The Journal of Nutrition. First published ahead of print September 18, 2012 as doi: 10.3945/jn.112.164442.

Contributions of Processed Foods to Dietary Intake in the US from 2003–2008: A Report of the Food and Nutrition Science Solutions Joint Task Force of the Academy of Nutrition and Dietetics, American Society for Nutrition, Institute of Food Technologists, and International Food Information Council[1–4]

Heather A. Eicher-Miller,[5]* Victor L. Fulgoni, III,[6] Debra R. Keast[7]

[5]Purdue University, West Lafayette, IN; [6]Nutrition Impact, LLC, Battle Creek, MI; and [7]Food & Nutrition Database Research, Inc., Okemos, MI

Abstract

Processed foods are an integral part of American diets, but a comparison of the nutrient contribution of foods by level of processing with the recommendations of the Dietary Guidelines for Americans regarding nutrients to encourage or to reduce has not been documented. The mean reported daily dietary intakes of these nutrients and other components were examined among 25,351 participants ≥2 y of age in the 2003–2008 NHANES to determine the contribution of processed food to total intakes. Also examined was the percent contribution of each nutrient to the total reported daily nutrient intake for each of the 5 categories of food that were defined by the level of processing. All processing levels contributed to nutrient intakes, and none of the levels contributed solely to nutrients to be encouraged or solely to food components to be reduced. The processing level was a minor determinant of individual foods' nutrient contribution to the diet and, therefore, should not be a primary factor when selecting a balanced diet. J. Nutr. doi: 10.3945/jn.112.164442.

Introduction

American diets today incorporate a spectrum of minimally to heavily processed foods that contribute to the total daily intake of nutrients and other dietary components. The 2010 Dietary Guidelines for Americans provide recommendations for a healthful diet based on individual foods and "nutrients to encourage" along with "food components to reduce" (1). Recommendations

[1] Published in a supplement to *The Journal of Nutrition*. Published as a report of the Food and Nutrition Science Solutions Task Joint Task Force of the Academy of Nutrition and Dietetics, the American Society for Nutrition, the Institute of Food Technologists, and the International Food Information Council. The supplement coordinator for this supplement was Heather A. Eicher-Miller, Purdue University. Supplement Coordinator disclosures: Heather A. Eicher-Miller received compensation for author services provided for this supplement from The Academy of Nutrition and Dietetics, the American Society for Nutrition, and the Institute of Food Technologists. In-kind support was provided by the International Food Information Council. The supplement is the responsibility of the Guest Editor to whom the Editor of *The Journal of Nutrition* has delegated supervision of both technical conformity to the published regulations of *The Journal of Nutrition* and general oversight of the scientific merit of each article. The Guest Editor for this supplement was Kevin Schalinske. Guest Editor disclosure: Kevin Schalinske had no conflicts to report. Publication costs for this supplement were defrayed in part by the payment of page charges. This publication must therefore be hereby marked ''advertisement'' in accordance with 18 USC section 1734 solely to indicate this fact. The opinions expressed in this publication are those of the authors and are not attributable to the sponsors or the publisher, Editor, or Editorial Board of *The Journal of Nutrition*.

* To whom correspondence should be addressed. E-mail: heicherm@purdue.edu

[2] The manuscript was reviewed by all members of the Joint Task Force: Katie Brown (Academy of Nutrition and Dietetics); Mary Christ-Erwin (Porter Novelli); Roger Clemens (E.T. Horn Company); John Courtney (American Society for Nutrition); Johanna Dwyer (Tufts University); Mario Ferruzzi (Purdue University); William Fisher (Institute of Food Technologists); Sheila Fleischhacker (Institute of Food Technologists); Guy Johnson (Johnson Nutrition Solutions); Katie Koecher (University of Minnesota); Lindsey Loving (International Food Information Council); Penny Kris-Etherton (Pennsylvania State University); Gil Leveille (Leveille Associates); Indra Mehrotra (General Mills Bell Institute of Health and Nutrition); Esther Myers (Academy of Nutrition and Dietetics); Sarah Ohlhorst (American Society for Nutrition); Wendy Reinhardt Kapsak (International Food Information Council); Sylvia Rowe (SR Strategy); David Schmidt (International Food Information Council); Marilyn Schorin (Schorin Strategies); Marianne Smith Edge (International Food Information Council); Connie Weaver (Purdue University); and Krystle Zuniga (University of Illinois, Urbana)

[3] Author disclosures: H. A. Eicher-Miller, V. L. Fulgoni, III, and D. R. Keast received compensation for data analysis and author services provided for this supplement publication from the Academy of Nutrition and Dietetics, American Society for Nutrition, and Institute of Food Technologists. In-kind support was provided by the International Food Information Council.

[4] Supplemental Table 1 is available from the ''Online Supporting Material'' link in the online posting of the article and from the same link in the online table of contents at http://jn.nutrition.org.

doi: 10.3945/jn.112.164442.

for a healthy diet based on the level of processing of food do not exist, but a recent classification for food based on processing level has been completed by the International Food Information Council (IFIC)[8] Foundation (2). These categories are helpful for determining the contribution of processed foods to nutrient intake in the US diet.

Food processing is any deliberate change made in a food from the time of origin to the time of consumption (3). Its origins date back to the discovery of cooking in prehistoric times, which made food edible for a longer period (4). Later processing techniques, including fermentation, desiccation, and preservation with salt, which further enhanced food shelf-life (5,6), improved palatability, digestibility, safety, stability, and ease of preparation. Appert's invention of canning in the late 18th century stimulated major advances in food preservation (7). A rationale for safe preservation techniques was provided in the following years with Pasteur's discovery that food borne pathogens caused food spoilage (8). The widespread translation and application of these discoveries was popularized in the US with the publication of the USDA's 1909 Farmers Bulletin. Recommendations were made to consumers regarding proper canning techniques, and explanations of food spoilage caused by bacteria and other microorganisms were provided (9). Enrichment and fortification further enhanced the micronutrient content of certain foods. Enrichment is the addition of micronutrients lost in processing, and fortification is the addition of nutrients regardless of their initial concentration (10). The fortification of salt with iodine in 1924 successfully reduced the occurrence of goiter in the U.S. population (11) and the enrichment of flour in the 1940s with vitamin B-1 (thiamin), vitamin B-2 (riboflavin), vitamin B-3 (niacin), and iron further improved the health of Americans (12). The World Health Organization and Food and Agriculture Organization of the United Nations regard fortification as a strategy to decrease the incidence of nutrient deficiencies worldwide (10). Fortification of commercially produced foods may be at the discretion of the manufacturer or mandatory when required by regulations designed to address public health concerns.

Rapid advances in food processing during the 20th century that continue to promote preservation and safety include methods of refrigeration, freezing, dehydration, acidification, irradiation, extrusion, extraction, filtering, concentrating, microwaving, sterilizing, and packaging (11). Contemporary foods may go through many or few levels of processing. The IFIC Foundation developed a set of definitions to categorize such processing levels (2). All foods in the diet may be assigned to one of the IFIC Foundation categories on the basis of the complexity of processing and the physical, chemical, and sensory changes found in food as the result of processing. Thus, foods contained within an IFIC Foundation category may undergo different specific processing techniques but may maintain a similar state of change compared with their original unprocessed state (**Supplemental Table 1**). The first level or category of processing, "minimally processed," are foods that retain most of their inherent properties and include such foods as washed and packaged fruits and vegetables and roasted nuts. "Foods processed for preservation," nutrient enhancement, and freshness are the next level of processing and include such foods as canned tuna and beans and frozen fruits and vegetables. The "mixtures of combined ingredients" category includes foods containing sweeteners, spices, oils, colors, flavors, and preservatives used for the purpose of promoting safety, taste, and visual appeal. Examples include cake mix, jarred tomato sauce, salad dressing, and rice. "Ready-to-eat processed foods" comprise the next level and include breakfast cereal, crackers, ice cream, yogurt, luncheon meats, fruit drinks, and carbonated beverages. The final category, "prepared foods/meals," includes foods packaged for freshness and ease of preparation such as frozen dinners and entrées as well as prepared deli foods (2).

Processed foods are a well-established part of U.S. diets, yet an objective assessment of their contribution to total daily dietary intakes has not been reported. The Dietary Guidelines recommends a reduction of saturated fat, cholesterol, added sugars, and sodium intake (food components to reduce or limit), and an increase in fiber, calcium, vitamin D, and potassium intake (nutrients to encourage or increase) in the U.S. diet (1). This study documents the mean reported daily intake of processed foods and the percent contribution of each IFIC Foundation category to the total daily energy, nutrients to encourage, food components to reduce, and other select nutrient and dietary constituent intakes among a population-based sample of Americans 2 y of age and older in the US using data from the NHANES 2003–2008.

Participants and Methods

Study population. NHANES 2003–2004, 2005–2006, and 2007–2008 are nationally representative cross-sectional surveys conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention (13). Survey respondents are representative of the noninstitutionalized, civilian, U.S. population and are selected according to age, sex, and race-ethnicity using a complex, multistage, probability sampling method. Certain subpopulations, which vary across the sampling periods, were oversampled to allow for reliable assessment of these groups. NHANES respondents provided age, gender, race/ethnicity, and other information in the questionnaire portion of the survey, which was completed in participant homes. Respondents visited the NHANES Mobile Examination Center to complete a health examination and a 24-h dietary recall using the USDA automated multiple-pass method. Consent was required for all participants and was given by a parent or guardian for children younger than 18 y of age. Child consent was requested for children aged 12 y and older who completed some portions of the interview independently of parents or guardians. Proxy reporting for children 1 to 5 y of age was provided by the child's parent or guardian, whereas the reporting of children 6 to 11 y of age was assisted by a parent or guardian (14). The National Center for Health Statistics Research Ethics Review Board reviewed and approved all NHANES protocol and content (15). Participants in this analysis included 27,181 individuals with a complete and reliable 24-h recall. The 1830 infants and children younger than 2 y of age were excluded, leaving 25,351 individuals ≥2 y of age in the sample (n = 10,298 for ages 2–18 y; n = 15,053 for ages ≥19 y). The latest 6 years of NHANES data were used to analyze recent changes in the food supply and to allow for an ample sample size to perform various subgroup analyses.

Nutrients from foods. The nutrient and energy content of foods reported in the 24-h dietary recall were derived using various USDA food composition databases. The Standard Reference (SR)-Link file of the Food and Nutrient Database for Dietary Studies (FNDDS) version 2.0 (16) was used with SR release 18 (17) for quantifying nutrient content of foods in the 2003–2004 NHANES data, the FNDDS version 3.0 (18) was used with the SR release 20 (19) for the 2005–2006 NHANES data, and the FNDDS version 4.1 (20) was used with the SR release 22 for the 2007–2008 NHANES data. The vitamin D addendum was used to match foods reported in NHANES 2003–2004 (21) and in the case of a nonmatch, recipe calculations were performed using the SR-Link file of the FNDDS version 2.0. The SR release 22 was linked to determine

[8] Abbreviations used: FNDDS: Food and Nutrient Database for Dietary Studies; IFIC: International Food Information Council; SR: Standard Reference; Vitamin B-1, thiamin; vitamin B-2, riboflavin; vitamin B-3, niacin.

vitamin D values for 2005–2008 NHANES foods (22). Foods reported in recipes were matched by ingredients to the food composition data provided by the SR for nutrient computation. Nutrients of interest for this analysis included total, saturated, monounsaturated, and polyunsaturated fat; cholesterol; carbohydrates; total and added sugars; dietary fiber; protein; vitamins A, E, C, B-1 (thiamin), B-2 (riboflavin), B-3 (niacin), B-6, B-12, and D; total folate; dietary folate equivalent; calcium; phosphorus; magnesium; iron; zinc; sodium; and potassium. Energy was also selected as a dietary component of interest in this study.

Categorizing processed foods. Each reported food was assigned to one of the IFIC Foundation categories described above: minimally processed, foods processed for preservation, mixtures of combined ingredients, ready-to-eat processed foods, or prepared foods/meals (2). The "mixtures of combined ingredients" category was separated into 2 subcategories: "packaged mixes and jarred sauces" and "mixtures probably home prepared." Similarly, the "ready-to-eat processed foods" category was separated into 2 subcategories: "packaged ready-to-eat foods" and "mixtures possibly store prepared." Foods such as macaroni salad or lasagna are often made at home from other processed ingredients, (i.e., both macaroni and mayonnaise are a mixture of combined ingredients). Rather than aggregating the ingredients of such foods to their individual categories or classifying them as "prepared foods/meals" due to their appearance as prepared deli foods, they were classified to a further level of processing, "ready-to-eat processed foods." Ready-to-serve, canned, and condensed soups were assigned to the "mixtures of combined ingredients" category whereas homemade soups were classified as "minimally processed" foods. Soups made from other canned vegetables or broth were classified as having a greater level of processing: "foods processed for preservation." Finally, insufficient information was available to classify foods originating from restaurants, schools, dining halls, or other eating establishments into one of the IFIC Foundation categories, and thus, these foods were left as a distinct category.

Estimation of intake and percent contribution of processed foods. Total energy and nutrient intake, as well as intake according to the IFIC Foundation categories, were estimated by summing across all foods consumed by each individual using the first 24-h recall for each subject. Individuals with incomplete dietary recalls, as determined by USDA staff, were excluded from these analyses. The respondent level totals were then summed across the sample population to determine total energy and nutrients consumed, and the same was done for each IFIC Foundation category. Statistics calculated include means ± SEM, mean percent contribution ± SEM provided by a particular IFIC Foundation category (total nutrient i provided by category j/total nutrient i provided by all foods × 100, where i = energy and nutrients detailed above, and j = IFIC Foundation categories in Supplemental Table 1), and standard errors. The most frequently reported foods were also determined by computing a weighted frequency for all reported foods among all participants within each category. Foods deemed very similar, i.e., "soft drink cola type" and "soft drink cola type sugar-free" were combined for this purpose. Survey weights and adjustment for the complex survey design were applied to all computations allowing inference to the noninstitutionalized U.S. population. Analyses were completed in SUDAAN 10.0 (RTI International) using PROC RATIO and other related procedures.

Results

Frequently reported foods. Supplemental Table 1 shows the most frequently reported foods and beverages in each processed food category for the U.S. population ≥2 y of age. Frequently consumed "minimally processed" foods included milk, coffee, fruit, vegetables, meat and eggs. Various fruit juices ranked high on the list of frequently reported "foods processed for preservation" although some cooked, canned, or frozen vegetables and fruits were also present in this category. The "mixtures of combined ingredients" category included breads or rolls as the most frequently reported items followed by sugars and sweeteners, cheeses, various condiments, and tacos or tortillas. The "ready-to-eat processed foods" category, ordered by reported frequency, included soft drinks, sweets, salty snacks, cereal, lunchmeats, and alcoholic beverages. The "prepared foods / meals" category listed pizza, prepared meat dishes, and pasta and prepared meals as those most frequently consumed. The foods listed in these categories were used to calculate the nutrient contributions listed in **Tables 1 and 2**.

Macronutrients. The means and proportional contributions to daily macronutrient and energy intake derived for total foods, foods not from restaurants or dining halls, and foods from restaurants or dining halls, are shown in Table 1. Foods not from restaurants or dining halls comprised the foods assigned to the IFIC Foundation categories and comprised a higher proportional contribution to the number of reported foods (77%) compared with their contributions to daily total energy intake (71%). Daily macronutrient intake of these foods ranged from 66 to 80% and varied by 5 to 9% from total daily energy contribution. Foods from restaurants or dining halls contributed proportionally less to the number of reported foods (23%) compared with their contribution to daily energy intake (29%), whereas daily macronutrient contributions ranged from 20 to 34%. Resulting macronutrient means and percent contributions to total foods not eaten in restaurants or dining halls are also shown for each category (Supplemental Table 1 and **Figure 1**). "Minimally processed" foods exhibited a proportionally large contribution to the number of reported foods (27%) compared with the daily energy contributions made by this category (14%). Relative to energy, nearly equivalent contributions to all types of fat intake contrasted with relatively large contributions to daily cholesterol intake (32%). Contributions to daily added sugar intake (2%) derived from the "minimally processed" foods category were also a small percentage relative to daily energy intake , whereas contributions to fiber (20%) and protein (26%) intakes were considerably greater. The category "foods processed for preservation" contributed only 4 and 3% to the total number of reported foods and daily energy intake, respectively. The category, "mixtures of combined ingredients", contributed ~19% to the total percentage for the number of reported foods and ~17% to the daily reported energy intake. Compared with energy, this category made proportionally minimal additions to daily total sugar intake (11%). "Ready-to-eat processed foods," however, added a proportionally larger percentage to daily total sugar intake (45%) and added sugar intake (60%), whereas their contributions to the total number of reported foods and daily energy intake were 27 and 34%. Additions to daily cholesterol intake were proportionally minimal (19%) for "ready-to-eat processed foods." The percentage of contributions made by the subcategory "packaged ready-to-eat foods" was very similar to the "ready-to-eat processed food" category. Finally, the "prepared foods / meals" category contributed only 1 and 3% to the total number of reported foods and daily energy intake, respectively.

Micronutrients. The mean reported intake and the percentage of contributions of micronutrients derived from intake of all reported foods, all foods not from restaurants, and all foods from restaurants is shown in Table 2. Foods not from restaurants or dining halls had prominent proportional contributions to daily vitamin A (80%) and vitamin D (84%) intake compared with daily energy (71%) and the number of reported foods (77%). Foods from restaurants or dining halls had proportionally minimal contributions to daily vitamin C (17%) and vitamin D (16%) intake compared with their contributions to daily total energy (29%) intake and reported number of foods (23%).

TABLE 1 Intake and percent contribution of all foods and each IFIC processing level to the total daily reported dietary macronutrient intake of the US population ≥2 y of age[1]

Food component unit	Foods, *n/d*	Energy, *kcal/d*	Total fat, *g/d*	SFA[2], *g/d*	MUFA, *g/d*	PUFA, *g/d*	Cholesterol[2], *mg/d*	CHO, *g/d*	Total sugar[2], *g/d*	Added sugar[2], *g/d*	Fiber[3], *g/d*	Protein, *g/d*
All foods	16.1 ± 0.1	2140 ± 13	80.9 ± 0.7	27.3 ± 0.2	30.0 ± 0.2	16.8 ± 0.2	278 ± 2.6	265 ± 1.6	126 ± 1.1	81.2 ± 1.2	15.0 ± 0.2	80.1 ± 0.6
% contribution	100	100	100	100	100	100	100	100	100	100	100	100
Foods not from restaurants or dining halls	12.4 ± 0.1	1530 ± 14	54.6 ± 0.6	18.7 ± 0.2	19.9 ± 0.2	11.3 ± 0.1	188 ± 2.4	199 ± 1.7	100 ± 0.9	62.4 ± 0.9	11.4 ± 0.2	55.0 ± 0.6
% contribution	77.1 ± 0.5	71.4 ± 0.6	67.5 ± 0.6	68.5 ± 0.6	66.4 ± 0.7	67.1 ± 0.6	68.0 ± 0.6	75.0 ± 0.5	79.7 ± 0.5	76.8 ± 0.6	75.6 ± 0.6	68.7 ± 0.6
Processed foods												
Minimally processed	4.3 ± 0.1	301 ± 4	12.4 ± 0.2	4.4 ± 0.1	4.7 ± 0.1	2.2 ± 0.1	88.1 ± 1.8	28.1 ± 0.4	18.5 ± 0.3	1.7 ± 0.2	3.1 ± 0.1	20.4 ± 0.3
% contribution	26.6 ± 0.4	14.1 ± 0.2	15.4 ± 0.2	16.1 ± 0.3	15.5 ± 0.3	12.8 ± 0.3	32.0 ± 0.6	10.6 ± 0.2	14.8 ± 0.3	2.1 ± 0.2	20.4 ± 0.4	25.5 ± 0.4
Processed for preservation	0.6 ± 0.0	60 ± 2	0.6 ± 0.0	0.1 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.9 ± 0.1	13.1 ± 0.4	9.9 ± 0.3	0.9 ± 0.1	0.9 ± 0.0	1.3 ± 0.1
% contribution	3.5 ± 0.1	2.8 ± 0.1	0.7 ± 0.0	0.5 ± 0.0	0.6 ± 0.0	1.1 ± 0.1	0.3 ± 0.0	4.9 ± 0.1	7.9 ± 0.3	1.1 ± 0.1	5.9 ± 0.2	1.6 ± 0.1
Mixtures of combined ingredients	3.0 ± 0.0	360 ± 6	13.3 ± 0.3	4.6 ± 0.1	4.4 ± 0.1	3.2 ± 0.1	34.6 ± 1.0	50.0 ± 0.8	14.2 ± 0.3	10.7 ± 0.2	2.8 ± 0.1	10.8 ± 0.2
% contribution	18.8 ± 0.2	16.8 ± 0.3	16.4 ± 0.3	16.9 ± 0.3	14.6 ± 0.3	19.3 ± 0.3	12.6 ± 0.4	18.9 ± 0.3	11.3 ± 0.2	13.1 ± 0.3	18.4 ± 0.3	13.5 ± 0.2
Packaged mixes and jarred sauce	2.9 ± 0.0	301 ± 5	10.8 ± 0.2	3.8 ± 0.1	3.5 ± 0.1	2.7 ± 0.1	16.8 ± 0.5	43.4 ± 0.7	13.1 ± 0.3	10.5 ± 0.2	2.2 ± 0.1	8.1 ± 0.2
% contribution	17.9 ± 0.2	14.1 ± 0.2	13.4 ± 0.3	14.0 ± 0.3	11.7 ± 0.2	16.3 ± 0.3	6.1 ± 0.2	16.4 ± 0.2	10.4 ± 0.2	13.0 ± 0.3	14.7 ± 0.2	10.1 ± 0.2
Mixtures probably home-prepared	0.2 ± 0.0	59 ± 2	2.4 ± 0.1	0.8 ± 0.0	0.9 ± 0.0	0.5 ± 0.0	17.9 ± 0.8	6.6 ± 0.3	1.1 ± 0.1	0.1 ± 0.0	0.5 ± 0.0	2.7 ± 0.1
% contribution	1.0 ± 0.0	2.8 ± 0.1	3.0 ± 0.1	2.9 ± 0.1	2.9 ± 0.1	3.0 ± 0.1	6.5 ± 0.3	2.5 ± 0.1	0.9 ± 0.0	0.1 ± 0.0	3.6 ± 0.2	3.3 ± 0.1
Ready-to-eat	4.4 ± 0.0	737 ± 8	24.9 ± 0.3	8.4 ± 0.1	9.4 ± 0.1	5.1 ± 0.1	52.6 ± 1.0	101.5 ± 1.2	56.4 ± 0.9	48.9 ± 0.9	4.2 ± 0.1	18.7 ± 0.3
% contribution	27.1 ± 0.2	34.4 ± 0.3	30.8 ± 0.4	30.9 ± 0.4	31.3 ± 0.4	30.1 ± 0.4	19.1 ± 0.3	38.3 ± 0.4	45.0 ± 0.5	60.1 ± 0.6	28.1 ± 0.3	23.4 ± 0.3
Packaged ready-to-eat	4.2 ± 0.0	682 ± 8	22.4 ± 0.3	7.6 ± 0.1	8.5 ± 0.1	4.5 ± 0.1	39.7 ± 0.8	97.0 ± 1.2	55.7 ± 0.9	48.7 ± 0.9	3.8 ± 0.1	15.1 ± 0.2
% contribution	26.0 ± 0.2	31.9 ± 0.3	27.7 ± 0.4	28.0 ± 0.4	28.3 ± 0.4	26.6 ± 0.4	14.4 ± 0.3	36.6 ± 0.4	44.4 ± 0.5	59.9 ± 0.6	25.0 ± 0.3	18.8 ± 0.3
Mixtures possibly store-prepared	0.2 ± 0.0	55 ± 3	2.5 ± 0.1	0.8 ± 0.0	0.9 ± 0.0	0.6 ± 0.0	13.0 ± 0.5	4.4 ± 0.2	0.7 ± 0.0	0.2 ± 0.0	0.5 ± 0.0	3.6 ± 0.2
% contribution	1.1 ± 0.0	2.6 ± 0.1	3.1 ± 0.2	2.9 ± 0.2	3.0 ± 0.2	3.5 ± 0.2	4.7 ± 0.2	1.7 ± 0.1	0.6 ± 0.0	0.2 ± 0.0	3.1 ± 0.2	4.5 ± 0.2
Prepared foods or meals	0.2 ± 0.0	70 ± 2	3.4 ± 0.1	1.1 ± 0.0	1.3 ± 0.0	0.6 ± 0.0	11.3 ± 0.4	6.0 ± 0.3	0.9 ± 0.0	0.3 ± 0.0	0.4 ± 0.0	3.8 ± 0.1
% contribution	1.1 ± 0.0	3.3 ± 0.1	4.2 ± 0.1	4.1 ± 0.1	4.3 ± 0.1	3.8 ± 0.1	4.1 ± 0.1	2.3 ± 0.1	0.7 ± 0.0	0.4 ± 0.0	2.9 ± 0.1	4.7 ± 0.1
Foods from restaurants or dining halls	3.7 ± 0.1	612 ± 13	26.3 ± 0.6	8.6 ± 0.2	10.1 ± 0.2	5.5 ± 0.1	88.1 ± 2.0	66.2 ± 1.4	25.5 ± 0.7	18.8 ± 0.6	3.7 ± 0.1	25.0 ± 0.5
% contribution	22.9 ± 0.5	28.6 ± 0.6	32.5 ± 0.6	31.5 ± 0.6	33.6 ± 0.7	32.9 ± 0.6	32.0 ± 0.6	25.0 ± 0.5	20.3 ± 0.5	23.2 ± 0.6	24.4 ± 0.6	31.3 ± 0.6

[1] Values are mean ± SEM (n = 25,351). Survey weights and adjustment for the complex survey design were properly applied allowing inference to the non-institutionalized U.S. population. Total numbers do not always add to sample size due to missing values. Percentages do not always add to 100 due to rounding. Abbreviations: CHO: carbohydrates; IFIC: International Food Information Council Foundation.

[2] Dietary component identified by 2010 Dietary Guidelines Advisory Committee as being a food component of public health concern to reduce.

[3] Dietary component identified by 2010 Dietary Guidelines Advisory Committee as being a nutrient of public health concern to increase.

TABLE 2 Intake and percent contribution of all foods each IFIC processing level to the total daily reported dietary micronutrient intake of the U.S. population ≥2 y[1]

	Vit A, μg RAE/d	Vit E, mg AT/d	Vit C	Vit B-1	Vit B-2, mg/d	Vit B-3	Vit B-6	Total folate, μg/d	Folate, μg DFE/d	Vit B-12, μg/d	Vit D[2], μg/d	Ca[2]	P	Mg	Fe, mg/d	Zn	Na[3]	K[2]
All foods	605±8	7.0±0.1	86.2±1.6	1.6±0.0	2.2±0.0	24.2±0.2	1.9±0.0	398±3.9	538±5.4	5.3±0.1	4.8±0.1	945±11	1320±11	277±2.8	15.4±0.1	12.0±0.1	3390±26	2580±23
% contribution	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Foods not from restaurants or dining halls	487±8	5.2±0.1	71.5±1.5	1.2±0.0	1.7±0.0	17.4±0.2	1.5±0.0	302±3.9	410±5.5	4.0±0.1	4.1±0.1	720±10	956±11	214±2.8	11.6±0.1	8.6±0.1	2280±25	1951±23
% contribution	80.4±0.4	74.5±0.6	83.0±0.5	74.4±0.5	77.3±0.4	71.8±0.6	76.5±0.5	75.9±0.5	76.2±0.5	75.1±0.8	84.4±0.4	76.2±0.5	72.5±0.6	77.3±0.5	74.9±0.5	72.3±0.7	67.2±0.6	75.5±0.5
Processed foods																		
Minimally processed	185±5	1.3±0.0	21.0±0.7	0.3±0.0	0.6±0.0	4.3±0.1	0.4±0.0	59.3±1.1	60.2±1.1	1.5±0.1	2.4±0.1	269±5	322±5	76.5±1.1	1.7±0.0	2.8±0.1	336±5	838±12
% contribution	30.6±0.6	18.3±0.4	24.3±0.6	15.4±0.2	28.7±0.4	17.9±0.4	22.7±0.4	14.9±0.2	11.2±0.2	29.3±0.7	50.8±0.6	28.5±0.3	24.4±0.3	27.6±0.3	11.0±0.2	23.1±0.4	9.9±0.2	32.5±0.3
Processed for preservation	24±1	0.3±0.0	25.1±0.8	0.1±0.0	0.0±0.0	0.5±0.0	0.1±0.0	17.8±0.5	17.8±0.5	0.0±0.0	0.1±0.0	41±2	28±1	13.0±0.3	0.5±0.0	0.3±0.0	61±3	179±5
% contribution	4.0±0.2	4.0±0.1	29.1±0.6	3.0±0.1	1.8±0.1	2.0±0.1	4.1±0.1	4.5±0.1	3.3±0.1	0.8±0.1	1.8±0.2	4.3±0.2	2.1±0.1	4.7±0.1	3.3±0.1	2.3±0.1	1.8±0.1	6.9±0.2
Mixtures of combined ingredients	82±2	1.1±0.0	2.8±0.1	0.3±0.0	0.3±0.0	3.3±0.1	0.2±0.0	74.5±1.3	109±1.8	0.4±0.0	0.3±0.0	165±3	198±4	38.1±0.9	2.7±0.0	1.4±0.0	717±10	263±6
% contribution	13.5±0.3	16.3±0.3	3.3±0.1	19.2±0.3	13.5±0.2	13.8±0.2	9.3±0.2	18.7±0.3	20.2±0.3	8.2±0.3	7.2±0.2	17.5±0.3	15.0±0.3	13.8±0.2	17.8±0.2	12.0±0.3	21.1±0.3	10.2±0.2
Packaged mixes and jarred sauce	64±2	0.8±0.0	1.7±0.1	0.3±0.0	0.2±0.0	2.6±0.0	0.1±0.0	61.0±1.0	89.4±1.5	0.3±0.0	0.2±0.0	143±3	160±3	30.7±0.7	2.3±0.0	1.1±0.0	585±8	192±4
% contribution	10.6±0.2	11.8±0.2	1.9±0.1	15.9±0.2	10.9±0.2	10.8±0.2	6.9±0.1	15.3±0.2	16.6±0.2	5.9±0.2	5.0±0.1	15.2±0.3	12.2±0.2	11.1±0.2	14.6±0.2	8.9±0.2	17.3±0.2	7.4±0.1
Mixtures probably home-prepared	18±1	0.3±0.0	1.1±0.1	0.1±0.0	0.1±0.0	0.7±0.0	0.1±0.0	13.6±0.5	19.4±0.8	0.1±0.0	0.1±0.0	22±1	37±1	7.4±0.3	0.5±0.0	0.4±0.0	132±4	71±3
% contribution	2.9±0.1	4.5±0.2	1.3±0.1	3.3±0.1	2.7±0.1	3.0±0.1	2.4±0.1	3.4±0.1	3.6±0.1	2.3±0.1	2.2±0.1	2.3±0.1	2.8±0.1	2.7±0.1	3.2±0.1	3.2±0.1	3.9±0.1	2.8±0.1
Ready-to-eat	183±3	2.3±0.0	21.4±0.5	0.5±0.0	0.7±0.0	8.2±0.1	0.7±0.0	139.4±2.4	207±3.8	1.8±0.0	1.1±0.0	218±4	360±5	79.8±1.1	6.1±0.1	3.7±0.1	997±14	606±8
% contribution	30.2±0.4	32.8±0.4	24.8±0.6	33.1±0.4	30.7±0.4	33.7±0.4	37.6±0.5	35.0±0.4	38.5±0.5	33.6±0.5	23.2±0.5	23.1±0.3	27.3±0.3	28.8±0.3	39.6±0.4	31.4±0.4	29.4±0.4	23.5±0.3
Packaged ready-to-eat	170±3	2.1±0.0	19.9±0.5	0.5±0.0	0.6±0.0	7.2±0.1	0.7±0.0	130±2.3	195±3.7	1.6±0.0	1.0±0.0	199±3	321±5	72.8±1.0	5.7±0.1	3.3±0.1	873±14	530±8
% contribution	28.0±0.4	29.9±0.4	23.1±0.6	30.7±0.4	28.7±0.3	29.7±0.4	34.5±0.5	32.7±0.4	36.2±0.5	30.1±0.4	20.1±0.4	21.1±0.3	24.3±0.3	26.3±0.3	36.7±0.4	27.3±0.4	25.8±0.4	20.5±0.3
Mixtures possibly store-prepared	13±1	0.2±0.0	1.5±0.1	0.0±0.0	0.0±0.0	1.0±0.0	0.1±0.0	9.0±0.6	12.1±0.8	0.2±0.0	0.2±0.0	19±1	39±2	7.0±0.3	0.4±0.0	0.5±0.0	124±6	75±3
% contribution	2.2±0.1	2.9±0.1	1.7±0.1	2.4±0.1	2.0±0.1	4.0±0.2	3.2±0.1	2.3±0.1	2.2±0.1	3.6±0.2	3.1±0.2	2.0±0.1	3.0±0.1	2.5±0.1	2.9±0.1	4.1±0.2	3.7±0.2	2.9±0.1
Prepared foods or meals	13±1	0.2±0.0	1.2±0.1	0.1±0.0	0.1±0.0	1.0±0.0	0.1±0.0	11.3±0.5	15.8±0.7	0.2±0.0	0.1±0.0	26±1	48±2	6.8±0.2	0.5±0.0	0.4±0.0	165±6	65±2
% contribution	2.2±0.1	3.2±0.1	1.4±0.1	3.7±0.1	2.7±0.1	4.3±0.1	2.8±0.1	2.8±0.1	2.9±0.1	3.1±0.2	1.5±0.1	2.8±0.1	3.6±0.1	2.4±0.1	3.2±0.1	3.5±0.1	4.9±0.2	2.5±0.1
Foods from restaurants or dining halls	119±3	1.8±0.0	14.7±0.5	0.4±0.0	0.5±0.0	6.8±0.1	0.5±0.0	96.1±2.0	128±2.7	1.3±0.0	0.7±0.0	225±5	363±8	62.8±1.4	3.9±0.1	3.3±0.1	1114±23	631±14
% contribution	19.6±0.4	25.5±0.6	17.0±0.5	25.6±0.5	22.7±0.4	28.2±0.6	23.5±0.5	24.1±0.5	23.8±0.5	24.9±0.8	15.6±0.4	23.8±0.5	27.5±0.6	22.7±0.5	25.1±0.5	27.7±0.7	32.8±0.6	24.5±0.5

[1] Values are mean ± SEM (n = 25,351). Survey weights and adjustment for the complex survey design were properly applied allowing inference to the noninstitutionalized U.S. population. Total numbers do not always add to sample size due to missing values. Percentages do not always add to 100 due to rounding. Abbreviations: IFIC: International Food Information Council Foundation; AT: alpha tocopherol; DFE: dietary folate equivalent; RAE: retinol activity equivalents; Vit: vitamin; Vitamin B-1, thiamin; vitamin B-2, riboflavin; vitamin B-3, niacin.

[2] Dietary component identified by 2010 Dietary Guidelines Advisory Committee as being a nutrient of public health concern to increase.

[3] Dietary component identified by 2010 Dietary Guidelines Advisory Committee as being a nutrient of public health concern to reduce.

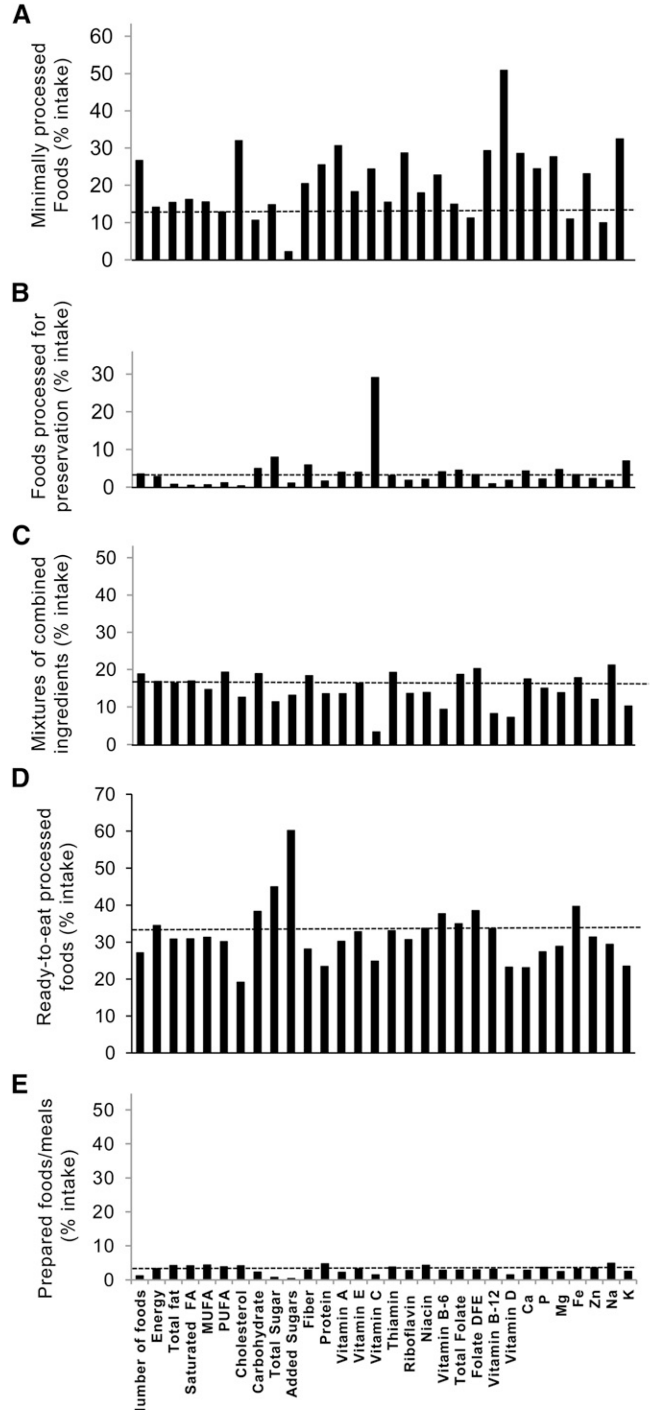

FIGURE 1 The contribution of energy and nutrients to the total daily dietary intake in the U.S. population ≥2 y of age as drawn from NHANES 2003–2008, by the International Food Information Council Foundation categories: (*A*) minimally processed foods, (*B*) foods processed for preservation, (*C*) mixtures of combined ingredients, (*D*) ready-to-eat processed foods, and (*E*) prepared foods/meals. *Bars* represent mean percent contribution to the total daily dietary intake (*n* = 25,351), *Dotted line* indicates energy contributions to total diet of each respective IFIC Foundation category represented. Survey weights and adjustments for the complex survey design were properly applied allowing inference to the noninstitutionalized U.S. population.

Separate consideration of food not from restaurants or dining halls revealed that proportional contributions of the "minimally processed" foods category to daily nutrient intake were considerable (≥20%) for vitamin A (31%), vitamin B-2 (29%), vitamin C (24%), vitamin B-12 (29%), vitamin D (51%); calcium (29%); phosphorous (24%); magnesium (28%); zinc (23%); and potassium (33%), despite a proportionally small contribution to daily energy (14%) intake. This category made proportionally low contributions to daily added sugar (2%) compared with energy. "Foods processed for preservation" made contributions to daily vitamin C (29%) intake despite a small proportional contribution to energy (3%). The "mixtures of combined ingredients" category made only small contributions to daily vitamin C (3%) intake when contrasted with daily energy contributions (17%). "Ready-to-eat processed foods" contributed 34% to total energy intake and, made relatively small additions to daily vitamin C (25%), vitamin D (23%), calcium (23%), and potassium (24%) intake. Finally, the "prepared foods/meals" category provided proportionally equivalent amounts of daily energy intake (3%) to the range of daily nutrient contributions (1 to 5% of total daily intake).

Discussion

Foods categorized by level of processing make major contributions to the nutrient and energy intake of the U.S. population. Food processing can add nutrients to the diet to help meet the Dietary Reference Intakes (23). A recent analysis of usual nutrient intake in the US found that, "enrichment and/or fortification dramatically improved intakes of several key nutrients, including folate, iron, and vitamins A, B-1 and D" (24). Nutrient inadequacy and deficiency is prevented for many Americans because of the contributions of processed foods. However, there are also concerns regarding the processing of food, including the potential loss of nutrients and other beneficial constituents such as bioactives. Energy-rich and nutrient-poor foods may result when dietary components that have been deemed "food components to reduce" such as sodium, added sugars, and solid fats (1) are added to processed foods without adding nutrients or other favorable components such as fiber. This study provides evidence for both the benefits and concerns regarding processed foods.

All categories of foods contributed a variety of nutrients to the daily total U.S. dietary intake. Prominent contributions by the various categories are neither consistently "healthy" (i.e., high in nutrients to encourage and low in food components to reduce) nor uniformly "unhealthy," (i.e., low in nutrients to encourage and high in dietary components to reduce) (Figure 1). Results from the "minimally processed" food category and other processed food categories demonstrate this inconsistency. "Minimally processed" foods provided proportionally low contributions to daily energy intake with a large percentage of contributions to the daily intake of several nutrients essential for nutrient adequacy, disease prevention, and overall good health (1), including dietary fiber, vitamin D, calcium, and potassium. In addition, proportionally minimal contributions to daily added sugar intake were made. Many foods in this category (e.g., milk, fresh fruits, vegetables, and meats) are nutrient-dense and accounted for ~27% of total foods consumed. However, foods in this category, including eggs and meat, also contributed proportionally large amounts to total cholesterol.

"Ready-to-eat processed foods" made greater proportional contributions to total daily energy than any other category. The foods comprising this category are more extensively processed than the "minimally processed" foods yet also made diverse contributions. For example, this category contributed proportionally low amounts of cholesterol yet made proportionally large contributions to other food components to reduce, such as total sugars and added sugars. In addition, proportionally low amounts of dietary fiber were added by this set of foods. Carbonated soft drinks and other foods with considerable amounts of total and added sugars and small amounts of dietary fiber such as cookies, cakes, muffins, candy, juice drinks and other beverages, ice cream and frozen desserts were prominent members of this category. Other foods in this set included certain fortified and enriched products like breads and ready-to-eat cereals. Thus, the foods included in this category are heterogeneous with respect to nutrient contribution. Dietary selections within this category based on nutrient content are particularly important due to the diverse nutrient densities of the included foods.

A modification of the IFIC Foundation classification may be necessary to reduce the diversity of nutrient contributions exemplified by the "ready-to-eat processed foods." Further classification using additional criteria such as beverage or nonbeverage might lessen the diversity of nutrient contributions for each category of foods. Beverages included in a particular IFIC Foundation category may have a more uniform contribution as a set compared with the nonbeverage set of foods in that category. Beverages lead the lists in 3 out of 5 of the processed-food categories, may be consumed separately from nonbeverages in the diet, and may involve different patterns of consumption than nonbeverages. Beverages are frequently consumed on multiple occasions within the same 24-h period, whereas nonbeverage items are most often consumed one time per day. The often heavy influence of beverages to nutrient contributions within the various categories may lead to an inaccurate perception of the contributions of other foods that comprise these categories. The influence of beverages is also disproportionately small among the categories of "mixtures of combined ingredients" and "prepared foods/meals" where they are infrequently consumed. Separate consideration of beverages may yield clearer results with regard to the health of each processed food category and allow for a better understanding of the unique contributions of processed nonbeverages and beverages to the total dietary intake in the US.

The 3 remaining categories: "foods processed for preservation," "mixtures of combined ingredients," and "prepared foods/meals," generally contributed nutrient intakes in proportion to that of energy. The vitamin C intake from the "foods processed for preservation" category was exceptionally high due to the contribution of foods such as fruit juice. However, the contribution of this nutrient from the "mixtures of combined ingredients" category was minimal compared with energy contributions. The category, "mixtures of combined ingredients" provided the least food components to reduce. The most extensively processed food category, "prepared foods/meals," made proportional contributions to nutrients and energy. Each IFIC Foundation category contributed proportionally similar amounts of saturated fat and sodium as energy. Foods containing these food components to reduce are found among all categories and cannot be identified by the level of processing.

The NHANES 2003–2008 was a large well-designed and well-executed national survey that is representative of the noninstitutionalized U.S. population. This survey is one of the few data sources with comprehensive dietary data for the population that may be used to complete such analyses as are described here. Under-reporting is common in 24-h recall data and may be especially problematic among certain population subgroups (25,26). Forgotten or under-reported foods are most often desserts, sweet baked goods, butter, and alcoholic beverages (27,28), which may affect an underestimation of intake among more extensively processed foods compared with less extensively processed foods. These data should be interpreted with caution; the gross characterization of population-based group diets cannot be extended to individuals or sub-groups. In addition, estimates in this study are cross-sectional and are not necessarily representative of usual daily intakes.

Conclusions

Each processed food level category discussed above encompasses a wide variety of foods. The foods comprising each category contribute diverse proportions of dietary components to the U.S. diet. Although conclusions for individual dietary components can be made for each category in the aggregate, a clearly "healthy" or "unhealthy" category, as identified by processing level, does not emerge from this analysis. The "minimally processed" and "ready-to-eat processed foods" categories are at the ends of the processed-food spectrum, but both make prominent contributions to nutrients to encourage and food components to reduce. The remaining categories, "foods processed for preservation," "mixtures of combined ingredients," and "prepared foods/meals," are approximately equal contributors of these categories of nutrients. Given the diversity within each category, it is difficult to objectively rank them on the basis of overall nutritional value. Generalized public health messages or recommendations based on such a ranking would likely be simplistic and/or misleading. In conclusion, processing level is not a major determinant of foods' nutrient contributions to the diet and does not have a clear association with the health of a food as determined by either "nutrients to encourage" or "food components to reduce" as specified in the Dietary Guidelines for Americans 2010. A food's nutrient composition and the frequency and amount eaten, rather than level of processing, should be stressed as the most important considerations for the selection of a healthy diet.

Acknowledgments

V.L.F. designed research, V.L.F. and D.R.K. analyzed data, H.A.E-M. wrote the paper, H.A.E-M. had primary responsibility for final content. All authors read and approved the final manuscript.

References

1. US Department of Agriculture, US Department of Health and Human Services. Dietary guidelines for Americans, 2010. 7th ed. Washington, DC: U.S. Government Printing Office; 2010.
2. International Food Information Council Foundation. Understanding our food communications tool kit, 2010 Sept [cited 2012 Feb 19]. Available from: http://www.foodinsight.org/For-Professionals/Understanding-Our-Food/tabid/1398/Default.aspx.
3. Shewfelt RL. Introducing food science. Boca Raton, FL: CRC Press; 2009.
4. Wrangham R. Catching fire: how cooking made us human. New York: Basic Books; 2009.
5. Hall RL. Pioneers in food science and technology: giants in the earth. Food Technol. 1989;43:186–95.
6. Floros J. Food science: feeding the world. Food Technol. 2008;62:11.
7. Potter NN, Hotchkiss JH. Food science. 5th ed. New York: Chapman & Hall; 1995.
8. Labuza T, Sloan AE. Force of change: from Osiris to open dating. Food Technol. 1981;35:34–43.
9. Andress EL, Kuhn GD. Critical review of home preservation literature and current research: Early history of USDA home canning recommendations. 1983 [cited 2012 Feb 19]. Available from: http://nchfp.uga.edu/publications/usda/review/earlyhis.htm>]

10. Allen L, de Benoist B, Dary O, Hurrell R, editors. Guidelines on food fortification with micronutrients.Geneva, Switzerland: WHO; 2006.
11. Floros JD, Newsome R, Fisher W, Barbosa-Canovas GV, Chen H, Dunne CP, German JB, Hall RL, Heldman DR, Karwe MV, et al. Feeding the world today and tomorrow: the importance of food science and technology. Comprehensive Reviews in Food Science and Food Safety. 2010;9:572–99.
12. Bing FC. Paul Edward Howe (1885–1974): a biographical sketch. J Nutr. 1985;15:297–302.
13. Agricultural Research Service, US Department of Agriculture. What we eat in America, NHANES 2003–2004, 2005–2006, and 2007–2008. 2012 [cited 2012 Feb 19]. Available from: http://www.ars.usda.gov/Services/docs.htm?docid=13793
14. Centers for Disease Control and Prevention, National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey questionnaires, datasets, and related documentation. 2012 [cited 2012 Feb 19] Available from: http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm
15. Centers for Disease Control and Prevention, National Center for Health Statistics (NCHS). NCHS Research Ethics Review Board (ERB) Approval. 2012 [cited 2012 Feb 19]. Available from: http://www.cdc.gov/nchs/nhanes/irba98.htm
16. US Department of Agriculture, Agricultural Research Service, Food Surveys Research Group. USDA food and nutrient database for dietary studies, version 2.0. 2006 [cited 2012 Feb 19] Available from: http://www.ars.usda.gov/Services/docs.htm?docid=12083
17. US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. USDA national nutrient database for standard reference release 18. 2005 [cited 2012 Feb 19]. Available from: http://www.ars.usda.gov/Services/docs.htm?docid=8964
18. US Department of Agriculture, Agricultural Research Service, Food Surveys Research Group. USDA food and nutrient database for dietary studies, version 3.0. 2008 [cited 2012 Feb 19]. Available from: http://www.ars.usda.gov/Services/docs.htm?docid=17031
19. US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. USDA national nutrient database for standard reference release 20. 2007 [cited 2012 Feb 19]. Available from: http://www.ars.usda.gov/Services/docs.htm?docid=8964
20. US Department of Agriculture, Agricultural Research Service, Food Surveys Research Group. USDA food and nutrient database for dietary studies, 4.1. 2010 [cited 2012 Feb 19]. Available from: http://www.ars.usda.gov/Services/docs.htm?docid=20511
21. US Department of Agriculture, Agricultural Research Service, Food Surveys Research Group. Vitamin D addendum to USDA food and nutrient database for dietary studies, version 3.0. 2008 Available from: http://www.ars.usda.gov/Services/docs.htm?docid=18807
22. US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. USDA national nutrient database for standard reference release 22. 2009 [cited 2012 Feb 19]. Available from: http://www.ars.usda.gov/Services/docs.htm?docid=8964
23. National Research Council. Dietary reference intakes: the essential guide to nutrient requirements. Washington, DC: The National Academies Press; 2006.
24. Fulgoni VL, Keast DR, Bailey RL, Dwyer JT. Foods, fortificants, and supplements: where do Americans get their nutrients? J Nutr. 2011;141:1847–54.
25. Subar AF, Kipnis V, Troiano RP, Midthune D, Schoeller DA, Bingham S, Sharbaugh CO, Trabulsi J, Runswick S, Ballard-Barbash R, et al. Using intake biomarkers to evaluate the extent of dietary misreporting in a large sample of adults: the OPEN study. Am J Epidemiol. 2003;158:1–13.
26. Champagne CM, Baker NB, DeLany JP, Harsha DW, Bray GA. Assessment of energy intake underreporting by doubly labeled water and observations on reported nutrient intakes in children. J Am Diet Assoc. 1998;98:426–33.
27. Lafay L, Mennen L, Basdevant A, Charles MA, Borys JM, Eschwege E, Romon M. Does energy intake underreporting involve all kinds of food or only specific food items? Results from the Fleurbaix Laventie Ville Sante (FLVS) study. Int J Obes Relat Metab Disord. 2000;24:1500–6.
28. Pryer JA, Vrijheid M, Nichols R, Kiggins M, Elliott P. Who are the “low energy reporters” in the dietary and nutritional survey of British adults? Int J Epidemiol. 1997;26:146–54.