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Report

The USDA's National Food and Nutrient Analysis Program: update 2002

P.R. Pehrsson*, D.B. Haytowitz, J.M. Holden

Nutrient Data Laboratory, Agricultural Research Service, US Department of Agriculture, Room 309 A, Building 005 10300 Baltimore Avenue, Beltsville, MD 20705, USA

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Abstract

The National Food and Nutrient Analysis Program (NFNAP) was designed in 1997 to develop robust and nationally representative estimates of the mean nutrient content of important foods in the food supply and significantly improve the quality of food composition data in the US Department of Agriculture's National Nutrient Databank. The underlying aims defining the process behind the NFNAP are: (1) evaluation of existing data; (2) identification of Key Foods and nutrients for analysis; (3) development of nationally based sampling plans; (4) analysis of samples; and (5) compilation and calculation of representative food composition data. Supported by a self-weighting stratified sampling design, the NFNAP approach has been applied to other sampling programs for the analysis of specific nutrients (e.g., fluoride-containing beverages and foods) and ethnic foods (e.g., American Indian foods). For select nutrients of potential health significance, additional sampling approaches allow for the estimation of serving-to-serving variability (e.g., highly processed foods). Under NFNAP, over 500 foods of the targeted 1000 important foods in the US food supply have been analyzed. Unrivaled research on food sampling, sample handling, and analytical methodology (e.g., for study of perishable nutrients in fresh produce) is integral to this effort. The NFNAP data are current, reflective of the market and nationally representative of the US food supply and therefore a crucial resource to health researchers, architects of nutrition policy, the nutrition and medical communities, and the food industry. They are released through the Web site: www.nal.usda.gov/fnic/foodcomp

Keywords: NFNAP; Key Foods; Critical nutrients

*Corresponding author. Tel.: +-301-504-0716; fax: +-301-504-0713.
E-mail address: ppehrsson@rbhnrc.usda.gov (P.R. Pehrsson).

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1. Introduction

The National Food and Nutrient Analysis Program (NFNAP), initiated in 1997 as an Interagency Agreement between the National Institutes of Health (NIH) and US Department of Agriculture (USDA), has become the most important means of accomplishing a comprehensive update to the USDA National Nutrient Databank. Funded by 17 NIH Institutes, Centers and Offices and USDA, NFNAP is an integrated system for identifying foods and nutrients, food sampling, food preparation and compositing, sample preparation, chemical analysis, and data dissemination.

Under the structure of the five aims of NFNAP, NDL will provide representative nutrient estimates for foods and selected ingredients, increase data acquisition for important foods, add data for selected new components to the database, and validate factors and algorithms for compilation of nutrient data. The primary objective of NFNAP is to provide the best estimates of the nutrient means for the population of each food identified as important in the food supply. Through this process, we continuously adjust the foods in our database to accurately represent what is currently being consumed by the population. For some important contributors of selected nutrients, preliminary estimates of variability will be generated through NFNAP. To achieve these goals, the NFNAP is structured under five aims: (1) evaluation of existing data; (2) identification of Key Foods and nutrients for analysis; (3) development of nationally based sampling plans; (4) analysis of samples; and (5) compilation and calculation of representative food composition data.

To support the five aims of the NFNAP, a probability based (i.e., probability proportional to size or PPS) national sampling plan was developed to sample and analyze those Key Foods for which existing data were of poor quality or absent, or where foods or methods have changed (Perry & Beckler, 1999). Through NFNAP, we have identified approximately 1000 foods (including 660 Key Foods, and in addition, ethnic foods, mixed dishes, foods used in metabolic studies, and food ingredients) that are important contributors of critical nutrients in the US food supply or to the diet of specific subpopulations (Pehrsson, Haytowitz, Holden, Perry, & Beckler, 2000; Haytowitz, Pehrsson, & Holden, 2002).

This report focuses on the update of the 1000 foods in the database (described below), the foundation of which is a rigorous national sampling in retail outlets, fast food restaurants, American Indian reservations, and sampling of seasonal foods over time.

2. NFNAP process

2.1. Prioritization of foods and nutrients

To set analytical priorities, the Key Foods approach (Haytowitz et al., 1996, 2002), which combines USDA food composition data with consumption data from the USDA Continuing Survey of Food Intake by Individuals (CSFII) (USDA, 1998) and the US Department of Health and Human Services, National Health and Nutrition Examination Study (NHANES) (USDHHS, 2002), was used. A scoring system by nutrient and food was also developed. The score by food for each nutrient was determined by first calculating the contribution to total intake for each nutrient,

or multiplying the amount of food consumed by the specific nutrient content. The foods were ranked in descending order, according to the sum of intake contributions across 20 nutrients of public health significance. These nutrients, called Critical Nutrients, have been defined through scientific consensus as those nutrients of public health importance for which data are still needed (FASEB, 1995). Following the ranking of foods, the resulting list was divided into quartiles, which were useful and necessary in establishing priorities for analysis. The foods, classified as being in the top contributing quartile Q1, contribute up to 25% of the intake of Critical Nutrients. Foods in Quartiles 2–4 are determined similarly: Q2 contributing the next 26–50%, Q3 51–75%, and Q4 76–100% of the intake of Critical Nutrients. The top 3 quartiles include about 660 foods; in addition, important mixed dishes, industrial ingredients, ethnic foods, and foods used in clinical trials, have been added to the foods targeted for analysis.

NDL continues to analyze samples for the traditional nutrients—the historical core of the database—which are nutrients long established as important in the diet (i.e., proximates, vitamins and minerals, amino acids, and fatty acids). Analyses now include individual sugars, starch, and total dietary fiber (Pehrsson et al., 2000).

Research at NDL is also focused on emerging nutrients or nutrients where scientific interest has increased dramatically in recent years or, in some cases, where new Dietary Reference Intakes (DRI) have been developed by the National Academy of Science's Food and Nutrition Board. They include: individual carotenoids, vitamin K, procyanidins and anthocyanidins, flavonoids, fluoride, choline and sphingolipids, trans fatty acids, n-3 fatty acids. Analyses for these food components have been included in NFNAP for foods where measurable concentrations are expected. In addition to nutrient analysis and study of variability under NFNAP, NDL is improving and expanding data on nutrient yields and retention following cooking, and on portion sizes and weights.

2.2. *Development of the sampling frame*

The goal of the sampling and analysis of foods is to generate statistically robust and nationally valid estimates of the mean and variance of the nutrient content of the chosen foods. To achieve this goal, NDL and the National Agricultural Statistics Service (NASS) devised a nationally representative sampling frame for retail foods, including fresh produce, across the 48 conterminous states. The country was divided into 4 regions of similar population size (65–68 million). Within each region, 3 generalized Consolidated Metropolitan Statistical Areas (gCMSAs) were randomly selected to provide coverage for large, medium, and smaller populations. Within each gCMSA, 2 counties were selected based on urbanicity (i.e., urban, suburban, and rural demographics). Within each county, 1 retail location was randomly selected from a pool of supermarkets with sales volumes exceeding $2 million/year.

In this three-stage retail sampling design, counties were selected, grocery stores were selected within the counties, and specific food products were selected for purchase in the grocery stores. In effect, this procedure gives a sample of grocery outlets from selected geographically dispersed areas across the United States. The sampling frame is described in detail in Pehrsson et al. (2000).

In most cases, 6 or 12 samples were analyzed for each food. Each sample was a composite of packages or units from 12 or 24 outlets, yielding brand-specific samples representing the mean content of selected nutrients. Using this sampling and compositing scheme, the composite

contribution to the total is self-weighting. By compositing sample 1 across locations, then sample 2, and so forth, we achieved a nationally representative nutrient profile for that food. Although the mean is supported by an n of 6–12, the theoretical n is equal to the number of locations multiplied by the number of samples. For top quartile Key Foods (heavily sampled), the theoretical n may represent as many as 288 sample units. The frequency of samples per brand for a given food depends on the extent of the brand name distribution across market shares. The sampling profile of brand names and generic brands varies for each processed food and depends on the market distribution pattern for that food. For foods eaten raw and cooked or only cooked, NDL analyzes a split sample of both forms to build yield and nutrient retention factors. For example, as many as 72 individual samples of ground beef were analyzed raw and after one of three cooking methods.

2.2.1. *Additional sampling for serving-to-serving variability estimates*

Formulation changes in processed foods, regional differences, shipping and storage conditions, analytical variability, and serving-to-serving variability due to preparation may account for considerable differences in levels of certain nutrients in foods. These differences are crucial for many individuals, where intake over a specified amount has health consequences. For some foods, where concentrations of specific critical nutrients are very high and where we would expect wide fluctuations of these nutrients, additional, randomly selected sample units within the selected locations are prepared and analyzed individually to determine estimates of variability. This sampling approach is also described in earlier work (Pehrsson et al., 2000).

2.2.2. *Fresh fruits, nuts and vegetables*

For fresh fruits and vegetables, samples were composited by region and sampled at least twice, over time. Based on earlier information, we hypothesized that the effect of seasonality and ripeness influences nutrient variability more than growing location.

Many fruits and vegetables have 2 major market seasons—domestically grown summer produce and winter produce imported from geographic areas including the Southern Hemisphere. A subset of 12 locations (gCMSAs) was used, with sampling over at least 2 seasons for each food. The sample units collected from each location were composited by region to form 4 regional composites for analysis. This yielded a total of 8 data points, representing an effective sample size of 24 sample units for each food, for the most important analytes in this study. Fewer samples were analyzed for certain components, which are found in low concentrations in these foods (e.g., pantothenic acid) or are of lesser public health significance (e.g., protein). A few foods having very short market seasons will be sampled over a couple of years to provide representative data.

As part of the NFNAP phytonutrient research initiative, NDL sampled and analyzed 59 fresh fruits, dried fruits, fresh vegetables, and tree nuts, listed in Table 1. In addition to the analysis for traditional nutrients, these foods were analyzed for individual carotenoids (α-carotene, β-carotene, β-cryptoxanthin, lycopene, lutein, zeaxanthin, phytoene and phytofluene) and five major classes of flavonoids (flavonols, flavones, flavonones, flavan-3-ols, and anthocyanidins) by USDA's Food Composition Laboratory (FCL) in Beltsville, MD. A companion project was also initiated to develop a procyanidin database at the Arkansas Children's Center, University of Arkansas.

Table 1
Fruits, vegetables, and nuts analyzed during 2000–2001

Almonds	Dates	Pears, Bosc[a]
Apples, Golden Delicious[a]	Figs, dried, Mission	Pecans
Apples, Red Delicious[a]	Grapefruit, red[a]	Pine nuts
Apples, Gala[a]	Hazelnuts	Pineapple, Del Monte gold
Apples, Fuji[a]	Honeydew[a]	Pineapple[a]
Apples, Granny Smith[a]	Kiwi fruit[a]	Pistachios
Artichokes	Lettuce, Butterhead	Plums, red, fresh[a]
Avocados, Haas[a]	Lettuce, romaine	Plums, black diamond
Bananas[a]	Lettuce, iceberg[a]	Potatoes, russet[a]
Blackberries	Lettuce, green leaf[a]	Potatoes, red[a]
Blueberries	Lettuce, red leaf[a]	Potatoes, white[a]
Brazil nuts	Macadamia nuts	Prunes
Broccoli raab	Nectarines[a]	Radishes[a]
Broccoli[a]	Onions, sweet	Raisins
Cantaloupe[a]	Oranges, navel[a]	Raspberries, red
Carrots, baby	Peaches[a]	Strawberries[a]
Cashews, oil-roasted	Peanuts, oil-roasted	Tomatoes[a]
Celery[a]	Pears, red Anjou[a]	Walnuts
Cherries, sweet[a]	Pears, green Anjou[a]	Watermelon, seedless[a]
Cranberries[a]	Pears, yellow Bartlett[a]	

[a] Foods on Food and Drug Administration's list of the 20 most frequently consumed raw fruits and vegetables.

2.2.3. *Sampling plans for ancillary research*

For some specialized databases, e.g., choline, samples of foods collected under the NFNAP sampling approach were also targeted for a single nutrient of public health concern. For example, a Dietary Reference Intake was recently developed by National Academy of Sciences for choline. Because of choline importance for normal membrane function, acetylcholine synthesis, lipid transport, and methyl metabolism and its impact on humans with trimethylaminuria (fishy body odor related to consumption of foods high in choline), sampling and analysis of significant sources of choline were included in the NFNAP effort during 2002. Approximately 143 NFNAP were foods were analyzed for several 5 choline-containing compounds, total choline and betaine, in a collaborative effort with the University of North Carolina. In addition to NFNAP foods, foods from recognized food frequency questionnaires used in clinical studies are being analyzed for choline.

In addition to developing a sampling approach for retail foods and databases for specific nutrients using the NFNAP sampling approach, unique sampling frames for specific ethnic foods and nutrients were developed. Supported by the NIH National Center on Minority Health and Health Disparities (NCMHHD) and the Indian Health Service, sampling frames for sampling and analysis of traditional American Indian and Alaska Native (AIAN) foods and high-consumption USDA Commodity Foods were developed. Unlike the retail sampling approach, the sampling approach for AIAN foods allows for location substitutions because it is not possible to select for a tribe's willingness to or desire to participate. NDL, through the sampling and analysis of 150–200 traditional foods (i.e., indigenous plants and animals) will support development of nutrient

profiles for traditional recipes. Native foods across 48 states and Alaska are being sampled and analyzed; to date, 30 Navajo foods have been analyzed. Sampling programs with the Shoshone-Bannock tribe in Ft. Hall, Idaho, the University of New Mexico, and with the several Alaskan native villages are also underway.

To complement this database, several of the targeted 100 USDA Commodity Foods have been sampled and analyzed. This work is being carried out by the NDL and its contractors, in collaboration with other USDA agencies (i.e., Food and Nutrition Service, Agricultural Marketing Service, and the Farm Service Agency); samples are shipped by statistically selected vendors of these sponsoring agencies. The new data on the USDA Commodity Foods will be incorporated into the National Nutrient Databank and made available to these agencies. Canned fruit, bakery mixes and peanut butter have been sampled and analyzed and sampling and analysis of shortening and poultry and meat/meat products are planned for 2003.

Ancillary research also includes the development of a national fluoride database as part of the National Fluoride Database and Intake Assessment Study (NFDIAS), a collaboration between NDL and the Nutrition Coordination Center (NCC), University of Minnesota, and funded by the National Institute of Dental and Craniofacial Research, NIH. This project calls for USDA's development of a fluoride database for US beverages and foods; it, in turn, will be used in the development of software for assessing intake of fluoride at the NCC. The sampling frame, modeled after the NFNAP frame, was based on the new 2000 Census data and intended to account for fluoride variability in the drinking water supply over time and from location to location. Retail beverages and foods in up to 36 locations and drinking water in 144 locations were or will be sampled. These beverages include fruit juices and drinks, carbonated beverages, brewed tea and coffee, beer, wine, tap water, and bottled water. In addition, approximately 60 foods sampled under NFNAP (e.g., frozen novelties, ice cream, and non-dairy and fast food shakes) were analyzed. Details of this sampling approach and others are described in project progress reports, available from NDL.

In cooperation with the National Cattlemen's Beef Association, packages of ground beef were selected from 24 locations identified under the NFNAP sampling frame to represent the full range of products currently available in the US market place. These products were analyzed in the raw and cooked forms. The analytical data resulting from this study were included in Release 15 of the USDA National Nutrient Database for Standard Reference. In the future, users of NDL's online search program, through linear or curvilinear regression techniques, will be able to generate nutrient profiles for ground beef of any fat level between 5% and 25% by using the Ground Beef Calculator, a new module to be added to the Web site.

2.3. *Sample preparation of perishable foods*

Under NFNAP, fresh produce was procured by the NDL's contractor and prepared using NDL-specified protocols by staff at the Food Analysis Laboratory Control Center (FALCC) at Virginia Polytechnic Institute and State University. Composites frozen in liquid nitrogen were freeze-dried by FCL and NDL staff, returned to FALCC for further processing (i.e., homogenization), and shipped to the labs for analysis.

These foods presented complex sample handling and preparation challenges, including: (1) maintenance of refrigerated or frozen ship temperature; (2) shipment of fragile products (e.g.,

raspberries), (3) coordination of simultaneous arrival of products from different locations; (4) control of active enzymes which interfere with nutrient stability; (5) determination of multiple levels of food yield factors; and (6) handling multiple cooking methods. Pilot tests were conducted to develop food shipping and preparation protocols that minimize nutrient losses (e.g., customized shipping packages and freeze-drying for flavonoid analysis).

2.4. Quality control program and sample analysis

NDL required prospective contractors to submit a formal proposal, including methods of analysis, in response to a "Request for Proposals" (RFP) prepared by the Agricultural Research Service Headquarters contract office. Labs with satisfactory submissions were sent a "check sample" of known analytical content to analyze; contracts are awarded based on the results. The project covers a wide variety of foods; the labs select the best methods, usually those of AOAC International, for each food and nutrient.

Along with the analytical samples, FALCC includes "blind" quality control (QC) materials, including Standard Reference Materials (SRM) developed by the National Institute of Standards and Technology (NIST) and similar international organizations, as well as in-house control composites. QC reports, reviewed by NDL staff, include the analysis of the samples and QC materials, results of duplicate analyses, comparisons to the target values for certified nutrients, and results over time for control composites. When the results for QC materials are found to be outside the a priori acceptable ranges, NDL requests the lab repeat the analysis of the accompanying analytical samples. In some cases, the ranges on SRMs are rather narrow, as NIST may characterize the material in-house, using a limited number of definitive methods of analysis, not in general commercial use. When this occurs, an expanded range is calculated by NDL, FALCC, or field lab personnel to reflect probable laboratory bench performance and is used for the evaluation of results. If the results fall outside of the ranges, then these samples are reanalyzed. Residual standard deviations are calculated for all QC materials and samples. If the values achieve an RSD (CV) exceeding 10%, the samples are considered for repeat analysis. In some cases, where wide nutrient variability is known to be normal (e.g., β-carotene vitamin A in certain vegetables), the range is more flexible. Results are also compared against existing values in USDA databases, and if necessary, the samples are reanalyzed.

3. Summary of NFNAP status

By spring 2002, approximately 500 foods were sampled and analyzed, with a focus during 2000/2001 on fresh fruits, vegetables and fast foods. Nutrient data on these foods are now being reviewed by NDL staff and will be used to update future releases of the USDA nutrient databases. Fig. 1 shows the level of completion of analyzed foods by quartile. Those foods contributing 50% (half) of the intakes of Critical Nutrients (Quartiles 1 and 2) have been sampled and analyzed. This reflects 14 and 42 foods, respectively. A significant number of the Quartiles 3 and 4 foods have been sampled and some analyzed; once completed this will reflect data for over 600 foods. It is expected that analysis of these foods will be completed in the next few years. Approximately 200 foods related to the Key Foods (e.g., reduced fat versions, similar foods) have also been analyzed

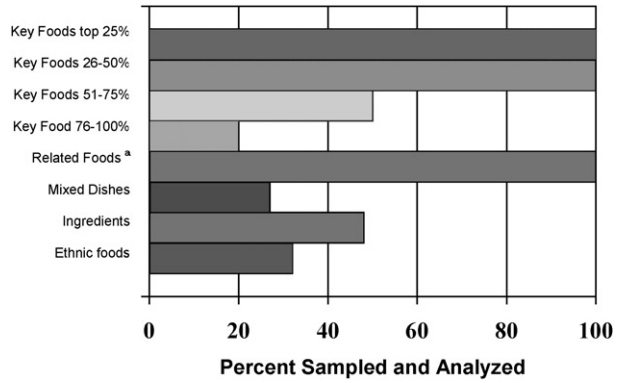

Fig. 1. Sampling and analysis of 1000 NFNAP foods: progress by June 2002. ([a]Variations of Key Foods (e.g., reduced fat) that are expected to be of significant market share or new, widely consumed foods introduced into the market since the most recent CSFII.)

Table 2
NFNAP provisional carotenoid data for raw and cooked tomatoes

Carotenoid		Mean	*n*	Range	Previous value[a]
α-carotene	Raw	0	6	0	112
	Cooked	0	6	0	
β-carotene	Raw	391	6	184–572	393
	Cooked	471	6	199–839	
β-cryptoxanthin	Raw	0	6	0	0
	Cooked	0	6	0	
Lutein	Raw	118	6	98–138	130
	Cooked	108	6	70–152	
Lycopene	Raw	1565	6	1136–2171	3025
	Cooked	1769	6	654–3320	
Zeaxanthin	Raw	0	6	0	
	Cooked	0	6	0	

[a] Blanks indicate no previous values available. Previous values from the USDA NCC carotenoid table for US foods, 1998.

because it is expected they have assumed a more prominent ranking on the Key Foods list since it was first determined. Mixed dishes comprised of ingredients from the Quartile listing of Key Foods have been sampled and analyzed, as have a number of ethnic foods, primarily Navajo foods. Several commercial ingredients such as flours and oils and shortenings are in various stages of sampling and analysis. The results of the analyses for all of these foods are in various stages of QC review and incorporation into the database. Data are available on the NDL Web site www.nal.usda.gov/fnic/foodcomp, through annual data releases (USDA, 2002).

Comparisons of new data to existing data often provides justification for replacing older data with more current, nationally representative data. Table 2 includes data for carotenoids in raw and cooked tomatoes; NFNAP data are used to provide data where none existed before or to

enrich limited or non-representative data. Although the apparent number of samples for the NFNAP estimates may be smaller than the number of samples generated through past aggregations of data, the sampling approach behind the NFNAP data ensures nationally representative estimates of any given nutrient. These new data show α-carotene and lycopene values for raw tomatoes are lower than values previously obtained, while values for β-carotene, β-cryptoxanthin and lutein are relatively unchanged. In this example, previous lycopene values were derived from 3 studies with non-representative, limited sampling. Also, NFNAP has generated analytical values for cooked tomatoes, where previously we imputed values from the raw form (Holden et al., 1999).

Acceptable National Health and Nutrition Examination Survey dietary intake will be included in the next release of Standard Reference. New foods for which data did not exist in earlier releases include: baby carrots, broccoli raab, sweet onions, and specific types (i.e., lettuce and potatoes) and varieties (i.e., apples, plums, avocados and pears) of select foods. In addition, new data on flavonoids will be released in 2003.

Other foods recently sampled and analyzed under NFNAP include eggs and fast foods. Analysis of fresh, frozen and cooked eggs included determination of yields and retention factors. Individual samples were analyzed for those components expected to be present in significant concentrations (e.g., cholesterol), while national and regional composites were used for components expected to be present in lesser concentrations (e.g., sugars and pantothenic acid). Cooking methods for eggs included frying (without added fat) and hard-cooking. Sampling of fast foods included 3 hamburger chains in 12 US locations; foods sampled and analyzed included hamburgers, cheeseburgers, French fries, chicken sandwiches, fish sandwiches, shakes, carbonated beverages, and coffee. These results are undergoing QC review prior to incorporation into the database. Table 3 shows how many foods have been analyzed since the inception of NFNAP, by food group. For a number of food groups where relatively few foods have been analyzed (e.g., fish, meat, poultry and snacks) and for industrial ingredient foods, sampling plans are being developed, often in collaboration with industry groups.

Results from the NFNAP testing for unit-to-unit variability include: cheese pizza, frozen and cooked (all nutrients); pepperoni pizza, frozen and cooked (proximates, minerals, fortification nutrients, fatty acids, and vitamin E); white bread (proximates, minerals, and fortification nutrients); eggs, (proximates, minerals, cholesterol, and vitamin B_{12}); milk (all fat levels, all nutrients); and selected fast foods (proximates, minerals, and fatty acids). Fifteen foods have been sampled and analyzed for the determination of unit-to-unit variability. A future report will examine this variability in greater detail.

Results of the choline study show the foods highest in total choline content were eggs, wheat germ, pork and pork products, dried soybeans, chicken, beef, cod, and salmon. Data from this study will be released in the spring of 2003.

During 2003–04, NFNAP emphasis will focus on: (1) completing the sampling and analysis of the 1000 foods; (2) monitoring Key Foods using new data on carotenoid data; (3) revising the sampling frame to reflect new Census 2000 data; (4) monitoring the highest-consumption Key Foods; (5) evaluating the variability of important nutrients using serving-to-serving analytical data collected on highly consumed foods; and (6) developing plans for archived samples. Through NFNAP, the Nutrient Data Lab will continue to update and improve USDA's food composition databases to support critical nutrition and health research in the scientific community. This

Table 3
National Food and Nutrient Analysis Program: sampling and analysis completed by May 2002[a]

Food group	No. of foods
Fast foods	60
Vegetables and products	58
Cereal grains and pasta	53
Fats and oils	46
Fruits and products	46
Mixed dishes	40
Baked products	39
Legumes and products[b]	32
Beverages[b]	29
Ethnic foods[c]	22
Dairy and eggs	20
Spices and herbs	15
Breakfast cereals	12
Meats	12
Nuts and seeds	10
Poultry and products	10
Soups, sauces, gravies	10
Sausages	6
Fish	1
Total	521

[a] Includes retail products and USDA Commodity Foods.
[b] Limited sampling on some Foods.
[c] Navajo foods.

includes research in analytical methodology, QC procedures, statistical sampling, and data quality evaluation with a multitude of applications in food safety, trade and research.

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