Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households?[1–4]

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ABSTRACT

Background: "Processed foods" are defined as any foods other than raw agricultural commodities and can be categorized by the extent of changes occurring in foods as a result of processing. Conclusions about the association between the degree of food processing and nutritional quality are discrepant.

Objective: We aimed to determine 2000–2012 trends in the contribution of processed and convenience food categories to purchases by US households and to compare saturated fat, sugar, and sodium content of purchases across levels of processing and convenience.

Design: We analyzed purchases of consumer packaged goods for 157,142 households from the 2000–2012 Homescan Panel. We explicitly defined categories for classifying products by degree of industrial processing and separately by convenience of preparation. We classified >1.2 million products through use of barcode-specific descriptions and ingredient lists. Median saturated fat, sugar, and sodium content and the likelihood that purchases exceeded maximum daily intake recommendations for these components were compared across levels of processing or convenience by using quantile and logistic regression.

Results: More than three-fourths of energy in purchases by US households came from moderately (15.9%) and highly processed (61.0%) foods and beverages in 2012 (939 kcal/d per capita). Trends between 2000 and 2012 were stable. When classifying foods by convenience, ready-to-eat (68.1%) and ready-to-heat (15.2%) products supplied the majority of energy in purchases. The adjusted proportion of household-level food purchases exceeding 10% kcal from saturated fat, 15% kcal from sugar, and 2400 mg sodium/2000 kcal simultaneously was significantly higher for highly processed (60.4%) and ready-to-eat (27.1%) food purchases than for purchases of less-processed foods (5.6%) or foods requiring cooking/preparation (4.9%).

Conclusions: Highly processed food purchases are a dominant, unshifting part of US purchasing patterns, but highly processed foods may have higher saturated fat, sugar, and sodium content than less-processed foods. Wide variation in nutrient content suggests food choices within categories may be important. *Am J Clin Nutr* 2015;101:1251–62.

Keywords: convenience food, diet, food processing, processed food, ultra-processed

INTRODUCTION

Food processing is defined as any procedure that alters food from its natural state, such as freezing, drying, milling, canning, mixing, or adding salt, sugar, fat, or additives (1, 2). Thus, the US government's definition of "processed food"—any food other than a raw agricultural commodity—includes a diverse array of foods ranging from frozen vegetables, dried fruit, and canned beans to whole-wheat bread, breakfast cereals, prepared meals, candy, and soda (1, 2). Because of this heterogeneity, classification systems were developed to subdivide processed foods into refined categories based on the complexity of processing, the physical and chemical changes in food as a result of processing, and the purpose of processing; foods are classified into levels along a spectrum, ranging from minimally processed to highly processed (3–6). Here, we define highly processed foods as multi-ingredient industrially formulated mixtures (7).

Food processing can help to ensure a safe, diverse, abundant, and accessible food supply (8). However, some researchers hypothesize that excessive consumption of highly processed food might contribute to poor dietary quality and obesity (5, 6, 9). In addition, many highly processed foods are manufactured to be ready-to-eat (RTE),[5] requiring no preparation before quick, easy consumption (10). Convenience foods are hypothesized to disrupt satiation/satiety signaling by encouraging a rapid eating rate and eating while distracted (e.g., watching television) (11–15). Evaluating the nutritional contributions of highly processed and convenience foods to US food purchases and dietary intake are necessary first steps to address these hypotheses.

Only 1 study has estimated processed food intake in the United States; in analysis that used cross-sectional 2003–2008 data, minimally processed and all other processed foods provided 14.1% and 57.3% of total energy intake, respectively (3). It is

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[3] Supplemental Material I and II, Supplemental Tables 1–5, and Supplemental Figure 1 are available from the "Supplemental data" link in the online posting of the article and from the same link in the online table of contents at http://ajcn.nutrition.org.

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[5] Abbreviations used: CPG, consumer packaged goods; DGA, Dietary Guidelines for Americans; RTE, ready-to-eat; RTH, ready-to-heat; SSB, sugar-sweetened beverage.

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unknown whether highly processed food intakes or purchases have increased in the United States in recent years. Convenience food purchases by Americans have not been quantified. Moreover, conclusions about the nutritional quality of processed foods are discrepant. US authors 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 (3, 16). On the contrary, studies in Canada, the United Kingdom, and Brazil found that moderately and highly processed foods were higher in saturated fat, added sugar, or sodium than less-processed foods (6, 17, 18). Additional studies are needed to understand these inconsistent findings.

In this study, we analyzed purchases of food and beverage consumer packaged goods (CPGs) recorded by barcode scanning in a nationally representative sample of US households. Using ingredient lists and nutrition information specific for each barcoded product can enhance the accuracy of processing classification and nutrient content comparison. We aimed *1*) to explicitly define categories for classifying products by the degree of industrial processing and separately by convenience, *2*) to determine trends from 2000 to 2012 in the caloric contribution of each category of processed and convenience food to CPG purchases, and *3*) to compare saturated fat, sugar, and sodium content of CPG purchases across levels of processing or convenience.

METHODS

This study used data from the 2000–2012 Nielsen Homescan Panel, a longitudinal study of food and beverage CPGs purchased by US households (19–22). Participating households were given barcode scanners, and household members were instructed to scan the barcodes on all purchased items on returning home after every shopping trip. Scanning occurred continuously throughout the year and included products purchased from supermarkets and grocery, drug, mass-merchandise, club, supercenter, and convenience stores. Homescan uses an open cohort study design in which households may exit any time after reporting purchases for at least 10 mo, and new households are enrolled to replace dropouts and rebalance the sample. Length of follow-up ranged from 10 mo to 13 y (mean 4.2 y). Households were sampled from 76 economic markets, defined as 52 metropolitan and 24 nonmetropolitan geographic areas, and were weighted to be nationally representative, as described previously (19, 22). Household size and demographic characteristics were collected by questionnaire. Yearly sample size ranged from 34,000 to 62,000 households. We excluded purchases during annual quarters deemed unreliable by study investigators and year-level observations including >1 unreliable quarter (2.2%), to ensure that we fully captured usual purchasing habits (23, 24). This study included 656,184 year-level observations from 157,142 unique households. This deidentified secondary data analysis was exempt from institutional review board approval.

Food and beverage purchase 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 energy, saturated fat, total sugar, and sodium content as well as information appearing on the product's package and the product's ingredient list (25). Any item without a barcode or not linked to nutrition information was not included in our analysis. Specifically, many fresh fruits, vegetables, and meats were not included because these random-weight products were not barcoded and therefore cannot be scanned. The method for this linking process has been described in detail elsewhere (23, 26).

Each product was assigned to a basic food group (including beverages and 10 food groups) and to a specific food group (45 groups) at the barcode level (**Supplemental Table 1**); methods used for food grouping are described in detail in **Supplemental Material I**.

Processing and convenience classification system

Scholars recommend that separate analysis of processing and convenience is needed because not all processed foods are RTE (10, 12). A classification system was developed to define 4 categories based on the degree of industrial food processing (**Table 1**) and to separately define 3 categories based on product convenience (**Table 2**) in consultation with a team of food scientists and registered dietitians. Objective criteria and decision rules for classification were established. A complete list of food and beverage products and their classification by processing, convenience, and food grouping was created (**Supplemental Table 2**); examples within each category of processing or convenience are provided in Tables 1 and 2.

Processing

Food processing was defined as any procedure that alters food from its natural state and includes all processes and technologies that transform raw food materials and ingredients into consumer food products (1, 2, 8). Only industrial processes were considered, with "industrial" including all commercial manufacturing operations that convert raw agricultural commodities into packaged, canned, frozen, dried, fermented, formulated, and otherwise modified forms of food but excluding processing (i.e., cooking) by the food service industry (27). Further processing by the consumer after purchase, such as cooking raw meat or preparing a recipe, was not included in our definition. With the exception of raw agricultural commodities, all foods and beverages can be considered "processed foods" (1, 2). To subdivide processed foods into more refined groups, we defined 4 mutually exclusive categories based on the extent to which a food was altered from its natural state by industrial food processing and the purpose of these processes (Table 1) (6). Items were classified based on the most extensive processes used. Our system was guided by the work of Monteiro and colleagues (28) but modified to adapt category definitions and example foods for the complexity of the US food supply and enhanced detail of dietary recall or purchase data. **Supplemental Material II** describes these modifications in detail.

"Unprocessed and 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

TABLE 1
Category definitions and criteria for classifying foods and beverages based on degree of industrial food processing[1]

Category/definition	Beverages	Fruit, vegetables, legumes	Meat/meat dishes/eggs	Grain products	Dairy products	Fats/oils, sweets, other
Less processed						
Unprocessed/minimally processed						
Unprocessed/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 plain milk, coffee (whole or ground beans), bottled plain water, tea leaves or bags	Fresh, frozen, or dried plain fruit, vegetables, or legumes; plain nuts	Eggs; unseasoned meat (refrigerated or frozen)	Whole-grain plain hot cereal, brown rice, popcorn kernels	Cream	Honey, herbs, spices, pepper
Basic processed						
Processed basic ingredients: single isolated food components obtained by extraction or purification using physical or chemical processes that change inherent properties of the food	Unsweetened fruit juice not from concentrate	—	Egg whites	Whole-grain flour, whole-grain pasta	—	Oil, unsalted butter, sugar, pure maple syrup, salt
Processed for basic preservation or precooking: single minimally processed foods modified by physical or chemical processes for the purpose of preservation or precooking but remaining as single foods	Unsweetened fruit juice from concentrate or frozen concentrate, dry milk, instant coffee	Unsweetened/unflavored canned fruit, vegetables, or legumes; unsweetened/unsalted peanut butter	Unseasoned canned meat	Refined-grain pasta, refined-grain flour, white rice, instant rice, plain refined-grain hot cereal	Sour cream, plain yogurt, evaporated milk	—
Moderately processed						
Moderately processed for flavor: single minimally or moderately processed foods with addition of flavor additives for the purpose of enhancing flavor; directly recognizable as original plant/animal source	Sweetened/flavored fruit or vegetable juice, tea, or soy milk; chocolate milk; cocoa mix	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	Seasoned refrigerated, frozen, or canned meat; smoked or cured bacon, ham, or seafood	Sweetened/flavored hot cereal, flavored pasta, flavored popcorn (microwaveable or prepopped)	Cheese, sweetened/flavored yogurt, sweetened condensed milk, whipped cream	Salted butter, flavored oil, seasoning salts
Moderately processed grain products: grain products made from whole-grain flour with water, salt, and/or yeast	—	—	—	Whole-grain breads, tortillas, crackers, or RTE cereals with no added sugar or fat	—	—

(Continued)

TABLE 1 (*Continued*)

Category/definition	Beverages	Fruit, vegetables, legumes	Meat/meat dishes/eggs	Grain products	Dairy products	Fats/oils, sweets, other
Highly processed						
Highly processed ingredients: multi-ingredient industrially formulated mixtures processed to the extent that they are no longer recognizable as their original plant/animal source and consumed as additions (condiments, dips, sauces, toppings, or ingredients in mixed dishes)	—	Tomato sauce, salsa, hummus, jelly	—	Bread crumbs/breading with refined grains or added sugar/fat	Creamer, whipped topping, dairy-based chip/veggie dip, cheese dip/queso, Alfredo sauce	Margarine; mayonnaise; salad dressing; shortening; pancake syrup; artificial sweetener; baking chocolate; icing; ketchup, barbecue sauce, marinades, and other condiments; sauce/seasoning mixes
Highly processed stand-alone: multi-ingredient industrially formulated mixtures processed to the extent that they are no longer recognizable as their original plant/animal source and not typically consumed as additions	Soda, alcohol, fruit drinks, sports drinks, energy drinks, flavored waters, coffee beverages	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; restructured 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	Sausage; hot dogs; pressed/formed lunchmeats (bologna, salami) or ham; Spam; RTH meat dishes (meatloaf, crab cakes, buffalo wings, pot roast, barbecue); meat-based frozen meals (Salisbury steak); breaded meat (chicken nuggets, fish sticks); meat-based soups	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; noodle- or rice-based soups; stuffing mix	Ice cream, frozen yogurt, pudding (RTE and mixes), processed cheese, cheesecake	Candy, chocolate, popsicles, sorbet, gelatin (RTE and mixes), broth, bouillon

[1]Industrial food processing was defined as any procedure that alters food from its natural state and includes all processes and technologies that transform raw food materials and ingredients into consumer food products. Mutually exclusive categories of processing were defined based on the extent to which a food was altered from its natural state by industrial food processing and the purpose of these processes. Food processing was considered separately from product convenience. 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. Fresh fruits and vegetables and fresh unseasoned meats were included in our study only if they were barcoded. "Plain," "unseasoned," and "unsweetened" indicate that the product contains no added sweeteners (natural or artificial), salt, flavors, fats, or oils. Whole-grain products were defined by the 2010 Dietary Guidelines for Americans criteria of 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. "Sweetened/flavored" indicates that the product contains added sweeteners (natural or artificial), salt, flavors, fats, and/or oils. Fruit drinks are defined as beverages primarily composed of sugar or sweetener (as first or second ingredients) with fruit juice or fruit juice concentrate as a lesser ingredient. RTE, ready-to-eat; RTH, ready-to-heat.

natural unprocessed form. Specific processes include cleaning, portioning, packaging, removal of inedible fractions, fat reduction, drying, chilling, freezing, or pasteurization (6). These products 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.

"Basic processed" foods and beverages have been processed but remain as single foods. They are divided into 2 subcategories. "Processed basic ingredients," including sugar, oil, or whole-grain flour, are isolated food components extracted or purified from unprocessed/minimally processed foods by physical or chemical processes that change the inherent properties of the food (28). Processes include extraction, pressing, clarification, refining, purification, and milling (28). Products "processed for basic preservation or precooking" are unprocessed/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 precooking grains. Examples are refined-grain flour or pasta, white or instant rice, and fruit or vegetables canned with no additional flavoring steps.

"Moderately processed" foods and beverages are divided into 2 subcategories. Products "moderately processed for flavor" are defined as single minimally or basic processed foods but with the addition of flavor additives (sweeteners, salt, flavors, or fats) for the purpose of enhancing flavor. They are directly recognizable as their original plant or animal sources (7). Examples are salted nuts, fruit canned in syrup, or vegetables canned with added salt. "Moderately 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.

"Highly processed" foods and beverages are multi-ingredient industrially formulated mixtures processed to the extent that they are no longer recognizable as their original plant or animal source (7). "Highly processed ingredients," such as ketchup, margarine, mayonnaise, and jarred pasta sauce, are highly processed products typically consumed as condiments, dips, sauces, toppings, or ingredients in mixed dishes. "Highly processed stand-alone" foods and beverages are not typically consumed as additions and include refined-grain breads, sugar-sweetened beverages (SSBs), cookies, salty snacks, candy, and preprepared mixed dishes.

Justification for this hierarchy of processing categories is demonstrated by the increasing degree of alterations in single foods from their natural state: single foods with no/minimal changes [unprocessed/minimally processed, in accordance with the Dietary Guidelines for Americans (DGA) definition (1)], single foods with more extensive changes (basic processed), multi-ingredient products composed of only single foods with flavor additives (moderately processed), and multi-ingredient formulated foods that are mixtures of ingredients [highly processed, as defined previously (7)].

Convenience

To separately classify foods by level of convenience, we defined 3 mutually exclusive categories based on the amount of food preparation required by the consumer before a product can be eaten (Table 2). Classification of convenience was based on whether a product can be consumed in purchased form (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 (10, 12, 29–31).

Products requiring "cooking and/or preparation" are least convenient and not typically consumed as purchased. These products require substantial input of the consumer's time, culinary skill, energy, or attention to cook or prepare before being eaten or drunk (29). 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 multistep 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) (30). Frozen dinners or pizza, frozen waffles, canned soup, hot dogs, instant oatmeal, canned or frozen vegetables, and powdered drink mixes are examples.

RTE products are highly convenient and can be consumed immediately with no preparation (12, 29, 30). Examples include bread, premade cookies, salty snacks, candy, canned fruit, most fresh fruit, baby carrots, and ready-to-drink beverages. To ensure mutually exclusive classification of convenience, we categorized products that can be prepared in alternative ways based on the most minimal preparation typically required (29). 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 by using the Perl-based pattern-matching syntax "regular expressions" and implemented within SAS 9.3 (SAS Institute). This technique was used to search ingredient lists, package information, and product attributes for keywords indicative of processing or convenience level. Supplemental Material I provides a detailed description of these methods. 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 convenience. Accuracy of classification was manually reviewed for >615,000 products.

Statistical analyses

Trends analysis was conducted by using survey commands in Stata 13 (StataCorp LP) 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 energy purchased and also as a percentage of energy from foods or beverages. 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 contributors to each category of processing or convenience, we ranked specific food groups by mean per capita calories purchased in 2000 and 2012.

TABLE 2
Category definitions and criteria for classifying foods and beverages based on convenience and the amount of preparation required by the consumer before food consumption[1]

Category/definition	Beverages	Fruit, vegetables, legumes	Meat/meat dishes/eggs	Grain products	Dairy products	Fats/oils, sweets, other
Cooking and/or preparation: Requires substantial input of consumer's time, culinary skill, energy, or attention to cook/prepare before consumption; not typically consumed as purchased	Coffee (whole/ground beans), tea (leaves/bags)	Fresh fruit or vegetables requiring preparation (heads of lettuce, onions, broccoli, whole melon) or cooking (potatoes); canned tomatoes; dried beans	Eggs, uncooked meat, uncooked sausage or bacon	Flour, dry pasta or rice, pasta/rice dish mixes (boxed macaroni and cheese), grain-based dessert mixes, pancake or biscuit mixes	Whipping cream, evaporated milk, pudding mixes, sweetened condensed milk	Oil, shortening, baking chocolate, gelatin mixes, cooking sauces, herbs and spices, sauce/seasoning mixes
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	Powdered mixes for sports drinks or flavored waters; instant tea mixes; frozen fruit juice concentrate; cocoa or coffee beverage mixes; dry milk; instant coffee	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	Precooked sausage; hot dogs; frozen or refrigerated meat dishes (meatloaf, crab cakes, pot roast, barbecue); meat-based frozen meals (Salisbury steak); breaded meat (chicken nuggets, fish sticks); meat-based soups	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	Frozen whipped topping, Alfredo sauce, cheese dip/queso	Ready-to-spread icing; broth and bouillon; premade gravy or sauces
RTE: Can be consumed immediately with no preparation	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	Fresh, canned, or dried fruit; fruit snacks; jam; jelly; fresh/refrigerated RTE vegetables (precut bagged salad, baby carrots); entrée garden salads; olives, pickles; salsa; potato chips; potato salad; peanut butter; nuts	Lunch meat; canned meat or processed meat (Spam); summer sausage; beef jerky; seafood or chicken salad	RTE cookies, doughnuts, pastries, and other grain-based desserts; salty snacks (potato chips, crackers, pretzels, tortilla chips, corn chips, prepopped popcorn); RTE bread, tortillas, rolls, bagels; RTE cereal	Cheese, ice cream, yogurt, creamer, cream, sour cream, dairy-based dip, RTE pudding, whipped cream	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 by the consumer before a product can be eaten. Products that can be prepared in alternative ways were categorized based on the most minimal preparation typically required. Convenience was considered separately from food processing. 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. Fresh fruits and vegetables and fresh unseasoned meats were included in our study only if they were barcoded. RTE, ready-to-eat; RTH, ready-to-heat.

We compared the saturated fat, sugar, and sodium content of less-processed vs. highly processed food purchases; these components were selected as the information available to consumers on Nutrition Facts Panels that best reflects a major theme in the 2010 DGA to reduce intake of foods high in solid fat, added sugar, and sodium (32–34). Because processed basic ingredients are food components not consumed alone but in combination with minimally or basic processed products, these categories were grouped as "less processed" (6). We calculated the saturated fat (% kcal), total sugar (% kcal), and sodium (mg/1000 kcal) content of a household's purchases within each category of processing in 2012 (hereafter referred to as "nutrient content"). Comparisons of the nutrient content of less-processed vs. highly processed food purchases may be confounded because less-processed food purchases include more fruits and vegetables than highly processed purchases. Therefore, by using household-level purchases within each processing category as the unit of analysis, we regressed nutrient content on dummy variables for level of processing (less, moderately, or highly processed) while adjusting for confounding by the contribution of each basic food group (% kcal) to purchases in that processing category. Variance inflation factors indicated the absence of collinearity problems. Because nutrient content distributions were skewed, quantile regression and Stata's margins command were used to find the weighted adjusted median nutrient content of purchases in each category of processing. To test whether median nutrient content differed significantly across categories while accounting for nonindependence of observations, we constructed bias-corrected CIs from estimates determined in each of 1000 bootstrap samples drawn accounting for market-level clustering and multiple observations per household. We also converted continuous nutrient content of household-level purchases in each category of processing into binary variables based on whether content exceeded limits for total dietary intake recommended by the DGA or FDA: >10% kcal from saturated fat, >15% kcal from sugar (the maximum allowance for energy from solid fat and added sugar), >2400 mg sodium per 2000 kcal (hereafter referred to as "DGA/FDA-recommended limits"), or exceeded all 3 DGA/FDA-recommended limits simultaneously (32, 35). Although many assumptions are made when applying dietary recommendations for total *intake* to *purchases*, these DGA/FDA-recommended limits are used primarily as cutpoints to categorize continuous variables into high vs. low nutrient content, because no US recommendations for the nutrient content of *purchases* exist. Adjusted survey-weighted logistic regression models with market-level clustering were run with these binary outcomes. Margins commands were used to predict the probability that purchases of foods within each processing category exceeded DGA/FDA-recommended limits, and categories were compared using Wald tests. This approach was repeated for categories of convenience. Nutrient content varies greatly for foods vs. beverages, so we focus on foods because recommendations specific for beverages were not available. For all analyses, significance was set at $P < 0.001$ to adjust for multiple comparisons and take into account large sample size.

RESULTS

The Homescan sample includes predominantly non-Hispanic white and highly educated households (**Supplemental Table 3**). More than three-fourths of energy in CPGs purchased by US households in 2012 came from moderately (15.9%) and highly processed (61.0%) foods and beverages (939 kcal/d per capita, **Figure 1**A). Top sources of energy among highly 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 4**). Peanut butter and salted nuts, potato chips and popcorn, cheese, and salted butter were the largest caloric contributors among products moderately processed for flavor. The percentage of total energy from unprocessed/minimally and basic processed products among CPG purchases was <25%. Top unprocessed/minimally processed products were plain milk, eggs, fresh potatoes, fresh fruit, and plain dried fruit.

Considering foods and beverages separately, the contribution of highly processed products to foods purchases (62.5%) was greater than the contribution of highly processed products to beverage purchases (47.4%). By volume, the pattern was similar (**Supplemental Figure 1**A). Although purchases of highly processed stand-alone foods remained stable between 2000 and 2012, decreases in refined breads, grain-based desserts, candy, and ice cream and increases in frozen grain-, pasta-, or rice-based dishes and processed meat were observed within this category. A significant upward trend in unprocessed/minimally processed food purchases occurred as purchases of fresh fruit increased across time. Increased purchases of cheese and sweetened/flavored yogurt contributed to the significant upward trend in purchases of foods moderately processed for flavor. Basic processed foods (mainly sugar and refined-grain flour) and highly processed ingredients (margarine and shortening) declined. Unprocessed/minimally processed beverage purchases decreased across time, as large declines in plain milk (−24 kcal/d) occurred. Shifts away from unsweetened fruit juice from concentrate (basic processed) and toward presweetened teas and juices (moderately processed) were significant. Highly processed beverage purchases dropped (−22 kcal/d) as SSB purchases declined between 2000 and 2012, but the linear trend in their percent contribution to beverage purchases was not significant.

Alternately, classification by convenience determined that RTE foods and beverages contributed more than two-thirds of energy in CPGs purchased in 2012 (Figure 1B). Top RTE caloric contributors were salty snacks, breads, grain-based desserts, milk, sugar and syrups, SSBs, and candy (**Supplemental Table 5**). Among RTH products, main sources of energy included frozen grain-based dishes; RTH pancakes, biscuits, or rolls; soup; preprepared or instant pasta/rice dishes; and precooked 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 caloric 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, almost all purchases (>90% kcal) were ready-to-drink products.

In 2012, median saturated fat, total sugar, and sodium content was higher for highly processed food purchases compared with less-processed food purchases and higher for RTE food purchases compared with foods requiring cooking and/or preparation, holding constant the contributions of fruit, vegetables, and all food groups to energy in CPG purchases (**Table 3**). However,

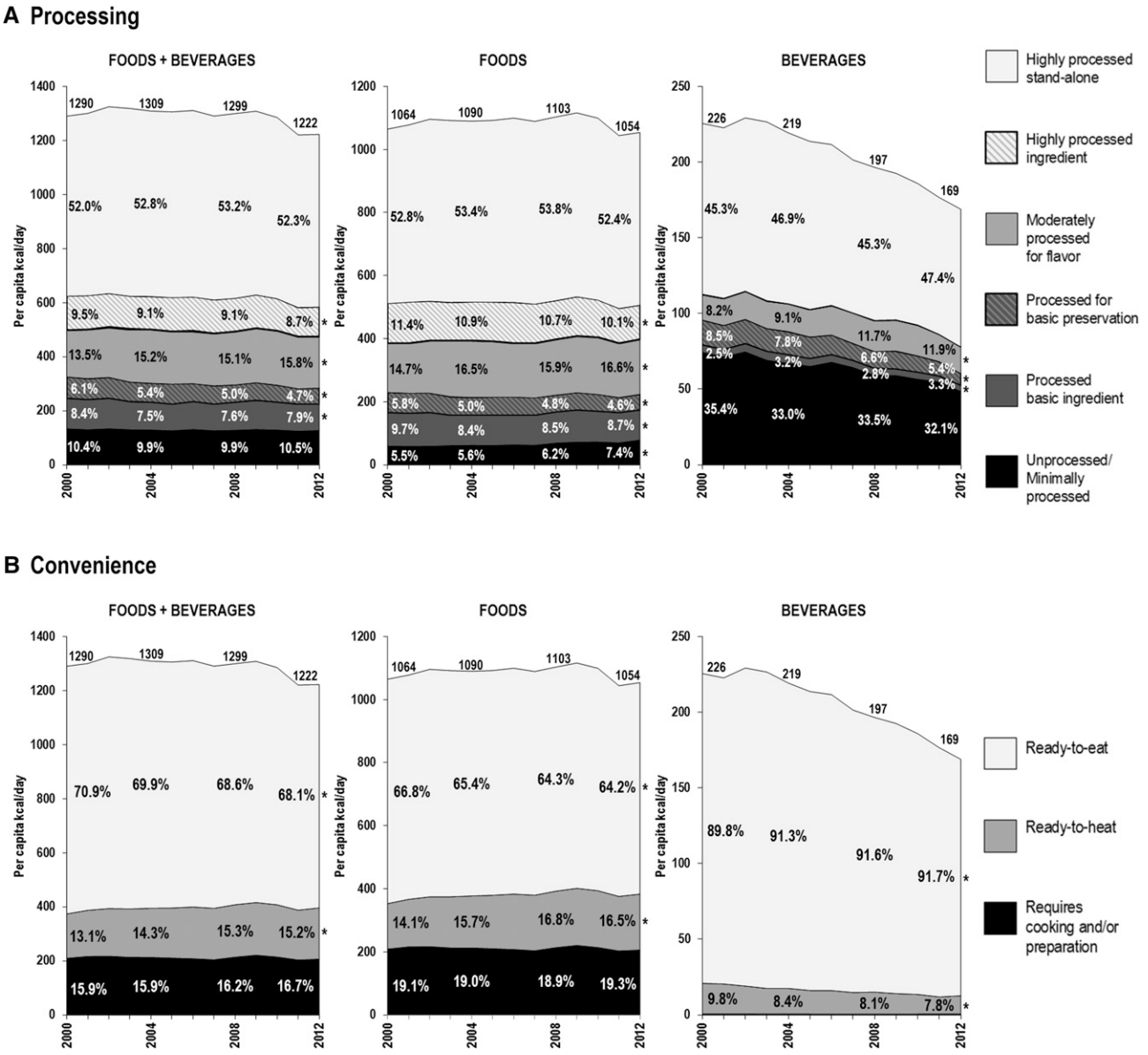

FIGURE 1 Trends in US household food and beverage purchases categorized by the degree of industrial processing and level of convenience, Homescan 2000–2012. Weighted unadjusted mean per capita kcal/d and % kcal purchased from each category defined by (A) degree of processing and (B) convenience by year. Each uniquely barcoded food or beverage was classified into a mutually exclusive category for (A) degree of processing based on the extent to which a food was altered from its natural state by industrial food processing and the purpose of these 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. Percentages labeled within the graph represent estimates in 2000, 2004, 2008, and 2012. Number of year-level observations and households: foods and beverages: n = 656,184 (157,142 households); foods: n = 656,172 (157,139 households); and beverages: n = 655,833 (157,114 households). Moderately processed grain products represented ≤0.2% kcal purchased and therefore do not appear in the figure. *Significant linear trend in the contribution of a given category of processing or convenience to purchases (% kcal), determined by using survey-weighted linear regression models accounting for market-level clustering. $P < 0.001$ to account for multiple comparisons and sample size.

wide variability in the nutrient content of household-level food purchases was observed in each category. For example, the IQR of sugar content for less-processed foods (12.9–23.9% kcal) was wide and overlapped the IQR for highly processed foods (17.3–26.2% kcal). After adjustment, 94.7%, 94.5%, and 96.3% of household-level highly processed food purchases exceeded 10% kcal from saturated fat, 15% kcal from sugar, and 2400 mg sodium per 2000 kcal, respectively (**Figure 2**). Independent of the smaller amount of fruits and vegetables among highly processed food purchases, the percentage of household-level highly processed food purchases that exceeded all 3 recommendations (60.4%) was significantly higher than the percentage of less-processed food purchases with the combination of high fat, sugar, and salt (5.6%). When classifying products 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 with foods requiring cooking/preparation (4.9%). Conclusions did not differ

TABLE 3
Median saturated fat, sugar, and sodium content of household-level food purchases by degree of processing and level of convenience, Homescan 2012[1]

	Processing[2]			Convenience[3]		
	Less processed (minimal/basic)	Moderately processed	Highly processed	Requires cooking/ preparation	RTH	RTE
Saturated fat[4] (% kcal)						
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[5] (IQR)	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[4] (% 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[5] (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[4] (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[5] (IQR)	1175 (313, 3248)	2079 (1674, 2582)*	1811 (1640, 2113)*	1463 (901, 2502)	2743 (2355, 3234)*	1911 (1658, 2420)*

[1]Data are 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: n = 177,726 purchases of processed food (less processed: n = 59,175; moderately processed: n = 59,267; highly processed: n = 59,284) and n = 177,566 purchases of convenience food (requires cooking/preparation: n = 59,043; RTH: n = 59,240; RTE: n = 59,283). *Median is significantly different from the referent group ("less-processed" food purchases or purchases of food that "require cooking/preparation"), using bias-corrected bootstrapped CIs with $P < 0.001$ to account for multiple comparisons and large sample size. RTE, ready-to-eat; RTH, ready-to-heat.

[2]Each barcoded food was classified into a mutually exclusive category for degree of processing based on the extent to which a food was altered from its natural state by industrial food processing and the purpose of these processes. "Less processed" includes unprocessed/minimally processed foods, processed basic ingredients, and foods processed for basic preservation or precooking. "Moderately processed" includes foods moderately processed for flavor and moderately processed grain products. "Highly processed" includes highly processed ingredients and highly processed stand-alone foods.

[3]Each barcoded food was separately classified into a mutually exclusive category for convenience based on the amount of food preparation required by the consumer before a product can be eaten. RTH includes products requiring minimal preparation.

[4]Saturated fat (% kcal), sugar (% kcal), and sodium (mg per 1000 kcal) content was calculated at the household level for all food purchases in 2012 within a category of processing or convenience. Values are median nutrient content of household-level purchases across all households.

[5]Determined by weighted quantile regression, regressing nutrient content 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 content at the 25th, 50th (median), and 75th percentiles for purchases in each category of processing or convenience. To determine whether median nutrient content differed significantly across categories while accounting for nonindependence of observations, bias-corrected confidence intervals were constructed from estimates determined in each of 1000 bootstrap replicate samples drawn accounting for clustering at the market level and multiple observations per household.

in a sensitivity analysis examining different recommended cut-points for sugar (10% or 25% kcal) or total purchases.

DISCUSSION

To our knowledge, this study is the first to determine US trends in the caloric contribution of highly processed and convenience foods and beverages to household purchases and to compare the saturated fat, sugar, and sodium content of purchases by degree of processing and convenience. In this nationally representative sample, moderately and highly processed products dominated purchasing patterns by collectively providing more than three-fourths of energy. These patterns were remarkably resistant to change between 2000 and 2012. By level of convenience, >80% of calories purchased came from RTE or RTH products. As categorized here, household-level highly processed food purchases and RTE food purchases were significantly more likely to simultaneously exceed DGA/FDA-recommended limits for saturated fat, sugar, and sodium content compared with purchases of less-processed foods or foods requiring cooking. Although the degree of food processing was associated with the saturated fat, sugar, and sodium content of purchases, wide variability in nutrient content was observed within each category of processing.

In our study, the contributions of moderately (15.9%) and highly processed (61.0%) products to food and beverage purchases were substantial. Our results are consistent with recent findings that moderately and highly processed products collectively dominate purchasing patterns in Canada (61.7%) and the United Kingdom (63.4%); these studies classified level of processing using definitions similar to ours (17, 36). Only 1 prior study was US based; categories of processed foods were defined by the International Food Information Council Foundation based on the "complexity of processing and the physical, chemical, and sensory changes found in food as the result of processing" (3). In analysis that used cross-sectional 2003–2008 National Health and Nutrition Examination Survey data, processed mixtures of combined ingredients, RTE foods, and prepared foods collectively provided 76.3% of energy intake from store-bought foods (54.5% total energy) (3). Direct comparison with our results is difficult because of differences in how categories were defined; for example, their category "processed mixtures of combined ingredients" includes foods we classify as basic (sugar), moderately (whole-wheat bread), or highly processed (margarine) (3). Furthermore, our findings for CPG purchases may differ from prior US findings for intake because of consumer-level food waste, which studies show is sizable for perishable minimally processed foods such as fresh fruit and vegetables (37, 38). Nonetheless, our estimate of the contribution of moderately and highly processed products to store purchases (76.9% kcal) was similar to the prior estimate of the

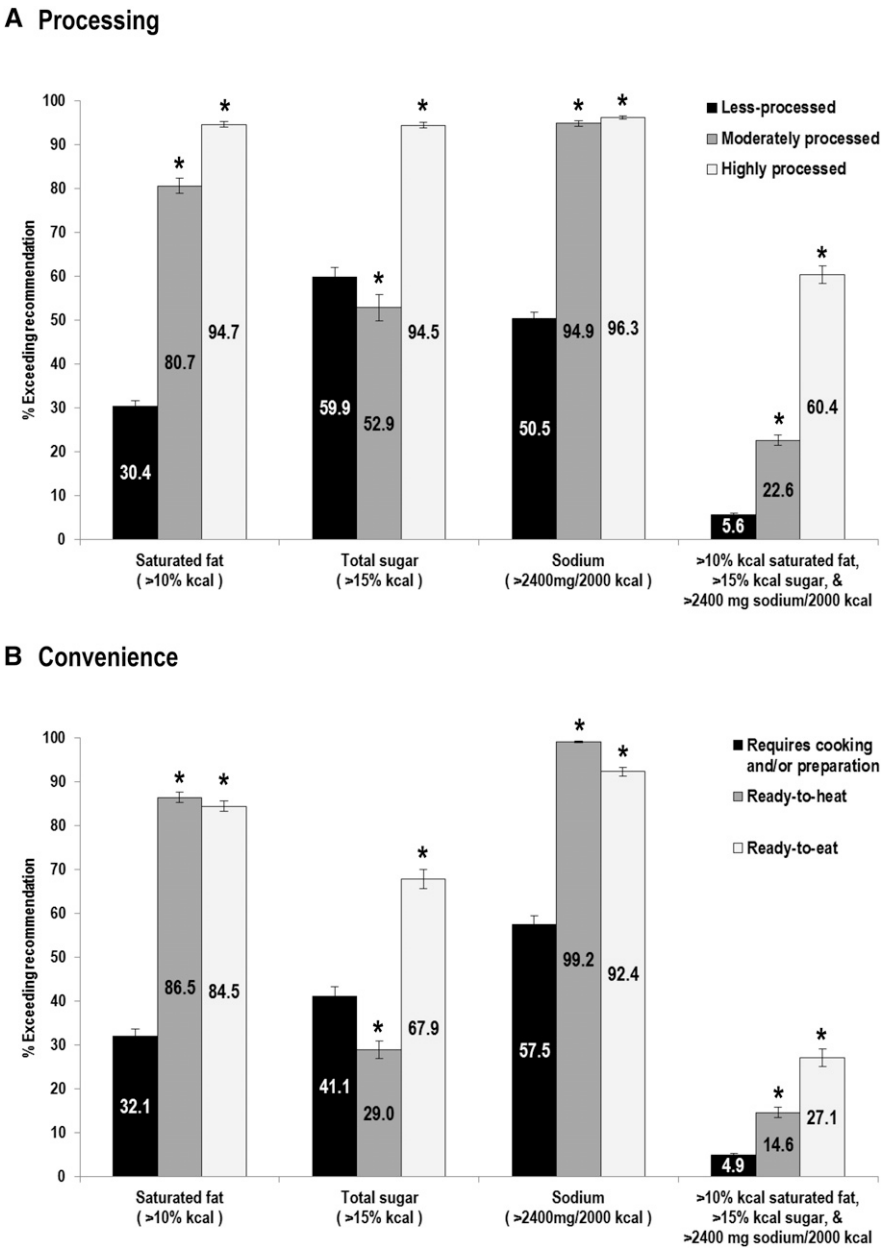

FIGURE 2 Adjusted proportion of household-level food purchases exceeding saturated fat, sugar, and sodium recommendations by degree of processing and level of convenience, Homescan 2012. Weighted adjusted percentage of household-level food purchases within a category defined by (A) degree of processing or (B) convenience that have >10% kcal saturated fat, >15% kcal sugar, >2400 mg sodium/2000 kcal, or exceed all 3 DGA/FDA-recommended limits. The 95% CIs are indicated by brackets. Nutrient content was calculated at the household level for all food purchases in 2012 within a category of processing or convenience. Determined from survey-weighted adjusted 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 that purchases in each category exceeded DGA/FDA-recommended limits. Data from the 2012 Homescan panel of household purchases of consumer packaged goods: (A) n = 177,726 household-level purchases of processed foods (less processed: n = 59,175; moderately processed: n = 59,267; highly processed: n = 59,284); (B) n = 177,566 household-level purchases of convenience foods (requires cooking and/or preparation: n = 59,043; ready-to-heat: n = 59,240; ready-to-eat: n = 59,283). "Less processed" includes minimally processed and basic processed products. "Ready-to-heat" includes products requiring minimal preparation. *Significantly different from less-processed foods (Figure 2A) or foods requiring cooking and/or preparation (Figure 2B). Wald test with $P < 0.001$ to account for multiple comparisons and sample size. DGA, Dietary Guidelines for Americans.

contribution of processed food categories to dietary intake from stores (76.3% kcal) (3, 16). Comparable elevated levels of highly processed purchases in other high-income countries have been resistant to change in recent years (39–41). We also found that in the United States, the contribution of highly processed products to purchases was remarkably stable from 2000 to 2012.

The amount of convenience food in the US diet is largely unknown because convenience is rarely considered separately from processing (10). However, not all processed foods are RTE; for example, boxed macaroni and cheese requires preparation and cooking (10). We revealed that most purchases by US households were RTE (68.1%) and RTH (15.2%) products, which is in line

with the minimal time Americans spend in home food preparation (<1 h/d) (42).

Scholars propose that processing should be considered a potentially relevant dietary metric that may be associated with dietary quality and obesity (9, 43). Our classification system may provide the framework needed to facilitate future studies evaluating this hypothesis. As categorized by the definitions developed here, highly processed food purchases had higher adjusted median saturated fat, sugar, and sodium content and were significantly more likely to exceed DGA/FDA-recommended limits for all 3 components in combination compared with less-processed (unprocessed/minimally or basic processed) food purchases. Our US findings are consistent with studies abroad that used similar category definitions and showed that a food basket composed of only moderately and highly processed foods was higher in saturated fat, added sugar, and sodium content compared with a food basket containing only less-processed foods (6, 17). Future studies are needed to determine whether this nutrient profile of highly processed food purchases translates to higher total energy intake, poor dietary quality, or weight gain.

On the other hand, the US study cited earlier suggests that processing is *not* a major determinant of a food's nutrient contributions to dietary intake (3). The study concludes that no processing category contains foods that are uniformly "healthy" or "unhealthy" (3). For example, minimally processed foods included fresh fruit and vegetables but also eggs and meat and thus made small contributions to added sugar and sodium intakes but contributed greatly to dietary cholesterol (3). We also observed a wide range of variability in saturated fat, sugar, and sodium content within each category of processed foods, reflective of the diverse products included. In agreement with the previous US work, our findings suggest that the selection of products within the highly processed category may be an important determinant of their nutrient content (3, 16).

A main limitation of our data is that participants did not record whether all purchases were consumed (37, 38). Products without barcodes or unlinked to nutrition information, including unprocessed/minimally processed items (unpackaged fresh fruit, vegetables, or meat) as well as highly processed items (deli meat, bakery items, and store-prepared RTE/RTH foods), were not captured. Furthermore, food away from home was not reported. Thus, our findings pertain only to purchases of packaged goods, not total food and beverage purchases. Consequently, our comparison of the nutrient content of CPG purchases to intake recommendations might be limited because these recommendations apply to total dietary intake, including not only food from stores but also from restaurants and other sources. Our analysis assesses nutritional quality by focusing on saturated fat, sugar, and sodium, yet these 3 components do not capture all aspects of food that affect dietary quality or health; in addition, we were not able to assess the content of nutrients that the DGA recommends Americans increase. Added sugar content is not required on nutrition labels, so total sugar was used; however, this substitution was found to be reasonable for nutrient profiling (44). Households did not report how products were prepared, so misclassification of convenience is possible. Nutrient content was analyzed for purchases within each category of processing or convenience, but households purchase a combination of products in all categories; future work is needed to examine the relation between the amount of highly processed foods purchased and the nutrient content of *total* purchases. Estimates were weighted to be nationally representative, but households may differ in unobservable characteristics not incorporated into sampling weights (19). A validation study found that the accuracy of the Homescan data was comparable to other widely used economic data sets, but misreporting is possible (20).

A major strength of our study is use of product-specific ingredients and nutrient content, which may improve accuracy of classification and nutrient comparisons (5, 45, 46). 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 purchasing patterns. We uniquely report results for foods separately from beverages.

In conclusion, we provide novel evidence that highly processed and RTE foods dominated US purchasing patterns over the past 15 y and have high saturated fat, sugar, and sodium content. Our findings suggest that highly processed products are, and will likely remain, a major portion of Americans' food and beverage purchases. Further research is needed to investigate whether industry and consumer efforts to improve choices among highly processed foods are more effective at decreasing saturated fat, sugar, and sodium in purchases than dietary guidance to shift purchases away from highly processed and toward minimally processed foods.

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The authors' responsibilities were as follows—JMP, MAM, and BMP: designed research; JMP: analyzed data; JMP, MAM, SWN, and BMP: wrote the paper and had responsibility for the final content. All authors read and approved the final manuscript. None of the authors have conflict of interests of any type with respect to this manuscript.

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