4***	**660 ± 7.2***	**Ref**	**-97 (-108, -86)**	**-81 (-95, -66)**
RTE salty snacks	98 ± 0.4	85 ± 1.1*	89 ± 1.5*	Ref	-13 (-15, -11)	-9 (-12, -6)
RTE breads/quick breads	75 ± 0.3	70 ± 0.9*	80 ± 1.2*	Ref	-6 (-8, -4)	5 (2, 7)
RTE grain-based desserts	75 ± 0.4	64 ± 1.1*	67 ± 1.4*	Ref	-11 (-13, -9)	-8 (-11, -5)
Candy/sweet snacks	68 ± 0.4	55 ± 1.2*	56 ± 1.6*	Ref	-13 (-15, -10)	-12 (-15, -9)
Sweeteners (sugar, syrups, jam, jelly)	50 ± 0.3	69 ± 1.0*	49 ± 1.4	Ref	18 (16, 20)	-1 (-4, 1)
RTE Fats/oils (butter, margarine)	49 ± 0.2	45 ± 0.7*	39 ± 0.9*	Ref	-4 (-5, -3)	-10 (-12, -9)
Nuts/nut butters	55 ± 0.3	41 ± 0.9*	44 ± 1.3*	Ref	-14 (-16, -12)	-11 (-13, -8)
Cheese	51 ± 0.2	33 ± 0.6*	44 ± 0.8*	Ref	-19 (-20, -17)	-7 (-9, -5)
RTE dairy-based desserts (ice cream, pudding)	37 ± 0.2	28 ± 0.6*	29 ± 0.8*	Ref	-9 (-10, -7)	-8 (-10, -6)

* Significantly different than non-Hispanic white, Wald test with $P<0.001$ to adjust for multiple comparisons and large sample size.

[1] Data from n=59,286 households participating in the 2012 Homescan panel of household purchases of consumer packaged goods. Categories of convenience based on the amount of food preparation required of the consumer before a product can be eaten. Food groups selected from preliminary unadjusted analysis as groups differing by ≥15 kcal across race/ethnic groups, as well as the top food group contributor to calories in each category. Beverages not shown because >90% kcal are ready-to-eat. NH, Non-Hispanic; RTE, ready-to-eat; RTH, ready-to-heat; SSB, sugar-sweetened beverage.

[2] Values are the adjusted mean ± SE daily per capita household purchases of selected food groups within categories of convenience. For food groups with <15% non-consumers, values are determined from multivariable adjusted linear regression models, regressing purchases (kcal/d) on race/ethnicity; for food groups with >15% zero non-consumers, values are determined from a 2-part model including 1) a probit model of the probability of purchasing and 2) linear regression of the amount purchased. All models are adjusted for education, income, household composition, household size (number of household members in each age and gender category), and geographic market/market-level unemployment rate. Stata's margins command was used to determine the adjusted mean outcome.

[3] Values are the difference in per capita household purchases between specified race/ethnic group and non-Hispanic whites. Determined from fully adjusted model using Stata's margins command with the "dydx" option.

Supplemental Table 4.1. Classification system for categorizing foods and beverages based on extent and purpose of processing[1]

Category	Definition	Examples
<u>MINIMAL</u>		
Minimally processed	Single ingredient foods with no or very slight modifications that do not change inherent properties of the food as found in its natural form	Fresh, frozen, or dried plain[2] fruit, vegetables, or legumes; eggs; unseasoned[3] meat; cream; brown rice; whole-grain plain hot cereal; honey; herbs and spices; fresh plain milk; whole bean/ground coffee; tea leaves/bags; bottled plain water
<u>MODERATE</u>		
Moderately processed ingredients	Isolated food components obtained by extraction or purification using physical or chemical processes that change inherent properties of the food	Oil, sugar, salt, unsweetened[4] fruit juice not-from-concentrate, whole-grain[5] flour, whole-grain pasta, unsalted butter, pure maple syrup
Moderately processed for preservation or pre-cooking	Minimally processed foods modified by physical or chemical processes for the purpose of preservation or pre-cooking but remaining as single ingredients	Unsweetened/unflavored canned fruit, vegetables, or legumes; plain yogurt; sour cream; refined-grain flour; refined-grain pasta; white rice; instant rice; plain refined-grain hot cereal; unsweetened fruit juice from-concentrate or frozen concentrate; instant coffee
<u>PROCESSED</u>		
Processed for flavor	Minimally or moderately processed foods with added moderately processed ingredients, combined for the purpose of enhancing flavor but not changing the inherent properties of the food	Sweetened/flavored[6] canned, dried, refrigerated, or frozen fruit, vegetables, or legumes; peanut butter; nuts with salt or oil; jam; seasoned refrigerated, frozen, or canned meat; smoked or cured meat; cheese; sweetened/flavored yogurt; sweetened/flavored hot cereal; microwaveable or pre-popped popcorn; potato chips; salted butter; sweetened/flavored fruit or vegetable juice, tea, or soy milk; chocolate milk; cocoa mix
Processed grain products	Grain products made from whole-grain flour with water, salt, and/or yeast	Whole-grain bread, tortillas, crackers, or RTE cereals with no added sugar or fat
<u>ULTRA-PROCESSED</u>		
Ultra-processed ingredients	Multi-component mixtures of combined ingredients not resembling their basic components and consumed as additions (condiments, dips, sauces, toppings, or ingredients in mixed dishes)	Margarine; mayonnaise; salad dressing; pasta sauce; ketchup, barbecue sauce, and other condiments; marinades; dip; salsa; jelly; creamer; shortening; pancake syrup; artificial sweetener; baking chocolate; icing; whipped topping
Ultra-processed products not consumed as additions	Multi-component mixtures of combined ingredients not resembling their basic components and not typically consumed as additions	Fruit snacks; frozen vegetables in sauce; onion rings; RTH/instant potato dishes (mashed potatoes, stuffed baked potatoes); tater tots; hash brown patties; canned baked beans; sausage; hot dogs; pressed/formed lunchmeats (bologna, salami) or ham; RTH meat dishes (meat loaf, crab cakes, barbecue); breaded meat (chicken

Category	Definition	Examples
		nuggets, fish sticks); ice cream; pudding (RTE and mixes); processed cheese; refined[7] bread, tortillas, or RTE breakfast cereals; pancakes, waffles, or biscuits (RTH, ready-to-bake, mixes); grain-based desserts (cookies, cake, pie, pastries; RTE, ready-to-bake, mixes); processed salty snacks (crackers, pretzels, tortilla chips, cheese puffs); re-structured potato chips; frozen meals/mixed dishes; soups; frozen pizza; RTH/RTE grain-based dishes (burritos, sandwiches, pot pies); frozen or canned pasta dishes; boxed macaroni-and-cheese; instant rice/pasta dish mixes; candy; chocolate; SSBs (soda, fruit drinks,[8] sports drinks, energy drinks, flavored waters); alcohol; coffee beverages

[1] Mutually exclusive categories of processing were defined based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes. Food processing was considered separately from product convenience. RTE, ready-to-eat; RTH, ready-to-heat; SSB, sugar-sweetened beverage.

[2, 3, 4] "Plain," "unseasoned," and "unsweetened" indicate that the product contains no added sweeteners (natural or artificial), salt, flavors, fats, or oils.

[5] Whole-grain products were defined by the 2010 Dietary Guidelines for Americans criteria of including bran, germ, and endosperm and primarily containing "whole-grain" wheat, rye, oats, corn, barley, or other grains labeled as "whole"; brown rice; buckwheat; bulgur; millet; oatmeal; popcorn; quinoa; or rolled oats.

[6] "Sweetened/flavored" indicates that the product contains added sweeteners (natural or artificial), salt, flavors, fats and/or oils.

[7] Refined grain products are defined as breads, tortillas, RTE cereals, or crackers composed of refined-grain flour or composed of whole-grain flour with added sweeteners or fat.

[8] Fruit drinks are defined as beverages primarily composed of sugar or sweetener (as 1st or 2nd ingredients) with fruit juice or fruit juice concentrate as a lesser ingredient.

Supplemental Table 4.2. Classification system for categorizing foods and beverages based on convenience and the amount of preparation required by the consumer prior to food consumption[1]

Category	Definition	Examples
Cooking and/or preparation	Requires significant input of consumer's time, culinary skill, energy, or attention to cook/prepare before consumption; not typically consumed as purchased	Fresh fruits or vegetables requiring preparation (heads of lettuce, onions, broccoli, whole melon) or cooking (potatoes); dried beans; canned tomatoes; eggs, uncooked meat, sausage, or bacon; pudding mixes; sweetened condensed milk; flour; dry pasta or rice; pasta/rice dish mixes (boxed macaroni-and-cheese); grain-based dessert mixes; pancake or biscuit mixes; oil; shortening; cooking sauces; whole bean/ground coffee, tea leaves/bags
Ready-to-heat or minimal preparation	Requires a small amount of consumer's time or effort and no culinary skill or attention (such as heating, microwaving, thawing, or adding water); not typically consumed as purchased	Frozen or canned vegetables or legumes; frozen French fries, onion rings, tater tots, or hash brown patties; frozen potato dishes (mashed potatoes, stuffed baked potatoes); instant mashed potatoes or potato mixes; frozen fruit; tomato sauce; canned baked beans; pre-cooked sausage; hot dogs; frozen or refrigerated meat dishes (meat loaf, crab cakes, barbecue); breaded meat (chicken nuggets, fish sticks); frozen pancakes or waffles; hot cereals; frozen prepared meals/mixed dishes; canned soup; frozen pizza; frozen grain-based dishes (burritos, sandwiches, pot pies); frozen pasta dishes; instant rice or pasta dish mixes; canned pasta dishes; instant rice; microwaveable popcorn; frozen cakes or pies; ready-to-bake cookies, biscuits, or rolls; pre-made gravy or sauces; powdered mixes for sports drinks or flavored waters; instant tea mixes; frozen fruit juice concentrate; cocoa or coffee beverage mixes; dry milk; instant coffee
Ready-to-eat	Can be consumed immediately with no preparation	Fresh, canned, or dried fruit; fruit snacks; jam; jelly; fresh/refrigerated RTE vegetables (pre-cut bagged salad, baby carrots); olives, pickles; peanut butter; nuts; cheese; ice cream; yogurt; RTE pudding; creamer; cream; sour cream; lunch meat; canned meat or processed meat (Spam); RTE bread, tortillas, rolls, bagels; RTE cereal; RTE cookies, pastries, and other grain-based desserts; salty snacks (crackers, potato chips, pretzels, tortilla chips, pre-popped popcorn); candy; sugar; pancake syrup; artificial sweeteners; butter; margarine; ketchup; barbecue sauce; other condiments; salsa; mayonnaise; salad dressing; milk; SSBs (soda, fruit drinks, sports drinks, energy drinks, flavored waters); alcohol; fruit or vegetable juice; ready-to-drink tea; bottled water; soy milk; ready-to-drink coffee beverages

[1] Mutually exclusive categories of convenience were defined based on the amount of food preparation required of the consumer before a product can be eaten. Products that can be prepared in alternate ways were categorized by the most minimal preparation typically required. Convenience was considered separately from food processing. RTE, ready-to-eat; RTH, ready-to-heat; SSB, sugar-sweetened beverage.

Supplemental Table 4.3. Sociodemographic characteristics of US households participating in the 2000-2012 Homescan panel[1]

	Year												
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Individual characteristics, n individuals (%)													
Total individuals, n	82,004	81,410	91,565	92,032	90,307	115,151	144,950	146,427	140,057	137,279	138,623	142,251	140,100
Age groups													
Children	17,193 (21.0%)	16,920 (20.8%)	19,376 (21.2%)	18,538 (20.1%)	17,456 (19.3%)	22,327 (19.4%)	29,554 (20.4%)	29,126 (19.9%)	26,512 (18.9%)	24,747 (18.0%)	24,254 (17.5%)	24,112 (17.0%)	23,843 (17.0%)
2-5 y	3,078 (3.8%)	3,104 (3.8%)	3,502 (3.8%)	3,326 (3.6%)	3,022 (3.3%)	3,980 (3.5%)	5,796 (4.0%)	5,966 (4.1%)	5,202 (3.7%)	4,626 (3.4%)	4,365 (3.1%)	4,211 (3.0%)	4,374 (3.1%)
6-11 y	6,145 (7.5%)	6,077 (7.5%)	6,978 (7.6%)	6,374 (6.9%)	5,967 (6.6%)	7,503 (6.5%)	9,948 (6.9%)	9,864 (6.7%)	9,037 (6.5%)	8,562 (6.2%)	8,349 (6.0%)	8,282 (5.8%)	8,137 (5.8%)
12-18 y	7,970 (9.7%)	7,739 (9.5%)	8,896 (9.7%)	8,838 (9.6%)	8,467 (9.4%)	10,844 (9.4%)	13,810 (9.5%)	13,296 (9.1%)	12,273 (8.8%)	11,559 (8.4%)	11,540 (8.3%)	11,619 (8.2%)	11,332 (8.1%)
Adults	64,811 (79.0%)	64,490 (79.2%)	72,189 (78.8%)	73,494 (79.9%)	72,851 (80.7%)	92,824 (80.6%)	115,396 (79.6%)	117,301 (80.1%)	113,545 (81.1%)	112,532 (82.0%)	114,369 (82.5%)	118,139 (83.0%)	116,257 (83.0%)
19-39 y	15,934 (19.4%)	15,311 (18.8%)	17,422 (19.0%)	16,277 (17.7%)	15,260 (16.9%)	19,688 (17.1%)	26,119 (18.0%)	25,620 (17.5%)	22,718 (16.2%)	21,746 (15.8%)	21,224 (15.3%)	22,194 (15.6%)	22,617 (16.1%)
40-59 y	29,140 (35.5%)	28,926 (35.5%)	32,553 (35.6%)	33,529 (36.4%)	33,466 (37.1%)	44,179 (38.4%)	55,821 (38.5%)	56,030 (38.3%)	53,958 (38.5%)	52,876 (38.5%)	53,555 (38.6%)	53,272 (37.4%)	50,480 (36.0%)
≥60 y	19,737 (24.1%)	20,253 (24.9%)	22,214 (24.3%)	23,688 (25.7%)	24,125 (26.7%)	28,957 (25.1%)	33,456 (23.1%)	35,651 (24.3%)	36,869 (26.3%)	37,910 (27.6%)	39,590 (28.6%)	42,673 (30.0%)	43,160 (30.8%)
Gender													
Male	38,300 (46.7%)	37,857 (46.5%)	42,538 (46.5%)	42,547 (46.2%)	41,949 (46.5%)	53,783 (46.7%)	68,096 (47.0%)	69,044 (47.2%)	65,846 (47.0%)	64,554 (47.0%)	65,274 (47.1%)	67,043 (47.1%)	65,591 (46.8%)
Female	43,704 (53.3%)	43,553 (53.5%)	49,027 (53.5%)	49,485 (53.8%)	48,358 (53.5%)	61,368 (53.3%)	76,854 (53.0%)	77,383 (52.8%)	74,211 (53.0%)	72,725 (53.0%)	73,349 (52.9%)	75,208 (52.9%)	74,509 (53.2%)
Household characteristics, n households (weighted %)[2]													
Total households, n	34,278	34,386	38,665	39,113	38,821	49,436	60,646	61,876	60,138	59,054	59,800	60,683	59,288

	Year												
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Household composition													
Single adults, no children	8,816 (25.7%)	9,267 (25.7%)	10,552 (26.6%)	10,751 (26.7%)	10,867 (26.6%)	13,540 (26.6%)	15,114 (26.7%)	15,627 (26.7%)	15,819 (26.7%)	15,494 (26.6%)	15,831 (26.4%)	15,592 (26.3%)	15,099 (26.4%)
Single adults, with children	936 (6.0%)	962 (5.7%)	1,170 (5.8%)	1,071 (5.2%)	990 (5.1%)	1,262 (6.2%)	1,553 (6.1%)	1,493 (6.0%)	1,363 (6.0%)	1,255 (6.1%)	1,186 (5.8%)	1,098 (5.2%)	944 (4.0%)
Multiple adults, no children	15,848 (39.4%)	15,711 (39.1%)	17,365 (38.3%)	18,021 (39.7%)	18,158 (39.6%)	23,390 (36.9%)	29,019 (37.5%)	29,891 (37.6%)	29,437 (38.1%)	29,545 (38.3%)	30,254 (38.9%)	31,487 (39.3%)	30,804 (40.1%)
Multiple adults, with children	8,678 (28.9%)	8,446 (29.4%)	9,578 (29.3%)	9,270 (28.5%)	8,806 (28.7%)	11,244 (30.3%)	14,960 (29.8%)	14,865 (29.6%)	13,519 (29.2%)	12,760 (29.0%)	12,529 (29.0%)	12,506 (29.2%)	12,441 (29.5%)
Race/ethnicity[3]													
Non-Hispanic white	28,886 (78.9%)	28,389 (76.3%)	31,286 (76.6%)	31,622 (76.2%)	31,343 (75.4%)	40,362 (75.0%)	50,031 (74.4%)	51,006 (73.9%)	49,474 (73.2%)	48,453 (72.6%)	48,752 (71.9%)	49,396 (71.8%)	47,835 (71.3%)
Non-Hispanic black	2,750 (10.9%)	3,016 (11.0%)	3,712 (10.8%)	3,671 (10.6%)	3,581 (10.8%)	4,287 (10.8%)	5,025 (10.8%)	5,194 (10.7%)	5,157 (11.0%)	5,075 (11.0%)	5,184 (10.9%)	5,390 (11.0%)	5,485 (11.2%)
Hispanic	1,828 (8.8%)	1,853 (9.6%)	2,300 (9.1%)	2,484 (9.7%)	2,442 (9.9%)	2,893 (10.1%)	3,205 (10.3%)	3,160 (10.6%)	3,030 (10.9%)	2,960 (11.2%)	3,118 (11.4%)	3,055 (11.4%)	3,069 (12.0%)
Non-Hispanic other race/ethnicity	814 (1.4%)	1,128 (3.1%)	1,367 (3.5%)	1,336 (3.4%)	1,455 (3.8%)	1,894 (4.2%)	2,385 (4.5%)	2,516 (4.8%)	2,477 (4.9%)	2,566 (5.2%)	2,746 (5.8%)	2,842 (5.8%)	2,899 (5.5%)
Household education[4]													
Less than high school	755 (3.6%)	799 (3.6%)	887 (3.4%)	850 (3.4%)	739 (2.9%)	912 (3.3%)	924 (3.0%)	883 (3.0%)	836 (2.8%)	747 (2.5%)	709 (2.6%)	699 (2.6%)	725 (2.7%)
High school or some college	17,749 (63.1%)	17,953 (62.8%)	20,419 (62.3%)	20,281 (61.9%)	20,046 (62.0%)	25,388 (61.7%)	30,253 (61.9%)	30,119 (60.8%)	28,865 (60.5%)	28,037 (60.0%)	27,813 (60.1%)	27,731 (60.1%)	26,914 (59.7%)
College degree or higher	15,774 (33.3%)	15,634 (33.7%)	17,359 (34.3%)	17,982 (34.8%)	18,036 (35.2%)	23,136 (35.0%)	29,469 (35.1%)	30,874 (36.2%)	30,437 (36.8%)	30,270 (37.5%)	31,278 (37.3%)	32,253 (37.3%)	31,649 (37.6%)
Household income													
<$25,000	7,027 (32.1%)	7,356 (30.3%)	8,652 (29.0%)	8,590 (25.0%)	8,398 (25.4%)	10,311 (24.1%)	10,685 (23.7%)	10,224 (23.3%)	9,962 (22.7%)	9,910 (22.3%)	10,111 (21.8%)	9,971 (21.9%)	9,739 (23.6%)
$25,000-$49,999	12,685 (30.5%)	12,466 (29.6%)	13,893 (34.4%)	13,683 (27.3%)	13,623 (27.4%)	17,165 (27.0%)	20,254 (26.6%)	19,873 (26.5%)	18,817 (26.1%)	18,370 (25.7%)	18,363 (25.3%)	18,649 (25.3%)	18,161 (26.6%)
$50,000-$74,999	6,927 (17.4%)	6,708 (17.4%)	7,361 (17.4%)	7,631 (15.7%)	7,387 (15.6%)	9,765 (15.8%)	11,730 (15.9%)	11,932 (15.9%)	11,532 (16.0%)	11,240 (15.9%)	11,146 (15.9%)	11,360 (15.9%)	10,735 (15.9%)
≥$75,000	7,639 (19.9%)	7,856 (22.7%)	8,759 (19.2%)	9,209 (32.1%)	9,413 (31.6%)	12,195 (33.1%)	17,977 (33.8%)	19,847 (34.3%)	19,827 (35.2%)	19,534 (36.0%)	20,180 (37.0%)	20,703 (36.9%)	20,653 (33.9%)

[1] Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods. Total sample includes 656,184 household-year level observations from 157,142 unique households (435,949 individuals).
[2] Percentages of households weighted to be nationally representative.
[3] Race/ethnicity self-reported by head of household.
[4] Highest level of education reported by male or female head of household.

Supplemental Table 4.4. Daily per capita purchases for top food group contributors to differences in processed food purchasing by education, Homescan 2012[1]

	Daily per capita purchases[2] Adjusted mean ± SE			Marginal effect of education[3] β (95% CI)		
	<HS	**HS**	**College**	**<HS**	**HS**	**College**
Total (foods + beverages)	**1514 ± 26.4**	**1343 ± 4.4***	**1219 ± 4.1***	**Ref**	**-171 (-224, -119)**	**-295 (-347, -242)**
Foods	**1296 ± 24.1**	**1166 ± 4.1***	**1062 ± 3.7***	**Ref**	**-130 (-178, -83)**	**-235 (-283, -187)**
Minimally Processed	**95 ± 3.2**	**88 ± 0.5**	**88 ± 0.5**	**Ref**	**-7 (-14, -1)**	**-7 (-14, -1)**
Eggs	22 ± 0.7	20 ± 0.1*	18 ± 0.1*	Ref	-3 (-4, -1)	-5 (-6, -3)
Moderately Processed	**203 ± 5.9**	**156 ± 1.0***	**139 ± 0.9***	**Ref**	**-47 (-59, -35)**	**-64 (-76, -53)**
Fats/oils (oil, unsalted butter)	76 ± 2.9	54 ± 0.5*	48 ± 0.4*	Ref	-22 (-27, -16)	-28 (-34, -22)
Sweeteners (table sugar)	65 ± 2.9	50 ± 0.5*	40 ± 0.4*	Ref	-15 (-21, -9)	-25 (-31, -19)
Processed	**199 ± 5.5**	**198 ± 0.9**	**191 ± 0.9**	**Ref**	**0 (-11, 10)**	**-7 (-18, 3)**
Nuts (salted/nut butters)	35 ± 2.0	40 ± 0.3	43 ± 0.3*	Ref	5 (1, 9)	8 (4, 12)
Ultra-processed	**799 ± 17.3**	**723 ± 2.9***	**644 ± 2.7***	**Ref**	**-76 (-110, -42)**	**-155 (-190, -121)**
Breads/quick breads	128 ± 2.9	105 ± 0.5*	90 ± 0.5*	Ref	-23 (-28, -17)	-37 (-43, -31)
Grain-based desserts	115 ± 3.4	105 ± 0.6	92 ± 0.5*	Ref	-11 (-17, -4)	-23 (-30, -17)
Candy/sweet snacks	73 ± 3.3	75 ± 0.6	70 ± 0.5	Ref	2 (-4, 9)	-3 (-9, 4)
Salty snacks	72 ± 2.3	74 ± 0.4	70 ± 0.4	Ref	2 (-2, 7)	-2 (-6, 3)
Fats/oils (margarine, shortening)	41 ± 1.7	30 ± 0.3*	23 ± 0.2*	Ref	-11 (-14, -8)	-17 (-21, -14)
Dairy-based desserts	40 ± 1.7	38 ± 0.3	35 ± 0.3	Ref	-2 (-5, 2)	-5 (-9, -2)
Processed meat	40 ± 1.2	31 ± 0.2*	24 ± 0.2*	Ref	-9 (-12, -7)	-16 (-19, -14)
Beverages	**218 ± 6.0**	**177 ± 1.0***	**158 ± 0.9***	**Ref**	**-41 (-53, -29)**	**-60 (-72, -48)**
Minimally Processed	**61 ± 2.2**	**52 ± 0.4***	**47 ± 0.3***	**Ref**	**-9 (-13, -5)**	**-14 (-18, -10)**
Milk	61 ± 2.2	52 ± 0.4*	47 ± 0.3*	Ref	-9 (-13, -5)	-14 (-18, -9)
Moderately Processed	**13 ± 0.8**	**12 ± 0.1**	**14 ± 0.1**	**Ref**	**0 (-2, 1)**	**1 (0, 3)**
Fruit juice (unsweetened)	10 ± 0.8	11 ± 0.1	12 ± 0.1	Ref	0 (-1, 2)	2 (0, 3)
Processed	**18 ± 1.1**	**17 ± 0.2**	**17 ± 0.2**	**Ref**	**-1 (-3, 1)**	**-1 (-4, 1)**
Fruit juice (sweetened/flavored)	5 ± 0.5	5 ± 0.1	6 ± 0.1	Ref	0 (0, 1)	1 (0, 2)
Ultra-processed	**126 ± 5.0**	**96 ± 0.9***	**80 ± 0.8***	**Ref**	**-30 (-40, -20)**	**-46 (-56, -36)**
SSBs	81 ± 3.4	57 ± 0.6*	44 ± 0.5*	Ref	-24 (-31, -17)	-37 (-44, -30)
Beer	22 ± 2.5	14 ± 0.4	9 ± 0.3*	Ref	-8 (-13, -3)	-12 (-17, -7)
Liquor	11 ± 1.9	9 ± 0.3	8 ± 0.3	Ref	-1 (-5, 2)	-2 (-6, 1)

	Daily per capita purchases[2] Adjusted mean ± SE			Marginal effect of education[3] β (95% CI)		
	<HS	HS	College	<HS	HS	College
Wine	8 ± 1.7	9 ± 0.3	11 ± 0.3	Ref	1 (-3, 4)	3 (0, 6)

* Significantly different than households with less than a high school education, Wald test with *P*<0.001 to adjust for multiple comparisons and large sample size.

[1] Data from n=59,286 households participating in the 2012 Homescan panel of household purchases of consumer packaged goods. Categories of processing are based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes. Food groups selected from preliminary unadjusted analysis as groups differing by ≥15 kcal (foods) or ≥5 kcal (beverages) across education groups as well as the top food group contributor to calories in each category. HS, high school.

[2] Values are the adjusted mean ± SE daily per capita household purchases of selected food groups within categories of processing. For food groups with <15% non-consumers, values are determined from multivariable adjusted linear regression models, regressing purchases (kcal/d) on household education; for food groups with >15% zero non-consumers, values are determined from a 2-part model including 1) a probit model of the probability of purchasing and 2) linear regression of the amount purchased. All models are adjusted for race/ethnicity, income, household composition, household size (number of household members in each age and gender category), and geographic market/market-level unemployment rate. Stata's margins command was used to determine the adjusted mean outcome.

[3] Values are the difference in per capita household purchases between specified education group and households with less than a high school education. Determined from the fully adjusted model using Stata's margins command with the "dydx" option.

Supplemental Table 4.5. Daily per capita purchases for top food group contributors to differences in processed food purchasing by income, Homescan 2012[1]

	Daily per capita purchases[2] Adjusted mean ± SE				Marginal effect of income[3] β (95% CI)			
	<$25,000	$25,000-$49,999	$50,000-$74,999	≥$75,000	<$25,000	$25,000-$49,999	$50,000-$74,999	≥$75,000
Total (foods + beverages)	**1337 ± 7.7**	**1306 ± 5.3***	**1279 ± 6.8***	**1228 ± 5.3***	**Ref**	**-31 (-48, -13)**	**-57 (-78, -37)**	**-109 (-128, -90)**
Foods	**1155 ± 7.0**	**1133 ± 4.9**	**1115 ± 6.2***	**1071 ± 4.8***	**Ref**	**-22 (-38, -6)**	**-40 (-58, -21)**	**-83 (-101, -66)**
Minimally Processed	**86 ± 0.9**	**89 ± 0.6**	**90 ± 0.8**	**88 ± 0.6**	**Ref**	**3 (1, 5)**	**4 (2, 7)**	**2 (-1, 4)**
Eggs	19 ± 0.2	19 ± 0.1	19 ± 0.2*	18 ± 0.1*	Ref	0 (-1, 0)	-1 (-2, 0)	-2 (-3, -1)
Moderately Processed	**168 ± 1.7**	**153 ± 1.2***	**143 ± 1.5***	**135 ± 1.2***	**Ref**	**-15 (-19, -11)**	**-25 (-30, -21)**	**-33 (-37, -29)**
Fats/oils (oil, unsalted butter)	56 ± 0.8	52 ± 0.6*	49 ± 0.7*	48 ± 0.5*	Ref	-4 (-6, -2)	-6 (-9, -4)	-7 (-9, -5)
Sweeteners (table sugar)	58 ± 0.8	47 ± 0.6*	42 ± 0.7*	38 ± 0.5*	Ref	-10 (-12, -9)	-16 (-18, -13)	-20 (-22, -18)
Processed	**184 ± 1.6**	**193 ± 1.1***	**199 ± 1.4***	**198 ± 1.1***	**Ref**	**9 (6, 13)**	**16 (12, 20)**	**14 (10, 18)**
Nuts (salted/nut butters)	37 ± 0.6	41 ± 0.4*	43 ± 0.5*	43 ± 0.4*	Ref	3 (2, 5)	6 (5, 8)	6 (4, 7)
Ultra-processed	**717 ± 5.0**	**698 ± 3.5**	**683 ± 4.5***	**651 ± 3.5***	**Ref**	**-19 (-31, -8)**	**-35 (-48, -21)**	**-66 (-79, -54)**
Grain-based desserts	103 ± 1.0	102 ± 0.7	96 ± 0.9*	93 ± 0.7*	Ref	-2 (-4, 1)	-7 (-10, -5)	-11 (-13, -8)
Breads/quick breads	104 ± 0.9	101 ± 0.6	97 ± 0.8*	91 ± 0.6*	Ref	-3 (-5, -1)	-6 (-9, -4)	-13 (-15, -11)
Candy/sweet snacks	67 ± 1.0	71 ± 0.7	74 ± 0.9*	75 ± 0.7*	Ref	3 (1, 6)	6 (4, 9)	7 (5, 10)
Salty snacks	67 ± 0.7	71 ± 0.5*	75 ± 0.6*	73 ± 0.5*	Ref	4 (3, 6)	7 (6, 9)	6 (4, 7)
Dairy-based desserts	40 ± 0.5	38 ± 0.3	36 ± 0.4*	34 ± 0.3*	Ref	-1 (-3, 0)	-3 (-4, -2)	-6 (-7, -5)
Processed meat	32 ± 0.3	28 ± 0.2*	27 ± 0.3*	24 ± 0.2*	Ref	-3 (-4, -2)	-5 (-5, -4)	-7 (-8, -7)
Fats/oils (margarine, shortening)	35 ± 0.5	29 ± 0.3*	25 ± 0.4*	21 ± 0.3*	Ref	-5 (-7, -4)	-10 (-11, -9)	-14 (-15, -12)
Pasta dishes	32 ± 1.1	27 ± 0.8*	27 ± 1.0*	23 ± 0.8*	Ref	-5 (-7, -2)	-5 (-8, -2)	-9 (-12, -6)
Beverages	**182 ± 1.8**	**173 ± 1.2***	**164 ± 1.6***	**156 ± 1.2***	**Ref**	**-9 (-13, -4)**	**-18 (-22, -13)**	**-26 (-30, -21)**
Minimally Processed	**55 ± 0.6**	**52 ± 0.4**	**48 ± 0.6***	**45 ± 0.4***	**Ref**	**-2 (-4, -1)**	**-7 (-8, -5)**	**-9 (-11, -8)**
Milk	54 ± 0.6	52 ± 0.4	48 ± 0.6*	45 ± 0.4*	Ref	-2 (-4, -1)	-7 (-8, -5)	-9 (-11, -8)
Moderately Processed	**13 ± 0.2**	**13 ± 0.2**	**13 ± 0.2**	**13 ± 0.2**	**Ref**	**0 (-1, 0)**	**0 (-1, 0)**	**-1 (-1, 0)**
Fruit juice (unsweetened)	11 ± 0.2	12 ± 0.2	12 ± 0.2	12 ± 0.2	Ref	0 (0, 1)	0 (0, 1)	0 (0, 1)
Processed	18 ± 0.3	**18 ± 0.2**	**17 ± 0.3**	**16 ± 0.2***	**Ref**	**-1 (-2, 0)**	**-1 (-2, 0)**	**-2 (-3, -1)**
Fruit juice (sweetened/flavored)	6 ± 0.1	6 ± 0.1	6 ± 0.1	6 ± 0.1	Ref	0 (0, 0)	0 (0, 1)	0 (-1, 0)
Ultra-processed	**96 ± 1.5**	**90 ± 1.0**	**86 ± 1.3***	**82 ± 1.0***	**Ref**	**-5 (-9, -2)**	**-10 (-14, -6)**	**-13 (-17, -10)**
SSBs	64 ± 1.0	54 ± 0.7*	48 ± 0.9*	42 ± 0.7*	Ref	-10 (-12, -7)	-16 (-18, -13)	-22 (-25, -20)
Beer	11 ± 0.6	11 ± 0.4	11 ± 0.6	12 ± 0.5	Ref	-1 (-2, 1)	-1 (-2, 1)	1 (-1, 2)

	Daily per capita purchases[2] Adjusted mean ± SE				Marginal effect of income[3] β (95% CI)			
	<$25,000	$25,000-$49,999	$50,000-$74,999	≥$75,000	<$25,000	$25,000-$49,999	$50,000-$74,999	≥$75,000
Wine	7 ± 0.4	9 ± 0.3*	10 ± 0.5*	13 ± 0.4*	Ref	3 (2, 4)	4 (3, 5)	6 (5, 7)
Liquor	7 ± 0.5	8 ± 0.3	9 ± 0.5	10 ± 0.4*	Ref	1 (0, 3)	1 (1, 4)	3 (0, 0)

* Significantly different than households with income <$25,000, Wald test with $P<0.001$ to adjust for multiple comparisons and large sample size.

[1] Data from n=59,286 households participating in the 2012 Homescan panel of household purchases of consumer packaged goods. Categories of processing are based on the extent to which whole foods as found in nature were transformed by industrial methods into food products and the purpose of these manufacturing processes. Food groups selected from preliminary unadjusted analysis as groups differing by ≥15 kcal (foods) or ≥5 kcal (beverages) across income groups, as well as the top food group contributor to calories in each category.

[2] Values are the adjusted mean ± SE daily per capita household purchases of selected food groups within categories of processing. For food groups with <15% non-consumers, values are determined from multivariable adjusted linear regression models, regressing purchases (kcal/d) on income; for food groups with >15% zero non-consumers, values are determined from a 2-part model including 1) a probit model of the probability of purchasing and 2) linear regression of the amount purchased. All models are adjusted for education, race/ethnicity, household composition, household size (number of household members in each age and gender category), and geographic market/market-level unemployment rate. Stata's margins command was used to determine the adjusted mean outcome.

[3] Values are the difference in per capita household purchases between specified income group and households with income <$25,000. Determined from the fully adjusted model using Stata's margins command with the "dydx" option.

Supplemental Table 4.6. Daily per capita purchases for top food group contributors to differences in convenience food purchasing by education, Homescan 2012[1]

	Daily per capita purchases[2] Adjusted mean ± SE			Marginal effect of education[3] β (95% CI)		
	<HS	HS	College	<HS	HS	College
Total (foods + beverages)	**1514 ± 26.4**	**1343 ± 4.4***	**1219 ± 4.1***	**Ref**	**-171 (-224, -119)**	**-295 (-347, -242)**
Foods	**1296 ± 24.1**	**1166 ± 4.1***	**1062 ± 3.7***	**Ref**	**-130 (-178, -83)**	**-235 (-283, -187)**
Requires cooking/preparation	**280 ± 6.8**	**226 ± 1.1***	**203 ± 1.1***	**Ref**	**-54 (-68, -41)**	**-77 (-90, -63)**
Fats/oils (oil, shortening)	79 ± 3.0	55 ± 0.5*	46 ± 0.4*	Ref	-24 (-30, -18)	-33 (-39, -27)
Starchy vegetables (fresh potatoes)	20 ± 0.7	15 ± 0.1*	12 ± 0.1*	Ref	-5 (-6, -4)	-9 (-10, -7)
Processed meat (uncooked bacon and sausage)	17 ± 0.7	15 ± 0.1*	12 ± 0.1*	Ref	-3 (-4, -1)	-6 (-7, -4)
Ready-to-heat/minimal preparation	**212 ± 11.1**	**186 ± 1.9**	**166 ± 1.7***	**Ref**	**-25 (-47, -3)**	**-45 (-68, -23)**
RTH grain-based mixed dishes	29 ± 1.3	27 ± 0.2	24 ± 0.2*	Ref	-2 (-5, 1)	-5 (-8, -2)
Ready-to-eat	**804 ± 14.4**	**754 ± 2.4***	**692 ± 2.2***	**Ref**	**-51 (-79, -22)**	**-112 (-141, -84)**
RTE salty snacks	102 ± 3.0	100 ± 0.5	92 ± 0.5*	Ref	-2 (-8, 4)	-10 (-16, -5)
RTE breads/quick breads	98 ± 2.5	80 ± 0.4*	69 ± 0.4*	Ref	-18 (-23, -13)	-29 (-34, -24)
RTE grain-based desserts	87 ± 2.9	78 ± 0.5	68 ± 0.4*	Ref	-9 (-14, -3)	-19 (-24, -13)
Candy/sweet snacks	66 ± 3.2	69 ± 0.5	63 ± 0.5	Ref	3 (-4, 9)	-4 (-10, 3)
Sweeteners (sugar, syrups, jam, jelly)	73 ± 2.7	57 ± 0.5*	46 ± 0.4*	Ref	-16 (-21, -11)	-27 (-32, -22)
Fats/oils (butter, margarine)	63 ± 1.8	52 ± 0.3*	44 ± 0.3*	Ref	-11 (-15, -7)	-18 (-22, -15)
Nuts/nut butters	44 ± 2.5	51 ± 0.4	55 ± 0.4*	Ref	7 (2, 12)	11 (6, 16)
RTE dairy-based desserts (ice cream, pudding)	38 ± 1.7	37 ± 0.3	34 ± 0.3	Ref	-1 (-5, 2)	-5 (-8, -1)

* Significantly different than households with less than a high school education, Wald test with *P*<0.001 to adjust for multiple comparisons and large sample size.

[1] Data from n=59,286 households participating in the 2012 Homescan panel of household purchases of consumer packaged goods. Categories of convenience based on the amount of food preparation required of the consumer before a product can be eaten. Food groups selected from preliminary unadjusted analysis as groups differing by ≥15 kcal across education groups, as well as the top food group contributor to calories in each category. Beverages not shown because >90% kcal are ready-to-eat. HS, high school; RTE, ready-to-eat; RTH, ready-to-heat.

[2] Values are the adjusted mean ± SE daily per capita household purchases of selected food groups within categories of convenience. For food groups with <15% non-consumers, values are determined from multivariable adjusted linear regression models, regressing purchases (kcal/d) on education; for food groups with >15% zero non-consumers, values are determined from a 2-part model including 1) a probit model of the probability of purchasing and 2) linear regression of the amount purchased. All models are adjusted for income, race/ethnicity, household composition, household size (number of household members in each age and gender category), and geographic market/market-level unemployment rate. Stata's margins command was used to determine the adjusted mean outcome.

[3] Values are the difference in per capita household purchases between specified education group and households with less than a high school education. Determined from the fully adjusted model using Stata's margins command with the "dydx" option.

Supplemental Table 4.7. Daily per capita purchases for top food group contributors to differences in convenience food purchasing by income, Homescan 2012[1]

	Daily per capita purchases[2] Adjusted mean ± SE				Marginal effect of income[3] β (95% CI)			
	<$25,000	**$25,000-$49,999**	**$50,000-$74,999**	**≥$75,000**	**<$25,000**	**$25,000-$49,999**	**$50,000-$74,999**	**≥$75,000**
Total (foods + beverages)	**1337 ± 7.7**	**1306 ± 5.3***	**1279 ± 6.8***	**1228 ± 5.3***	**Ref**	**-31 (-48, -13)**	**-57 (-78, -37)**	**-109 (-128, -90)**
Foods	**1155 ± 7.0**	**1133 ± 4.9**	**1115 ± 6.2***	**1071 ± 4.8***	**Ref**	**-22 (-38, -6)**	**-40 (-58, -21)**	**-83 (-101, -66)**
Requires cooking/preparation	**228 ± 2.0**	**221 ± 1.4**	**212 ± 1.8***	**204 ± 1.4***	**Ref**	**-7 (-11, -2)**	**-16 (-21, -11)**	**-24 (-29, -19)**
Fats/oils (oil, shortening)	56 ± 0.8	52 ± 0.6*	48 ± 0.7*	47 ± 0.6*	Ref	-4 (-6, -2)	-8 (-10, -6)	-9 (-11, -7)
Starchy vegetables (fresh potatoes)	15 ± 0.2	14 ± 0.1	13 ± 0.2*	12 ± 0.1*	Ref	-1 (-1, 0)	-2 (-2, -1)	-3 (-3, -2)
Ready-to-heat/minimal preparation	**190 ± 3.3**	**181 ± 2.2**	**175 ± 2.9***	**166 ± 2.2***	**Ref**	**-9 (-16, -1)**	**-15 (-23, -6)**	**-24 (-32, -16)**
All ready-to-heat foods	28 ± 0.4	27 ± 0.3	25 ± 0.3*	23 ± 0.3*	Ref	-1 (-2, -1)	-4 (-5, -3)	-6 (-7, -5)
Ready-to-eat	**738 ± 4.2**	**731 ± 2.9**	**728 ± 3.7**	**702 ± 2.9***	**Ref**	**-7 (-16, 3)**	**-9 (-20, 2)**	**-36 (-46, -25)**
RTE salty snacks	92 ± 0.9	96 ± 0.6*	99 ± 0.8*	96 ± 0.6*	Ref	5 (3, 7)	7 (5, 10)	4 (2, 7)
RTE breads/quick breads	80 ± 0.7	78 ± 0.5*	75 ± 0.6*	69 ± 0.5*	Ref	-3 (-5, -1)	-6 (-7, -4)	-11 (-13, -9)
RTE grain-based desserts	78 ± 0.8	75 ± 0.6	72 ± 0.7*	69 ± 0.6*	Ref	-3 (-5, -1)	-6 (-9, -4)	-9 (-11, -7)
Candy/sweet snacks	61 ± 0.9	64 ± 0.6	67 ± 0.8*	68 ± 0.6*	Ref	3 (1, 5)	6 (4, 9)	7 (4, 9)
Sweeteners (sugar, syrups, jam, jelly)	66 ± 0.8	55 ± 0.6*	49 ± 0.7*	44 ± 0.5*	Ref	-11 (-13, -9)	-17 (-19, -15)	-22 (-24, -20)
Fats/oils (butter, margarine)	54 ± 0.5	50 ± 0.4*	47 ± 0.5*	44 ± 0.4*	Ref	-4 (-5, -3)	-7 (-9, -6)	-10 (-11, -9)
Nuts/nut butters	46 ± 0.7	52 ± 0.5*	56 ± 0.6*	56 ± 0.5*	Ref	6 (4, 7)	10 (8, 12)	10 (8, 12)
RTE dairy-based desserts	38 ± 0.5	37 ± 0.3	35 ± 0.4*	32 ± 0.3*	Ref	-1 (-2, 0)	-3 (-4, -2)	-6 (-7, -4)

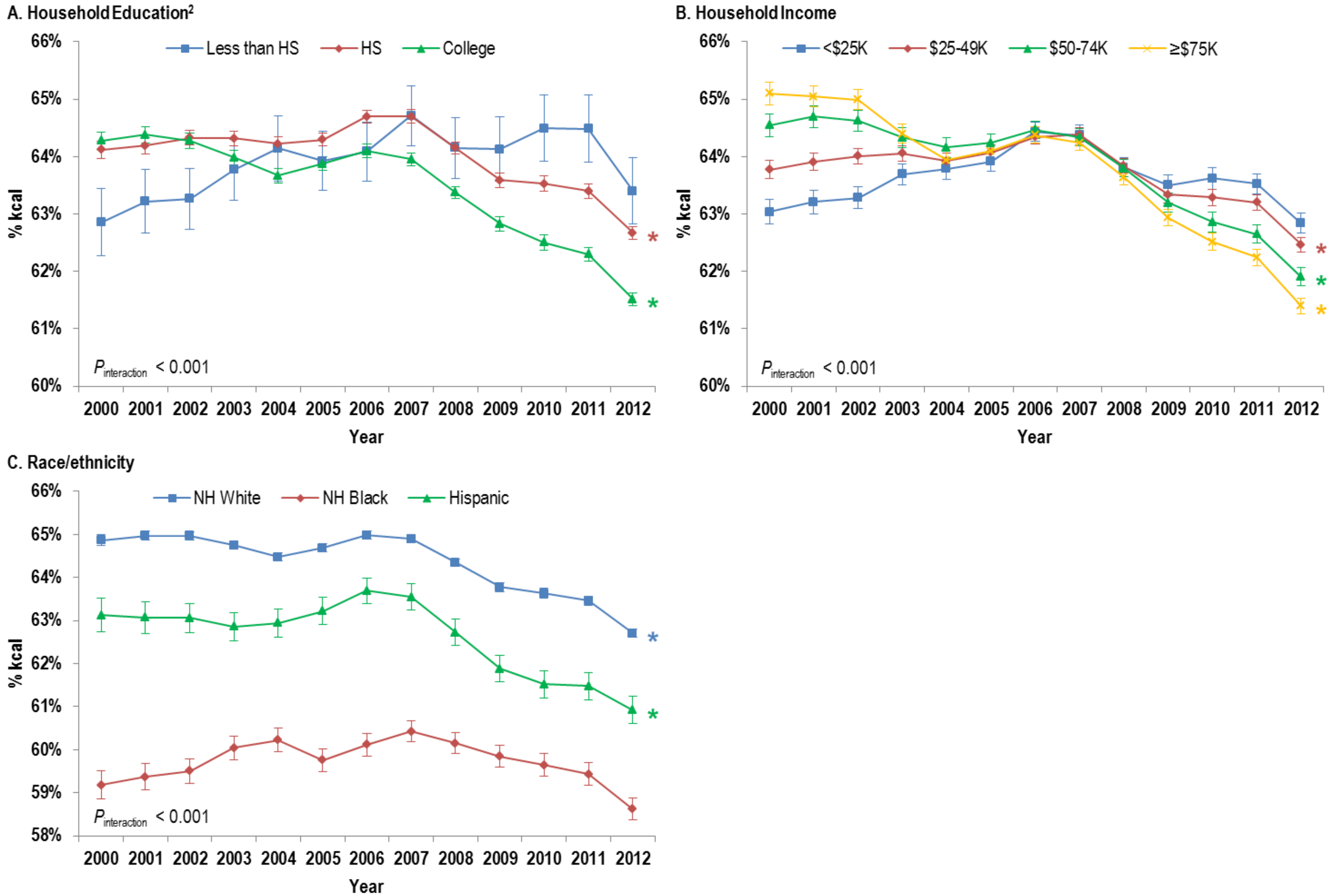
* Significantly different than households with income <$25,000, Wald test with *P*<0.001 to adjust for multiple comparisons and large sample size.

[1] Data from n=59,286 households participating in the 2012 Homescan panel of household purchases of consumer packaged goods. Categories of convenience based on the amount of food preparation required of the consumer before a product can be eaten. Food groups selected from preliminary unadjusted analysis as groups differing by ≥15 kcal (foods) or ≥5 kcal (beverages) across income groups, as well as the top food group contributor to calories in each category. Beverages not shown because >90% kcal are ready-to-eat. RTE, ready-to-eat; RTH, ready-to-heat.

[2] Values are the adjusted mean ± SE daily per capita household purchases of selected food groups within categories of convenience. For food groups with <15% non-consumers, values are determined from multivariable adjusted linear regression models, regressing purchases (kcal/d) on household income; for food groups with >15% zero non-consumers, values are determined from a 2-part model including 1) a probit model of the probability of purchasing and 2) linear regression of the amount purchased. All models are adjusted for education, race/ethnicity, household composition, household size (number of household members in each age and gender category), and geographic market/market-level unemployment rate. Stata's margins command was used to determine the adjusted mean outcome.

[3] Values are the difference in per capita household purchases between specified income group and households with income <$25,000. Determined from the fully adjusted model using Stata's margins command with the "dydx" option.

Figure 4.1. Longitudinal multivariable-adjusted associations of sociodemographic or economic characteristics with the contribution of ultra-processed foods to total food calories purchased among US households, Homescan 2000-2012[1]

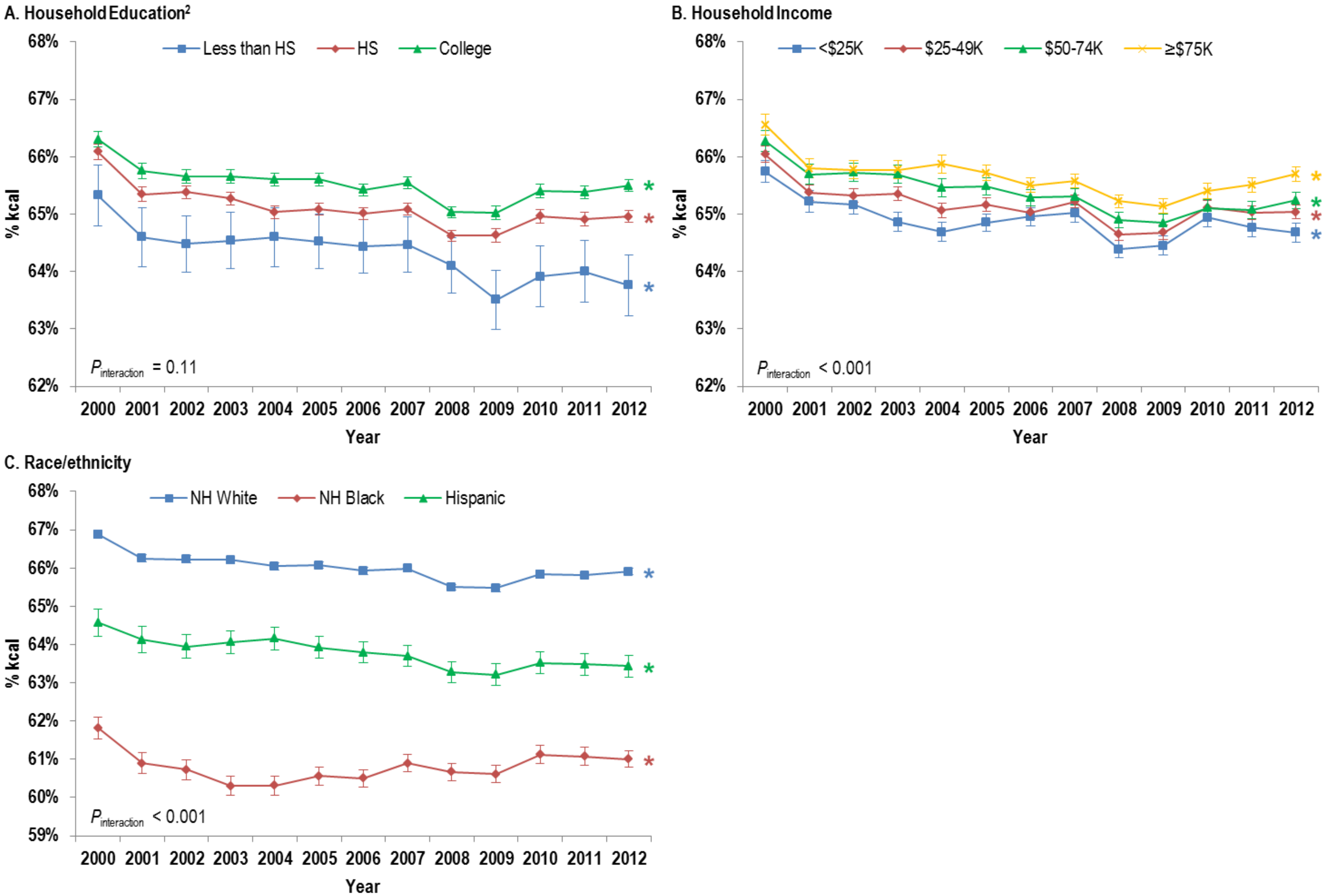


* Significant within-group change in % kcal/d from ultra-processed foods between 2000 and 2012, Wald test with $P<0.001$ to account for multiple comparisons and large sample size.

[1] Values are adjusted mean with 95% CI by household A) education, B) income, and C) race/ethnicity. Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods; n=656,172 year-level observations (157,139 households). Results from longitudinal random effects linear regression models that regress percent kcal/d from ultra-processed foods on year (dummy variables), household education level, income, race/ethnicity and the interaction of year with these factors. Models were additionally adjusted for household composition (single adult, single adult with children, multiple adults, multiple adults with children), the interaction of household composition and year, size (number of household members in each age and gender group), geographic market, and market-level unemployment rate. The contribution of ultra-processed foods was determined as a percentage of total calories in all food purchases. HS, High School; NH, Non-Hispanic.

[2] Highest level of education attained by the male or female head of household.

Figure 4.2. Longitudinal multivariable-adjusted associations of sociodemographic or economic characteristics with the contribution of ready-to-eat foods to total food calories purchased among US households, Homescan 2000-2012[1]

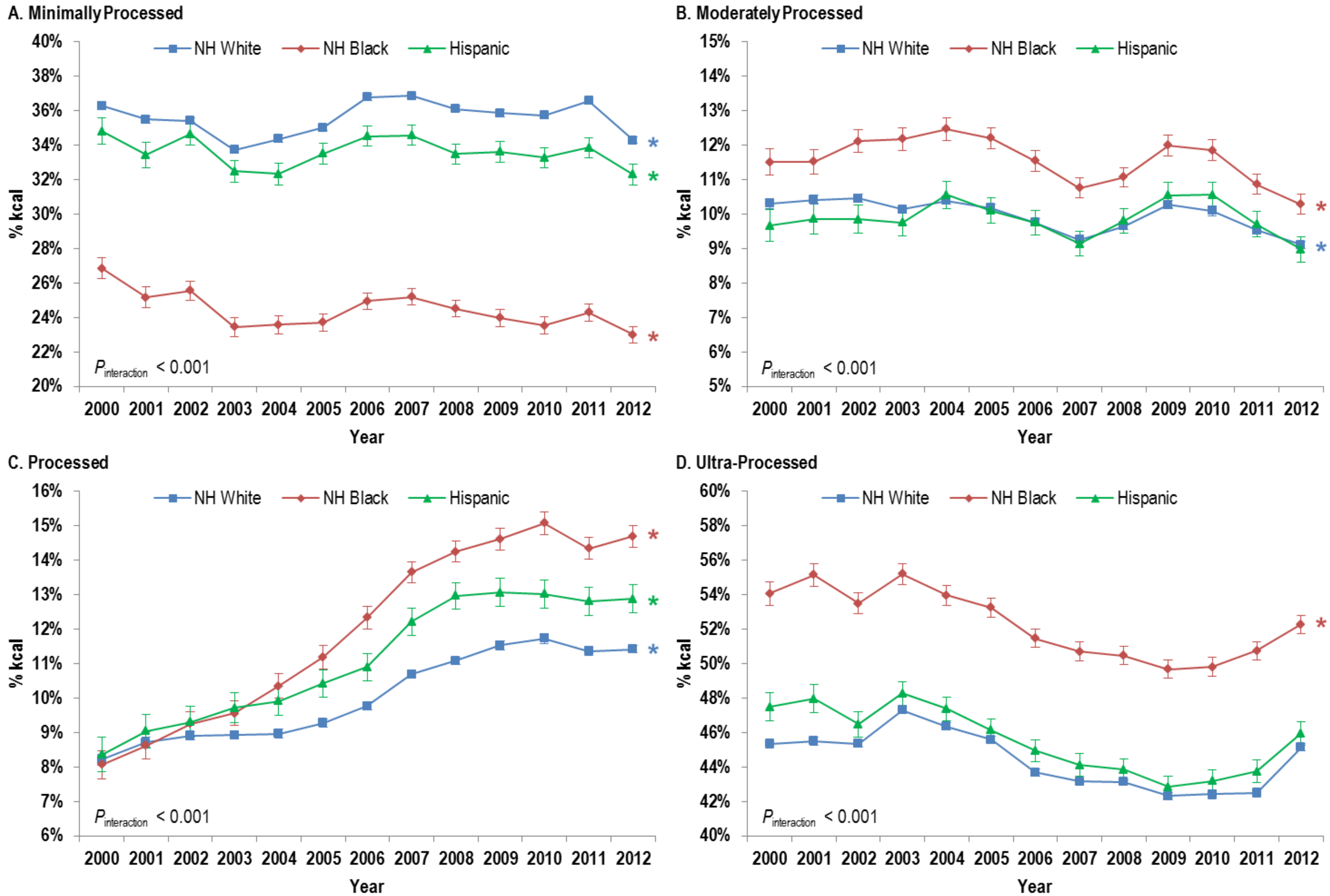


* Significant within-group change in % kcal/d from ready-to-eat foods between 2000 and 2012, Wald test with $P<0.001$ to account for multiple comparisons and large sample size.

[1] Values are adjusted mean with 95% CI by household A) education, B) income, and C) race/ethnicity. Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods; n=656,172 year-level observations (157,139 households). Results from longitudinal random effects linear regression models that regress percent kcal/d from ready-to-eat foods on year (dummy variables), household education level, income, race/ethnicity and the interaction of year with these factors. Models were additionally adjusted for household composition (single adult, single adult with children, multiple adults, multiple adults with children), the interaction of household composition and year, size (number of household members in each age and gender group), geographic market, and market-level unemployment rate. The contribution of ready-to-eat foods was determined as a percentage of total calories in all food purchases. HS, High School; NH, Non-Hispanic.

[2] Highest level of education attained by the male or female head of household.

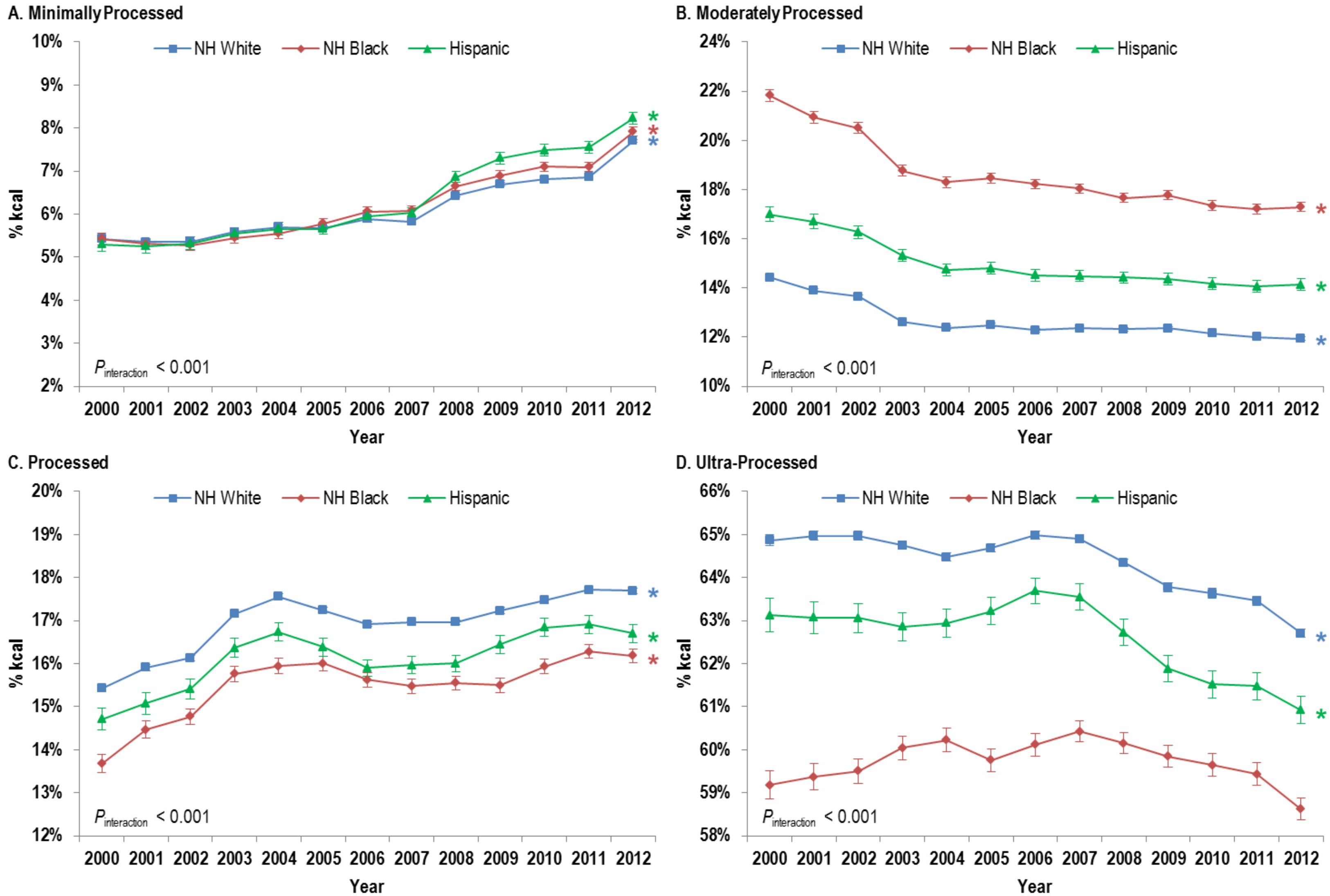
Figure 4.3. Longitudinal multivariable-adjusted associations between race/ethnicity and the contribution of processed beverages to total beverage calories purchased among US households, 2000-2012[1]



* Significant within-group change in % kcal/d from processed beverages between 2000 and 2012, Wald test with *P*<0.001 to account for multiple comparisons and large sample size.

[1] Values are adjusted mean with 95% CI for the contribution of A) minimally processed, B) moderately processed, C) processed, and D) ultra-processed beverages as a percentage of total calories in all beverage purchases among each race/ethnic group. Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods; n=655,833 year-level observations (157,114 households). Results from longitudinal random effects linear regression models that regress percent kcal/d from each processing category on year (dummy variables), household race/ethnicity, education level, income, and the interaction of year with these factors. Models were additionally adjusted for household composition (single adult, single adult with children, multiple adults, multiple adults with children), the interaction of household composition and year, household size (number of household members in each age and gender group), geographic market, and market-level unemployment rate. NH, Non-Hispanic.

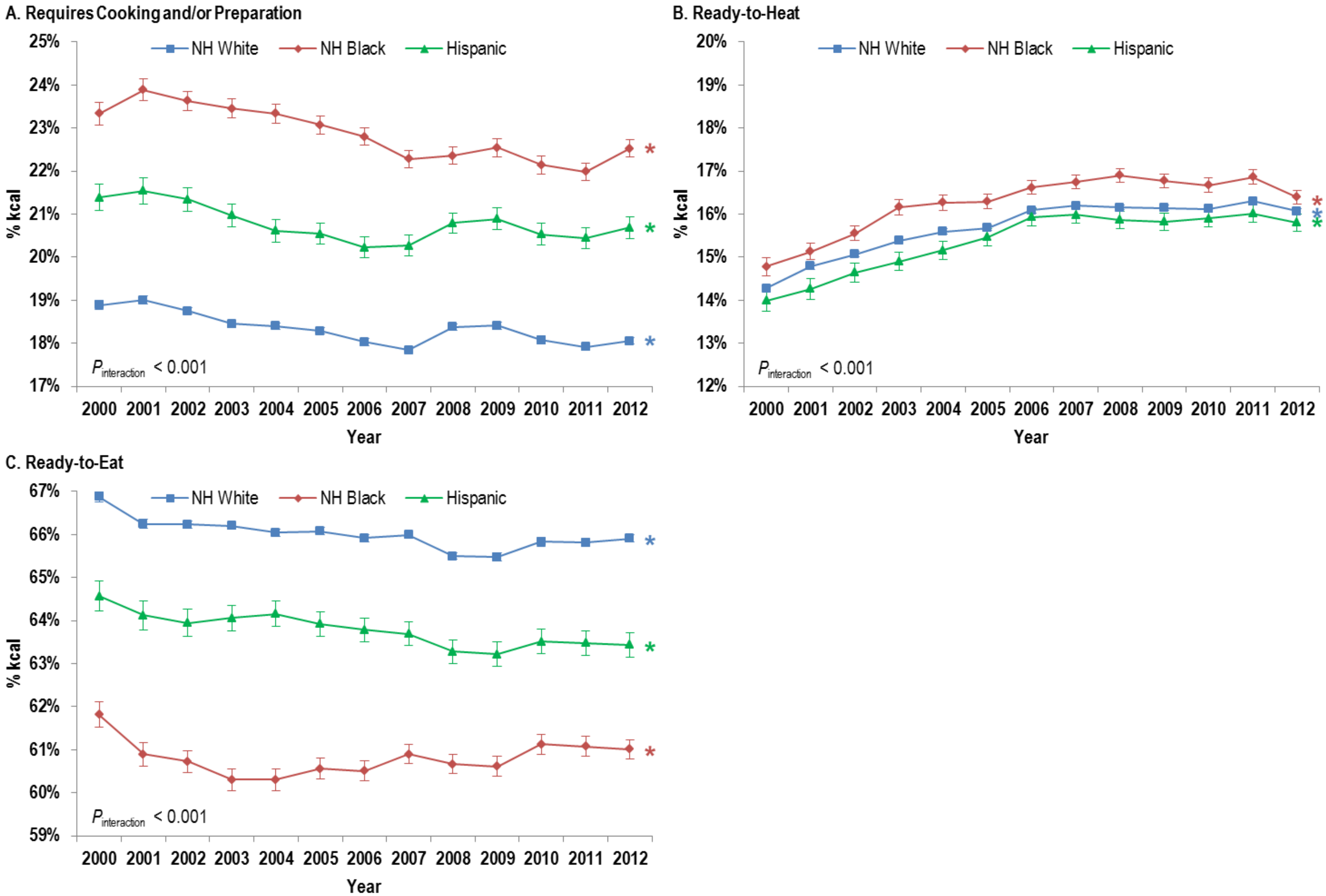
Supplemental Figure 4.1. Longitudinal multivariable-adjusted associations between race/ethnicity and the contribution of processed foods to total food calories purchased among US households, 2000-2012[1]



* Significant within-group change in % kcal/d from processed foods between 2000 and 2012, Wald test with *P*<0.001 to account for multiple comparisons and large sample size.

[1] Values are adjusted mean with 95% CI for the contribution of A) minimally processed, B) moderately processed, C) processed, and D) ultra-processed foods as a percentage of total calories in all food purchases among each race/ethnic group. Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods; n=656,172 year-level observations (157,139 households). Results from longitudinal random effects linear regression models that regress percent kcal/d from each processing category on year (dummy variables), household race/ethnicity, education level, income, and the interaction of year with these factors. Models were additionally adjusted for household composition (single adult, single adult with children, multiple adults, multiple adults with children), the interaction of household composition and year, household size (number of household members in each age and gender group), geographic market, and market-level unemployment rate. NH, Non-Hispanic.

Supplemental Figure 4.2. Longitudinal multivariable-adjusted associations between race/ethnicity and the contribution of convenience foods to total food calories purchased among US households, 2000-2012[1]



* Significant within-group change in % kcal/d from convenience foods between 2000 and 2012, Wald test with P<0.001 to account for multiple comparisons and

large sample size.

[1] Values are adjusted mean with 95% CI for the contribution of foods A) requiring cooking and/or preparation, B) ready-to-heat or requiring minimal preparation, and C) ready-to-eat as a percentage of total calories in all food purchases among each race/ethnic group. Data from the 2000-2012 Homescan longitudinal panel of household purchases of consumer packaged goods; n=656,172 year-level observations (157,139 households). Results from longitudinal random effects linear regression models that regress percent kcal/d from each convenience category on year (dummy variables), household race/ethnicity, education level, income, and the interaction of year with these factors. Models were additionally adjusted for household composition (single adult, single adult with children, multiple adults, multiple adults with children), the interaction of household composition and year, household size (number of household members in each age and gender group), geographic market, and market-level unemployment rate. NH, Non-Hispanic.

Chapter 5. Synthesis

Overview of Findings

This research investigated the role of processed and convenience foods in purchasing patterns among US households. We used data from the longitudinal 2000-2012 Homescan panel of households who use barcode scanners to record all food and beverage purchases from retail food stores that enter the home. This unique dataset collects detailed food descriptions and product-specific ingredient lists that facilitate classification of foods by level of processing and convenience and enhances accuracy by including product-specific nutritional content.

A primary reason for the scarcity of research examining the association of processed foods with nutritional and health outcomes is the lack of a clear consistent definition for "processed food." Therefore, we first developed a novel classification system to categorize foods based on their level of food processing and separately by their level of convenience. After applying this system to purchases by participants in the Homescan panel, we examined 13-year time trends in the caloric contribution of processed and convenience foods to total purchases and to food, beverage, and food group purchases. Because it is not clear whether processed and convenience foods contribute to disparities in diet across vulnerable subpopulations, we determined the longitudinal associations of household education, income, and race/ethnicity with ultra-processed and RTE food purchases. Finally, inconsistent conclusions about the nutritional quality of processed foods may arise from use of aggregate food composition tables and insufficient collection of product details for classifying level of processing and convenience.

Thus, we used product- and brand-specific nutrient content to compare the saturated fat, total sugar, and sodium densities of food purchases by level of processing and convenience.

Development of a multidimensional classification system for food processing and convenience

Previous classification systems for processed foods were limited by omission of key foods, unclear category definitions, and conflation of processing and convenience.[1,20] To address these limitations, we developed a multidimensional classification system for categorizing foods and beverages based on their level of processing and separately by their level of convenience. We built upon the work of Monteiro and colleagues; while receiving highest ratings in a recent systematic review, the Monteiro et al. system was developed in Brazil for use with household expenditure surveys collecting information on a limited number of different items.[20,21,27] Thus, we adapted category definitions for the complexity of the US food supply and enhanced food details provided by dietary recall or purchase data. To improve upon previous systems that omitted foods, we compiled an exhaustive list of foods and beverages with their corresponding classifications and included all foods identified in manual searching of >615,000 barcoded items. We developed explicit criteria and decision rules for classification to ensure that all categories of processing and of convenience were clearly defined.

Our system was novel in separating food processing from product convenience. Previous studies have suggested that RTE foods, which require no preparation before quick and easy consumption, may promote eating patterns that lead to overconsumption independently from food processing.[1,30-35] To the best of our knowledge, our classification system is the first to follow previous recommendations to separate processing and convenience into distinct dimensions.[1,35]

To apply our classification system to food and beverage purchase data, we used complex programming algorithms to search for pertinent information in ingredient lists, product attributes, and information appearing on the product's package and assign each barcoded product to a category for processing and separately to a category for convenience. This methodology was also used to create a multi-level food grouping system, with basic and more specific groups, again at the barcode-level. Over 1.2 million products were classified with this approach into a single category for food processing (minimally processed, moderately processed, processed, and ultra-processed) and a single category for convenience (requires cooking and/or preparation, RTH, or RTE). This aim filled an important gap in the literature by providing a classification system for processed and convenience foods suited to the complexity of the US food supply with comprehensive, clear category definitions.

Trends analysis of the caloric contributions of processed and convenience foods and beverages to purchases among US households from 2000-2012

In our nationally representative sample of US households, over ¾ of calories purchased came from processed and ultra-processed foods and beverages. By level of convenience, RTE and RTH foods and beverages contributed ~85% of calories purchased in 2012. We add to the research literature by additionally providing estimates of the percentage of calories from processed products separately among foods and among beverages, as suggested previously.[19] Contrary to prior hypotheses, the contribution of ultra-processed products was greater for foods than for beverages.[19] The dimension of convenience was relevant only for foods, as the majority (>90%) of beverages were RTE/ready-to-drink. Further, we provide the first evidence of the contribution of ultra-processed and RTE foods within food groups. Focusing on 3 food groups that were well-captured by our data, we found that the majority of grain products (~85%), dairy products (50-65%), and fats/oils (50-60%) were ultra-processed. The role of convenience varied by food group; all levels were important for grain products, while almost all dairy products were RTE (>90%) and a relatively large percentage of fats/oils were used in cooking (~1/3).

The only previous study in the US was limited to cross-sectional analysis from 2003-2008; we further contribute by providing trends analysis and updated findings through 2012. In our sample, purchases of ultra-processed foods plateaued at a high level with no significant changes occurring between 2000 and 2012. Although calories from all beverages declined during this time span, the relative contribution of ultra-processed beverages remained stable. However, by examining purchases within food groups and by convenience, we uniquely found shifts within the ultra-processed food category. Encouraging decreases in ultra-processed RTE refined breads, grain-based desserts, candy, and ice cream occurred, but were balanced by increases in ultra-processed RTH frozen grain-, pasta-, or rice-based dishes and processed meat. Additionally, the overall contribution of all RTH foods increased during this 13-year span.

Overall, this aim showed that ultra-processed foods and beverages dominate purchasing patterns of US households, and their contribution to diet appears resistant to change. Moreover, our finding that the majority of calories are purchased in RTE form, coupled with increases in RTH foods, together suggest that traditional meal patterns involving cooking and food preparation have been largely displaced by industrially prepared convenience foods.

Sociodemographic and economic predictors of ultra-processed and RTE food and beverage purchasing

For all education, income, and race/ethnic groups, ultra-processed foods provided ≥58%

of calories purchased. We found that lower levels of education and income were associated with a higher contribution of ultra-processed foods to purchases, with the association strengthening across time as households with high SES shifted away from ultra-processed foods while households with low SES did not. Black households had higher ultra-processed beverage purchases yet lower ultra-processed food purchases compared to white households. Both black and Hispanic households were significantly more likely than white households to be in the highest quartile for moderately processed food purchases and for foods requiring cooking and/or preparation. Of note, blacks had higher purchases of cooking oil and table sugar compared to whites. We unexpectedly found that black households had lower purchases of key ultra-processed foods, such as grain-based desserts, candy, salty snacks, and dairy-based desserts, compared to white households, after adjusting for differences in education and income. Black race/ethnicity and less education were associated with lower purchases of RTE foods and higher purchases of fats (cooking oils, shortening, and margarine) and table sugar, suggesting a greater role of cooking and food preparation among these households.

This study helped to fill an important gap in the research literature as the first to evaluate the association of sociodemographic and economic factors with processed and convenience food purchases. The surprising finding that black households had lower purchases of many ultra-processed RTE foods that are generally energy-dense and nutrient-poor warrants further study.

Comparison of nutrient densities by food processing and convenience level

Holding constant the distribution of purchases across food groups, we found that median saturated fat, total sugar, and sodium densities were higher for household-level purchases of ultra-processed foods compared to less-processed foods and higher for purchases of RTE foods compared to foods requiring cooking and/or preparation. Independent of the smaller amounts of fruits and vegetables among ultra-processed or RTE purchases, household-level ultra-processed and RTE food purchases were significantly more likely to exceed recommendations for saturated fat, sugar, and sodium when compared to purchases of less-processed foods or foods requiring cooking and/or preparation, respectively. The adjusted predicted probability of exceeding recommended maximums for all three food components was significantly higher for household-level ultra-processed food purchases (60.4%) compared to less-processed food purchases (5.6%). Consistent with other studies, our results suggest that the more favorable nutrient profile of less-processed foods occurs not simply because this category contains more fruits and vegetables than ultra-processed foods, but may occur in part because of a lesser degree of processing.[14,21]

One important consideration for evaluation of nutrient densities in relation to recommendations is the choice of recommended cutpoint. To the best of our knowledge, no recommendations have been made for *total* sugar. For this work, we focused on the Dietary Guidelines for Americans, 2010 and used a 15% cutpoint, which is the recommended maximum intake of calories from solid fats and added sugars collectively; a separate recommendation specific for added sugar is not provided.[75] We further conducted sensitivity analysis using the World Health Organization recommendation for free sugars (<10% kcal) and the Institute of Medicine recommendation for added sugars (<25% kcal); results were not materially changed.

Limitations

A key limitation of our study is that the Homescan data does not fully capture all retail food store purchases. Items without barcodes or nutrition labels, including minimally processed items (random-weight unpackaged fresh fruits, vegetables, and meats) and ultra-processed items (cut-to-order deli meats and cheeses, bakery products, and store-prepared RTE/RTH foods), were excluded. Thus, determining the impact of this missing data on our estimations is difficult. In a subsample of participants, expenditures on random-weight and other excluded items are provided for broad categories, such as “meats,” “fruits and vegetables,” or “home delivery and takeout.” Crudely classifying these categories by processing level, we determined that approximately 60% of dollar sales in 2007 and 2011 for store products excluded from the Homescan dataset were less-processed foods and beverages, with the remaining 40% processed or ultra-processed. Although we cannot readily translate expenditures into calories purchased, this brief examination suggests that missing data is not limited to only minimally processed fresh foods but might instead balance out across less-processed and ultra-processed foods.

Food away-from-home is not reported, and therefore our findings pertain only to purchases of packaged goods and may not be generalizable to total diet. Race/ethnicity and SES are associated with fast food intake and away-from-home eating, which may influence total calories and the types of items purchased from stores.[89,110] Of note, the percentage of calories consumed from store-bought foods and beverages was greater among black (72.3%) and Mexican American (73.7%) adults compared to white adults (70.8%) in 2009-2010.[111] Further, the percentage of calorie intake from all away-from-home sources declined slightly from 33% to 29% between 2003 and 2010 among US adults.[111] These sociodemographic differences and time trends in away-from-home food intake could potentially limit our ability to compare store purchases across subpopulations and across time. However, declines were similar among all race/ethnic groups, and results presented recently at a meeting of the 2015 Dietary Guidelines Advisory Committee suggest that the percentage of calories consumed away-from-home has remained about the same between 2003 and 2011.[111] Some foods or beverages might be purchased from stores and consumed either immediately or prior to returning to the home. These items are not brought into the home and therefore are not scanned or included in our data; examples might include convenience store purchases. In Aim 2, we found significantly lower purchasing of ultra-processed foods such as candy and salty snacks among black and Hispanic households; these foods are typically widely available in convenience stores, which are more prevalent in predominantly black or low SES neighborhoods.[112-114] Thus, missing data could potentially contribute to lower purchases of these items among black and Hispanic households.

Another limitation of our data is that households record only purchases, not consumption. Studies have found greater waste among perishable minimally processed foods and beverages.[109,115] Food waste is one component of food loss, and recent studies estimated that food loss at the consumer level represented a substantial percentage of calories available within food groups such as fresh fruit and vegetables (30-33% of available calories not consumed), fluid milk (20%), fresh meats (18-31%), and eggs (25%).[115] Further, reported food loss was also sizable for moderately processed foods, such as added sugars/sweeteners (30%) and added fats/oil (17%).[115] Previous studies suggest that greater food waste among less-processed foods may lead to an underestimation of the contribution of ultra-processed foods as a percentage of calories.[15] Nonetheless, differential food waste by households of different size, race/ethnicity, or income level may introduce bias into our Aim 2 analysis of sociodemographic and economic predictors of processed food purchases.[109] In particular, previous studies note that waste may be greater for oils discarded after use in frying, so higher purchases of cooking oils among black and less-educated households may not translate directly into higher calories consumed.[21,57] Purchases are recorded at the household-level, and participants do not report whether some food items are consumed by only select household members; thus, we cannot extrapolate our household-level findings to make inferences about individual-level diet. This issue might be particularly problematic for certain ultra-processed foods, such as diet sodas, that may not be consumed by all household members. Per capita absolute calorie estimates divide all purchases evenly by the number of household members, but this calculation may be highly inaccurate because males vs females and children vs adults have different total calorie requirements and likely consume unequal shares of household calories purchased. Therefore, we focused on the percent contribution of processed and convenience foods to purchases.

For Aim 3, although use of Nutrition Facts Panels was important for providing up-to-date and product-specific nutrient information, it was also a key limitation. Added sugar content is not required on Nutrition Facts Panels, so we used total sugar content; however, studies examined the substitution of total sugars for added sugars in nutrient profiling and concluded that this approach was reasonable.[91] Nutrition Facts Panels also do not require differentiation of specific types of saturated fatty acids, which may have heterogeneous associations with cardiovascular disease and diabetes.[92-94] Labeling of *trans* fat content was not required until 2006, midway through our study period, so we were not able to consider this food component.[116] Saturated fat has differential associations with disease risk depending upon the nutrient that replaces the saturated fat (e.g., carbohydrate vs polyunsaturated fatty acids); to take this into consideration, we evaluated compliance with saturated fat and sugar recommendations simultaneously.[92-94,117]

Moreover, our analysis assesses nutritional quality using only saturated fat, sugar, and sodium because of missing or incomplete data for other nutrients. These three nutrient densities do not capture all food components that impact dietary quality or health outcomes, such as refined carbohydrate content, micronutrients, phytochemicals, and other measures that were not sufficiently available in our data. In particular, inability to assess refined carbohydrate content of less-processed vs ultra-processed foods was a main limitation of our study. High amounts of sugar and refined carbohydrate in processed foods are an important potential mechanism through which ultra-processed foods might promote obesity and related chronic disease.[6,14] The American Heart Association recommends using a ratio of total carbohydrate to dietary fiber content ≤10:1 to identify fiber-rich whole grain foods; this ratio considers the balance of whole grain vs refined carbohydrate and sugar content in a product.[118,119] Missing data for fiber content precluded us from examining the carbohydrate to fiber ratio. Finally, we determined that energy density of foods as purchased was not a meaningful measure. Previous studies found that purchase data requires extensive adjustment for waste and weight increase/loss as a result of cooking or dilution before energy density should be calculated; such adjustments are not feasible for the large size of the Homescan data.[120,121] In preliminary analysis, we found that without these adjustments, energy density of foods requiring cooking was much higher compared to other foods; gram weights of foods such as flour, dry pasta and rice, cake mix, or boxed macaroni-and-cheese did not include water added/absorbed during preparation, and therefore were not appropriate for calculating energy density. Because of these limitations, conclusions about the nutritional quality of processed foods in our study pertain only to the three components examined, and may not translate to the total nutrient profile of these foods.

Selection bias may occur, as participants who willingly volunteer to participate in this time intensive data collection might have characteristics that are associated with purchasing behaviors.[95] Therefore, our results might not be generalizable to all US households. In Aims 1 and 3, estimates were weighted to be nationally representative, but households participating in the Homescan study might differ from the general US population in unobservable characteristics that were not incorporated into the sampling weights.[95] Furthermore, we did not have sufficient details to examine diversity within race/ethnic groups or account for differences in acculturation, and treating heterogeneous groups of individuals as a single population may mask important potential variation in diet.[57] Underreporting may occur if items or entire shopping trips are not scanned; however, validation studies comparing Homescan purchases to retailer's transaction data determined that the overall accuracy of the Homescan data is comparable to other commonly used economic datasets.[81] Whereas methods exist to identify potential implausible reported energy intakes based on total energy requirements, there are no methods for identifying underreporters of purchases that represent only a fraction of total energy intake.[122,123]

Finally, an important limitation of this study is that we lack information on health outcomes. Therefore, we could not examine whether a higher contribution of ultra-processed or RTE products in the diet is associated with obesity or nutrition-related chronic disease. As noted above, many other dietary components besides the nutrient densities considered in this study may influence dietary quality and health, and thus higher nutrient densities observed for ultra-processed and RTE foods may not translate into increased risk of obesity or chronic disease.

Strengths

A major strength of this study is use of product-specific ingredients and nutrition information collected by barcode scanning. First, ingredient lists and product attributes provide a complete description of each individual product, providing the necessary details essential for determining level of processing and convenience. Many researchers note that the insufficient details collected by traditional dietary assessment methods are a major reason for the lack of research studying processed foods.[14,17] We can readily determine the convenience level for most products (e.g., dry pasta vs prepared frozen pasta meals), whereas requiring the participant to recall this information for all mixed dishes might be overly burdensome. Second, scanning of barcodes linked to ingredient lists enables us to classify products without requiring the participant to be aware of product ingredients or report this information; for example, we can easily identify grain products with whole-grain as the first ingredient, whereas a participant might not know or be able to recall this information.[118] Third, using product-specific nutrition information that is frequently updated to reflect the rapidly changing profile of consumer packaged goods may improve the accuracy of our estimations.[78,79]

The Homescan dataset provides other advantages as well. Purchases are collected year-round, better capturing seasonal variation and usual purchasing patterns; thus, purchases potentially might be more reflective of usual intake than single 24-hour recalls. The large sample size allows us to examine associations of processed food purchases with education, income, and race/ethnicity, mutually adjusting for the other factors and for detailed measures of the economic landscape (market and market-level unemployment rate). Further, the longitudinal nature of the Homescan panel allowed us to examine associations of time-varying factors such as education and income with processed food purchasing using repeated measures on households across time.

A main strength of this analysis is that findings about processed and convenience foods were interpreted in context of the specific foods that were top calorie contributors within processing categories. Previous studies using the Homescan purchase data have used food group "modules" provided by Nielsen, despite great heterogeneity of products within these groups. For example, the module "fresh apples" includes not only fresh apples but also candied apples, placed similarly in the grocery store. The module for "soft drinks – carbonated" includes soda but also mineral water. "Poultry – 1 food – frozen" includes items ranging from frozen plain chicken breasts to chicken nuggets to chicken and noodle dinners. To better assess the main contributors to each category of processed foods, we disaggregated all modules and assigned products to a food group at the barcode-level using a combination of ingredient lists and product attributes. In this way, we could provide a detailed list of all products and their classification into processing and convenience categories, which is a key criterion for establishing the utility of classification systems.[20] Although time consuming, this re-organization of the data was essential for our study; it is generally known that ultra-processed foods comprise the majority of store purchases, but we were able to identify the specific ultra-processed food items that contribute to the dominance of these products and how purchasing of these products changed across time.

Our study uniquely provides estimates of the contribution of processed and convenience foods separately for foods, beverages, and within food groups. Previous US estimates were cross-sectional and somewhat outdated (from 2003-2008);[19] we provide updated trends analysis examining changes in processed and convenience food purchasing across time. Further, the only prior US estimates used a classification system that was developed for consumers, and categories were not clearly explained or comprehensively described.[19,20] The top-rated system developed by Monteiro et al. had not previously been applied to US data, and our study adapts and utilizes this framework.[20,27] Our classification system is the first to separate processing and convenience. No previous studies have examined the association of sociodemographic and economic factors with processed food purchasing in higher-income countries. Researchers caution that understanding race/ethnic and sociodemographic disparities is often hindered by differential bias in self-reported dietary intake, lack of cultural tailoring of dietary assessment, and food composition tables not reflective of cultural or ethnic food preferences; therefore, use of food purchasing data recorded by barcode scanning to examine these associations is a strength of our study.[44,56,82]

Prior US work evaluated the nutrient content of processed food based on disproportionate contributions to nutrient intake relative to energy intake without defining “disproportionate” or providing statistical testing.[19] Further, only mean nutrient content was examined, despite the wide variation in nutrient quality within categories.[19] To improve upon this work, we examined median nutrient content and the proportion of household-level purchases exceeding recommendations.

Significance and Public Health Impact

The dominance of ultra-processed and RTE foods as major calorie contributors in US purchasing patterns, combined with the high likelihood that these products exceed recommended limits for saturated fat, sugar, and sodium, together suggest that reducing consumption of these products may be a potential strategy for decreasing intake of food components to limit. We identified foods that were top calorie contributors among ultra-processed foods, and this could potentially help focus recommendations or public health efforts to specifically target grain-based desserts, SSBs, salty snacks, and candy. Our study suggests that reducing intake of ultra-processed foods may be particularly important for low SES groups.

Our findings have important implications about the differing role of cooking and food preparation across sociodemographic groups. In particular, our results suggest that dietary traditions and cultural food preparation methods among non-Hispanic black households might contribute to race/ethnic differences in diet.[98-100] Many scholars hypothesize that dietary patterns high in moderately processed ingredients have more favorable nutrient profiles compared to diets high in ultra-processed foods.[14,21] We found that black households were more likely to have this purchasing pattern compared to white households, yet the higher prevalence of obesity and nutrition-related chronic diseases among blacks vs whites in the overall US population is well-documented.[38-41] Because weight status and related outcomes are not measured in our sample, we do not know whether blacks in the Homescan sample have worse health outcomes than whites, and we cannot make inferences about individual associations about purchasing patterns and health from ecological prevalence data. Some researchers suggest that cultural variation in dietary traditions, food preferences, and methods of preparation may mediate racial differences in dietary quality.[47,82,98-100] These scholars note that traditional African American cooking and food preparation methods, such as frying or seasoning vegetables with fat, may contribute to poor dietary quality.[98-100] For example, a study of black adolescents found an association between greater frequency of meals cooked at home and higher adolescent BMI that was attributable to less healthful home-cooking methods such as deep-frying.[98] Moreover, healthier caregiver cooking methods, such as baking or grilling rather than deep-frying, were associated with lower prevalence of overweight and obesity among black adolescents.[98] Authors therefore suggest that cooking methods among African Americans may be an important correlate of dietary quality.[98] Furthermore, James et al. note that cooking methods, rather than the foods themselves, may contribute to poor health outcomes.[100] Our findings might suggest that public health policy and nutrition-related messages could more strongly emphasize recommendations in the Dietary Guidelines for Americans, 2010 to use cooking methods such as grilling, broiling, poaching, or roasting to avoid added fats; to limit the amounts of oils added to foods or used in cooking to keep calories in check; and to use healthier oils such as olive oil in cooking rather than solid fats.[75] Further research is needed to confirm the patterns observed in our study and investigate how diets higher in moderately processed foods in combination with these preparation methods may contribute to dietary quality.

We developed a multidimensional classification system for processed foods to provide explicit category definitions for all levels of processing and convenience and to include an exhaustive list of how all foods in the US food supply fit within our scheme. However, utility of this system for future research may be limited because defining “processed food” entails subjective decisions, and nutrition researchers have yet to reach a consensus about this definition.[20,37] In modern diets, almost all foods and beverages are processed in some way.[2,20] Moderate levels of processing may be beneficial for promoting food safety and security (for example, pasteurization of milk or freezing of fresh produce); however, more extensive levels of industrial processing create food products that are radical departures from foods found in nature.[6,19,20,37] Therefore, it is possible that consumers or nutrition researchers may not agree with our categorization. As noted throughout our work, differences in definitions and classification of processed foods make it difficult to compare estimates of their contribution to calories and their nutrient content across different studies. To avoid adding yet another disparate system, we tried to match the overall framework and terminology of our system to the highest-rated existing classification system of Monteiro and colleagues.[20,27]

Our definition of ultra-processed foods identified products that were collectively higher in saturated fat, sugar, and sodium content compared to less-processed foods, yet it may be necessary to further tease out the specific ultra-processed products with this poor nutrient profile. Some scholars emphasize that all categories defined by processing level contribute both nutrients to encourage and nutrients to limit.[37] In agreement, we noted wide variability in nutrient densities for household-level purchases in each category; for example, the interquartile range of sugar density for less-processed foods (12.9 to 23.9% kcal) was wide and overlapped the interquartile range for ultra-processed foods (17.3% to 26.2% kcal). As noted by Eicher-Miller et al., no processing category contains only foods that are “healthy” or only foods that are “unhealthy;”

minimally processed foods include red meat, and ultra-processed foods included whole grain breakfast cereals that may contribute to micronutrient or fiber intakes.[19] These authors conclude that the selection of foods within the ultra-processed food category may be particularly important, as different ultra-processed products make heterogeneous contributions to nutrient intakes.[19] Future work could further distinguish ultra-processed foods with high saturated fat and sugar densities vs ultra-processed foods with lower fat and sugar content. Unfortunately, differential associations of these types of ultra-processed foods with outcome measures cannot be evaluated with our data because no additional dietary or health outcomes were assessed. One important implication of our work is that a universally accepted definition of ultra-processed foods is needed.

Our findings could potentially have important implications for food monitoring in the US and future refinement of dietary assessment methods. Examination of purchases using extensive product details and ingredient lists was an essential first step to obtain a more comprehensive understanding of the role of ultra-processed and convenience foods in the US food supply. Many scholars emphasize the need for studies determining the association of ultra-processed foods with health outcomes, but note that more refined measurement of processing level is vital to facilitate this work.[14,17,21,37] Our research findings could potentially help future studies to target dietary assessment data collection to the most relevant food categories and pertinent details necessary to identify processed foods. For example, the relatively large and increasing contributions of RTH foods overall and among grain products suggest that a key detail to assess for mixed dishes might be whether the dish is home-made vs pre-prepared. Currently, even NHANES dietary recalls are not adequate for making this distinction. For example, a single foodcode is available for “lasagna with meat” with no ability to distinguish between a recipe prepared from less-processed ingredients and an industrially prepared RTH frozen product. Likewise, foodcodes such as "pancakes, plain" do not specify whether the item was home-prepared from less-processed ingredients, prepared from a mix, or purchased as fully-prepared RTH frozen pancakes.[124] Our analysis helped to identify the types of foods where enhanced detail or ingredients may be necessary to categorize foods by level of processing. More importantly, our results suggest that nutrition monitoring and surveillance efforts, such as NHANES, may need to refine food composition tables to accurately capture the nutrient content of ultra-processed foods, which may differ greatly from home-cooked alternatives.

Our classification system creates a framework to define categories of processing and convenience that could potentially be used or adapted by future studies. However, because our definitions incorporate product details and ingredients, the practicality and feasibility of applying our system to data collected by traditional dietary assessment methods is an important concern. Studies that collect less detailed food descriptions could retain our overall category framework while simplifying classification criteria. For example, we classified vegetables canned without added salt as "moderately processed," while vegetables canned with salt or other additions were considered "processed." While this distinction may be conceptually important, purchases of moderately processed vegetables canned with no additions were negligible. Thus, studies that do not collect this level of food detail do not need to make this distinction; all canned vegetables could reasonably be assumed to contain salt and be classified as processed. Importantly, we found that all top calorie contributors to ultra-processed foods are distinct foods that are already currently assessed even by food frequency questionnaires: refined breads, grain-based desserts, SSBs, salty snacks, candy, breakfast cereals, and ice cream. More research is needed to understand whether collection of relevant details needed to classify foods by processing or convenience level can be feasibly achieved without being overly burdensome to participants.

Overall, the substantial contribution of ultra-processed products to household purchases suggests that the food industry plays a large role in impacting the nutritional quality of the foods and beverages that Americans purchase. Thus, our work could be seen as a motivator for food manufacturers to improve the saturated fat, sugar, and sodium content of their products. The great variability in nutrient densities observed in our study suggests that more healthful versions of ultra-processed products are available and acceptable among households who currently purchase these items. In particular, the wide distribution of sodium density of household-level purchases implies that technological feasibility and consumer acceptability may not be barriers to the manufacture of lower-sodium products, and thus our study supports the need for product reformulations to reduce sodium content. A major implication of this dissertation work is that efforts by the food industry to reduce the saturated fat, sugar, and sodium density of ultra-processed products could potentially have substantial impact on the dietary quality of Americans.

Future Directions

While this study provided much-needed description of ultra-processed and convenience food and beverage purchasing trends and identified significant sociodemographic predictors of purchases, it also laid the groundwork for many ongoing investigations. Importantly, future work is needed to determine the amount of ultra-processed food that is compatible with a healthy diet. The reductionist approach used in the current study to compare the nutrient densities of ultra-processed vs less-processed foods was only a first step; dietary patterns are composed of a mixture of ultra-processed and less-processed foods. Therefore, further studies will identify food patterns that underlie high purchases of ultra-processed foods and determine the longitudinal associations of these patterns with the overall dietary quality of household purchases. Reduced rank regression will be used to identify a pattern of specific food items (predictor variables) that explain the maximum variation in ultra-processed food purchases (using % grams from ultra-processed products as the dietary response variable); this method will illustrate how foods across the spectrum of processing are purchased in combination. Then, we will examine association between adherence to this reduced rank regression ultra-processed dietary pattern and the nutrient density of total purchases. While the current study found that ultra-processed foods have less favorable nutrient content compared to less-processed foods, this subsequent research will build upon those findings by extending the focus to overall dietary quality.

When developing and introducing a new classification system for food processing and convenience, an important consideration is how this new method improves upon existing ones. To that end, all foods in the Homescan data were classified by criteria used in the IFIC and Monteiro classification systems. Preliminary analysis has compared the contribution of processed foods to household purchases across these various definitions of processed foods. Further work will determine whether the association with overall dietary quality is stronger for ultra-processed foods identified by our system vs processed foods defined by the IFIC system.

Furthermore, future studies will examine additional dimensions of processed foods that might be relevant for how we define these products. All products in the Homescan database were additionally classified based on perishability, distinguishing products that are perishable (fresh or refrigerated), moderately perishable (frozen), and non-perishable (shelf-stable). Many foods are processed to be shelf-stable; for example, methods such as canning inactivate pathogens and spoilage microorganisms to extend the shelf-life, and extrusion or control of water activity can produce shelf-stable snacks and desserts.[125] However, other ultra-processed foods are perishable (e.g., processed meats). We will examine nutrient densities across levels of perishability.

Forthcoming work will explore whether cross-classification of products by processing and convenience could help to refine our definition of processed foods. We hypothesize that foods classified as both ultra-processed and RTE, such as SSBs, salty snacks, candy, and ice cream, might have the least favorable nutritional profile compared to other categories. In preliminary work, we found that ultra-processed RTE foods and beverages contributed 44.6% of calories purchased. Among food purchases, the contribution of these products declined from 48.1% to 44.0% of calories purchased between 2000 and 2012, while the percentage of calories purchased from ultra-processed RTH foods increased (10.9% to 13.3%). Cross-classification could help to refine our definition of RTE products, as minimally processed RTE (6.2%) and moderately processed RTE (4.7%) foods and beverages may not have unfavorable nutrient profiles; these include fresh fruit, unsweetened dried fruit, bagged salad, baby carrots, milk, and unsweetened fruit juice.

Additional work is also needed to determine whether the presence of food additives can better define and identify processed foods that are most detrimental to dietary quality and health. Because of the extensive number of food additives present in the food supply, the substantial number of typographical misspellings in the ingredient lists provided by our data, and the complexity of distinguishing between different classes of food additives, classification based on presence of industrial food additives was beyond the scope of this dissertation. Future work is planned to collaborate with our food scientists to categorize food additives as natural or industrial, and to explore whether presence of additives is associated with poor nutrient profiles.

Importantly, additional work using other datasets is needed to determine whether excess consumption of ultra-processed food is associated with increased energy intake, obesity, or related chronic diseases. Mozaffarian and Ludwig emphasize that specific foods and dietary patterns, such as diets high in packaged foods, are substantially associated with risk of chronic disease, whereas discrete nutrients have major limitations for predicting health outcomes.[65] Therefore, Mozaffarian et al. recommend that future research efforts should explore whether processing is a relevant dietary metric for prevention of obesity and related chronic disease.[64] Findings of our study could help inform these future investigations.

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