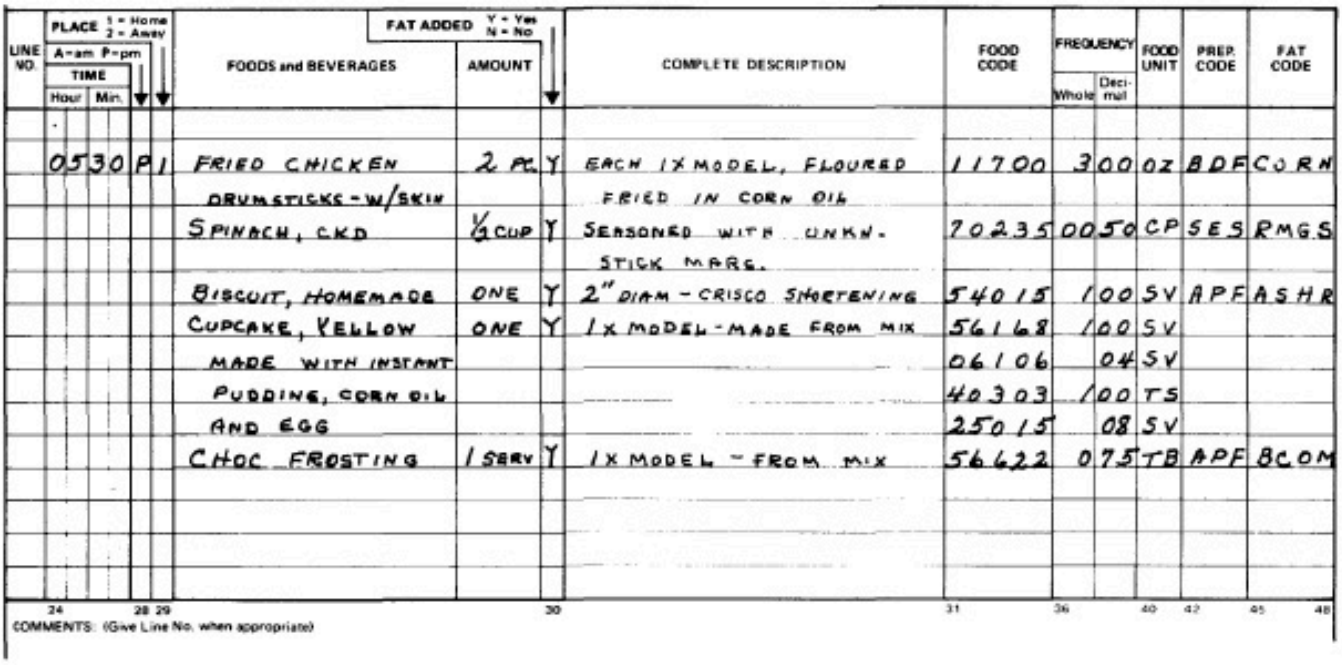
History of the University of Minnesota Nutrition Coordinating Center (NCC)

NCC was initiated in 1974 by the National Heart, Lung, and Blood Institute (NHLBI) to support the food coding and nutrient analysis needs of two historically significant, national collaborative research programs – the Multiple Risk Factor Intervention Trial (MRFIT)[1] and the Lipid Research Clinics (LRC).[2] For these studies, a mainframe computer-based food coding and nutrient analysis system was created by NCC in collaboration with NHLBI and outside experts in nutrition, statistics, computer science and education.[3,4] This system was designed for in-house use, with NCC staff responsible for entering food codes and amounts for computerized calculation of nutrient intake of study participants.

The figure below shows an example of the dietary intake forms that were sent to NCC from MRFIT and LRC clinics.[3,4] NCC food coders were responsible for recording onto the form the correct 5-digit food code number, frequency, food unit, preparation codes and fat codes (right hand columns in the figure below). A codebook provided a food and food code listing, coding rules, coding guidelines, and a recipe index. The food and food code listing was comprised of about 800 basic or elemental foods, including standardized portion sizes. After the manual coding was completed, an NCC staff member entered (i.e., key punched) the codes and amounts onto data tapes, which were loaded into the nutrient analysis system on the mainframe computer. None of the functionality on the mainframe allowed for interactive work.



LINE NO.	PLACE 1 = Home 2 = Away; TIME A=am P=pm Hour	Min.	FOODS and BEVERAGES	FAT ADDED Y = Yes N = No; AMOUNT	COMPLETE DESCRIPTION	FOOD CODE	FREQUENCY Whole	Decimal	FOOD UNIT	PREP. CODE	FAT CODE
	0530	P 1	FRIED CHICKEN DRUMSTICKS - W/SKIN	2 PC Y	EACH IX MODEL, FLOURED FRIED IN CORN OIL	11700	3	00	OZ	BDF	CORN
			SPINACH, CKD	½ CUP Y	SEASONED WITH UNKN. STICK MARG.	70235	00	50	CP	SES	RMGS
			BISCUIT, HOMEMADE	ONE Y	2" DIAM - CRISCO SHORTENING	54015	1	00	SV	APF	ASHR
			CUPCAKE, YELLOW	ONE Y	IX MODEL - MADE FROM MIX	56168	1	00	SV		
			MADE WITH INSTANT			06106		04	SV		
			PUDDING, CORN OIL			40303	1	00	TS		
			AND EGG			25015		08	SV		
			CHOC FROSTING	1 SERV Y	IX MODEL - FROM MIX	56622	0	75	TB	APF	BCOM

24 28 29 30 31 36 40 42 45 48

COMMENTS: (Give Line No. when appropriate)

By 1977 NCC services were made available to other researchers studying the impact of diet and nutrition on various health conditions including cardiovascular disease, cancer, hypertension, obesity, diabetes, age-related eye disease, and acquired immune deficiency syndrome.

To streamline and better standardize dietary intake information collection and coding, NCC began work developing a Dietary Data Collection (DDC) microcomputer system for 24-hour dietary recall collection. The system operated interactively, soliciting all necessary information on menu selection screens to ensure user entry of complete food descriptions and amount information. Descriptive data were then automatically converted to food codes and gram weights for subsequent calculation of nutrient content.[5] For the first time, coding of foods and amounts was computerized. After the first phase of system development, a preliminary test was performed to compare the amount of time required for certified NCC food coders to enter paper and pencil food records into the DDC system with the amount of time required to accomplish the same food coding task manually using the mainframe-based food coding and nutrient analysis system. Time savings ranged between 9% and 44% for NCC food coders to enter the paper and pencil food records into DDC.[6] DDC was used for the Third National Health and Nutrition Examination Survey (NHANES III), which was carried out

between 1988-1994. A team from NCC co-authored the NHANES III Dietary Interviewers' Manual that was used to train staff and standardize the dietary components of the interview.[8]

The DDC project led to NCC creating and releasing the Nutrient Calculation System (NCS) in 1988 followed by Nutrition Data System (NDS) in 1989.[7] NDS was a Microsoft Disc Operating System (MSDOS)-based software program designed to provide a standardized interview and direct data entry for collection of 24-hour dietary recalls or entry of paper and pencil food records. For the first time dietary recalls could be collected entirely electronically rather than by paper and pencil. Nutrient data was available in reports and data output files.

The software was developed for distribution to researchers for use on their personal computers. Thus began NCC's transition from only a service center to a software provider. A user manual, technical support, and training were among the services developed by NCC to support those using NDS. In addition to the research version of NDS, two other NDS products were developed. Counseling NDS was released in 1990. This program allowed a user to enter dietary data and view or print nutrient calculations, but nutrient values could not be exported for analysis. It was marketed to practitioners working with clients and patients on implementing dietary changes. NDS 32 was released in 1992. This program had the same functionality as the research version of NDS, but contained a database with only 32 nutrients. Both the Counseling NDS and NDS 32 products were discontinued in 1997, with NCC focusing on maintaining and developing NDS (full nutrient version) moving forward.

In the mid-1990's NCC embarked on developing a Microsoft Windows-based version of NDS so the program would be compatible with and designed to take advantage of the many benefits of this operating system. In 1998, a Windows-based version of the program was released, with a modified name- Nutrition Data System for Research (NDSR). 'Research' was added to the program name to reflect its focus on meeting the needs of researchers.

Since the release of NDSR, NCC has worked to keep the program up to date with computer hardware and software advances, dietary assessment methods, and dietary intake assessment methodological improvements (see Table 1). Today NDSR is designed for the collection and coding of 24-hour dietary recalls and the analysis of food records, menus, and recipes. For example, today NDSR includes features such as built in standardized prompts for the multiple pass approach to dietary recall collection; the ability to enter foods in a variety of forms (e.g. sliced, cubed, shredded) and amounts (e.g. cups, ounces, pieces); a suite of tools for carrying out quality assurance; a module for assessing dietary supplement use;[9-10] and a menu planner feature that may be used to plan menus that meet nutrient targets specified by the user.

NDSR has been used by clients outside of the US in countries including Brazil, Colombia, Canada, Saudi Arabia, and China. NCC has had a special role with some of the international clients, such as advising on studies in Brazil[23] and Nigeria and providing tailored training for a research group in Saudi Arabia.

NCC Food and Nutrient Database

Throughout its history NCC has maintained a food and nutrient database for use in conjunction with the food coding systems and software developed by the Center. Over time the database has grown in size and sophistication.[11-22]

Structure

The NCC Food and Nutrient Database is deeply relational in its design. It contains a collection of relations (tables) that include various data elements that are utilized to enter and analyze dietary recalls, records, menus, and recipes in NDSR. Dozens of tables exist in the database. A sampling of these tables include:

- Nutrient composition values per 100 grams for foods
- Food amount units for foods in the database with gram weight assignments for each unit
- Density forms for foods in the database with gram weight assignments per volumetric quantity (e.g., grams of carrot in 1 cup of diced, grated, and sliced carrots)
- Preparation codes and accompanying nutrient estimation algorithms for foods that may be prepared in various ways (e.g., preparation codes for chicken breast include fried, baked, microwave cooked, broiled, grilled, steamed, stewed, boiled, or stir fried)

- Variable ingredient options for each preparation code (e.g., possible fats that may be used if a food item is prepared by frying)

Although complicated to develop and maintain, the advantages of the structure of the NCC Food and Nutrient Database are numerous. Most notably, by linking ingredient choices and preparation methods to food items in the database, a food item may be created in NDSR that closely matches the food for which nutrient composition information is sought.

Size and Growth of the Database over time

The NCC Food and Nutrient Database has more foods and nutrients than any other research quality food and nutrient database. It has highly complete data for all nutrients and food components due to our reliance on a wide variety of sources of information on the nutrient composition of foods and our use of rigorous imputation methods that are made possible by the structure of our database (core foods approach). NCC does not analyze food for their nutrition, but rather we have developed procedures for seeking nutrient composition data for food from a range of reliable sources and imputing values using established procedures[5,11-14].

Currently, the NCC Food and Nutrient Database includes 178 nutrients, nutrient ratios and other food components. Nutrients and food components of interest are added on an ongoing basis, and the methodologies used are routinely published so those relying on the database are aware of data sources used and imputation methods relied upon. For examples, papers are available describing the methodology used to add trans-fatty acids[16], glycemic index[20], glycemic load[20], and gluten[22] to the database.

The NCC Food and Nutrient Database currently includes about 19,000 foods, including 8,300 brand products. Priority has been placed on making sure foods eaten in the U.S. by a range of individuals are included. For example, foods unique to various eating traditions have been added and expanded over time to include foods unique to eating traditions from around the world. For example, foods unique to eating traditions in the following parts of the world are included: East and Southeast Asia, India, Latin America, Caribbean, Nigeria, and Somali. In addition, foods unique to the eating traditions of Alaskan Natives, Mexican Pima Indians, Pima Indians and Hawaiians are included. The database is structured to allow ingredient choices and preparation methods to be specified as part of the data collection process in NDSR, thereby offering more than 160,000 food variations. A wide array of food amount units are available for foods in the database, including density, food specific units, shapes, and amount conversions.

The NCC Database also includes a Food Group Serving Count System to facilitate research examining dietary food patterns. Two additional food grouping schemes are available in the database (see Appendix 10 of the NDSR User Manual). Also, Healthy Eating Index (HEI) total and and index component scores along with MyPlate equivalent servings are calculated and available in NDSR output files

Innovation of core foods approach for calculating nutrient values for many multi-ingredients foods

Core Foods are foods in the NCC Food and Nutrient Database designated as the building blocks for creation of nutrient composition values for multi-ingredient foods. The approximately 2,700 Core Foods in the database are single ingredient foods (e.g., beef, apple, honey) and basic multi-ingredient foods (e.g., bread, sausage, cereal) for which comprehensive nutrient composition information is available. Because these items serve as building blocks for creation of nutrient composition information for other foods, every attempt is made to utilize analytic nutrient composition information for these items and minimize missing nutrient values.

Imputation procedures devised and used by NCC

NCC has prided itself on providing a complete nutrient profile for all foods in the database, and this only can be achieved through standardized imputing methods where analyzed values are unavailable. It has been the NCC philosophy that "It is better to have an estimated nutrient value than a blank which will calculate as a zero in dietary intake records." Because the primary source for nutrient values in NDSR is the USDA Database for Standard Reference, early on it was important that NCC and USDA agreed on standardized procedures to impute or logically calculate estimations. These procedures are described in detail in the article Procedures for Estimating Nutrient Values for Food Composition Databases.[14] To summarize, one of the following procedures is employed to estimate a nutrient value for a food when a value is not available from the USDA National Nutrient Database for Standard Reference (SR) or cannot be found in the literature:

- Use value from a different but similar food (e.g., missing nutrient for wild duck may be judged to be the same as known nutrient in domestic duck)
- Calculate value for another form of the same food (e.g., convert from raw to cooked values using retention factors)
- Calculate values from other components in the same food (e.g., estimate total vitamin A from provitamin A, carotenoids, and retinol)
- Calculate value from household recipes or commercial food product formulations for multi-component foods. This process involves building foods from basic food items (Core Foods). This is a relatively simple process for foods derived from household recipes (e.g., homemade lasagna) because both the ingredients and ingredient amounts are specified in recipes. The process is more complex for brand name food products for which ingredient information is generally known from the ingredient statement on product packaging, but the amount of each ingredient is not specified. Consequently, a special procedure is used for calculating nutrient values for brand name food products.

Missing values are allowed in the database for foods that are consumed in very small quantities, such as spices, or where there are no data to indicate whether the nutrient exists in the food.

Some nutrients have no missing values, but a high percentage of imputed values. An example is total vitamin A which is calculated from provitamin A, carotenoids and retinol.

In future versions of the database, missing and estimated values will be replaced by analytic values as they become available.

Approach to seeking reliable sources of nutrient composition values

Because values for some nutrients and food components are not available from the USDA National Nutrient Database for Standard Reference (SR) and information is lacking for many brand name food products, additional resources are utilized. These resources include values from other food and nutrient databases and articles in scientific journals containing values for food products obtained using appropriate analytic methodologies.

Time related aspect of the database

Since the database was created, NCC has maintained a time-related feature to permit comparability of dietary data over time. Time-related maintenance procedures allow previously collected food intake data to be re-run in the latest version of NDSR in order to calculate data for nutrients and food groups added to the database since the time that the data were collected, as well as to obtain updated or improved values for existing nutrients. Importantly, NCC's unique time-related feature also functions to protect food intake data from revisions that would be contrary to the database version and time period in which the data were originally collected. For example, the nutrient composition of Honey Nut Cheerios as formulated in the year the dietary data were collected and entered into NDSR is preserved when re-running food intake data through the latest version of NDSR.

Automation of database maintenance

Over the years, NCC has developed several database maintenance software programs that are used in-house.

- The NCC Database Maintenance system was developed in the late 1980's for use on the mainframe and allowed for real-time entry of food and nutrient data into the database.
- The mainframe maintenance system was later adapted for the personal computer and became the Nutrition Data System Maintenance (NDSM) program. NDSM is used to maintain the food hierarchy, food attributes, and nutrient strings.
- AutoCalc was also developed and used on the mainframe to facilitate creating recipes, generating formulas for branded products such as fast foods and commercial entrees, and imputing missing nutrients. Foods and amounts were entered which generated nutrients and then these nutrients were summed and matched to a set of known values.
- The AutoCalc program was also adapted for the personal computer and became known as FoodCalP. Mathematical optimization techniques (i.e., linear programming) were implemented in FoodCalp to

improve its accuracy and efficiency.[13] FoodCalp continues to be used today though much of the detailed work in generating formulas and imputing missing values is still performed by database staff.
- The NDSM Reports program is used by the NCC database team to perform quality assurance tasks (e.g., ensure the sum of fatty-acid values in the database equal total fatty acid values) and to validate the database before its release. The implementation of this program has enabled the database staff to run reports themselves rather than having to rely on the IT staff.
- The most recently developed program, Central Access Tool (CAT), was designed to automate the import of data obtained from external sources (e.g., USDA, NCHS) for use in the NCC Food and Nutrient database.

Research Services
Throughout NCC's history, its Research Services group has offered services such as 24-hour dietary recall collection over the telephone, entry of food records in NDSR, dietary data collection protocol development, and quality assurance of dietary data collected using NDSR. Over the decades hundreds of studies have used this service, including international clients.

NCC Today
In 2016 NCC modified its mission statement to include 'health promotion'. **Current mission**: The Nutrition Coordinating Center's mission is to support nutrition research and health promotion by providing state-of-the-art software and databases for nutrition assessment. This expanded mission was tied in with growing demand for the NCC Food and Nutrient Database as a source of high-quality reliable food and nutrient data for consumer-oriented mobile health (mHealth) apps. In addition, NDSR is being used for purposes beyond research such as planning menus that meet nutrition standards and developing healthy recipes.

Today NCC's dietary intake assessment software and services are widely used for an array of research and health promotion activities. For example, in Fiscal Year 2023 alone:

- Over 125 institutions were supported users of NDSR, using about 400 copies of the program in their work.
- NDSR was referenced in 300 scientific publications.
- The NCC Food and Nutrient Database was licensed by over 20 organizations for use as the source of nutrition composition data for food frequency questionnaires and mHealth apps.
- Over 800 dietary recalls were collected and 400 food records entered by NCC's Research Services staff.

Support for NCC
NCC was initially funded through a series of National Heart Lung and Blood Institute (NHLBI) contracts that recognized NCC as a national research resource. Some additional NIH Institutes and Centers contributed funds as part of these contracts, which were designed to support software and database improvements. It was expected that over time NCC would become financially self-sufficient through revenue generated by licensing NDSR and the NCC Food and Nutrient Database, and through fees paid for services provided. Toward this end, NIH discontinued support in 2014. As a result of this change in funding NCC had to downsize staffing, and is now fully supported through licensing and support fees and grants.

References

1. Caggiula AW, Christakis G, Farrand M, Hulley SB, Johnson R, Lasser NL, Stamler J, Widdowson G. The multiple risk intervention trial (MRFIT). IV. Intervention on blood lipids. Prev Med. 1981 Jul;10(4):443-75. doi: 10.1016/0091-7435(81)90060-8. PMID: 7027238.
2. The Lipid Research Clinics Coronary Primary Prevention Trial results. I. Reduction in incidence of coronary heart disease. JAMA. 1984 Jan 20;251(3):351-64. doi: 10.1001/jama.1984.03340270029025. PMID: 6361299.
3. Dennis B, Ernst N, Hjortland M, Tillotson J, Grambsch V. The NHLBI nutrition data system. J Am Diet Assoc. 1980 Dec;77(6):641-7. PMID: 6893713.
4. Tillotson JL, Gorder DD, DuChene AG, Grambsch PV, Wenz J. Quality control in the Multiple Risk Factor Intervention Trial Nutrition Modality. Control Clin Trials. 1986 Sep;7(3 Suppl):66S-90S. doi: 10.1016/0197-2456(86)90160-1. PMID: 3802847.
5. Buzzard M, Feskanich D. Maintaining a Food Composition Data Base for Multiple Research Studies: The NCC Food Table. In: W. Rand, C. Windham, B. Wyse, and Y. V (eds.), Food Composition Data: A User's Perspective: The United Nations University, 1987.
6. Feskanich D, Buzzard IM, Welch BT, Asp EH, Dieleman LS, Chong KR, Bartsch GE. Comparison of a computerized and a manual method of food coding for nutrient intake studies. J Am Diet Assoc. 1988 Oct;88(10):1263-7. PMID: 3171019.
7. Feskanich D, Sielaff B, Chong K, Bartsch G. Computerized collection and analysis of dietary intake information. Comput Methods Programs Biomed, 30(1): 47-57, 1989.
8. Center for Disease Control and Prevention, National Center for Health Statistics, Division of Health Examination Statistics. The Third National Health and Nutrition (NHAMES III) Examination Survey Dietary Interviewer Manual. Published 1988.
9. Harnack L, Stevens M, Van Heel N, Schakel S, Dwyer J, Himes J. A computer-based approach for assessing dietary supplement use in conjunction with dietary recalls. J Food Comp Anal, 21:S78-S82, 2008.
10. Schakel SF, Jasthi B, Van Heel N, Harnack L. A computer-based approach for assessing dietary supplement use in conjunction with dietary recalls. Adjusting a nutrient database to improve calculation of percent calories from macronutrients. J Food Comp Anal, 22 (Suppl 1): S32-S36, 2009.
11. Schakel S, Sievert Y, Buzzard IM. Sources of data for developing and maintaining a nutrient database. J Am Diet Assoc, 88: 1268-1271, 1988.
12. Sievert YA, Schakel SF, Buzzard IM. Maintenance of a nutrient database for clinical trials. Controlled Clin Trials, 10:416-425, 1989.
13. Westrich BJ, Buzzard IM, Gatewood LC, McGovern PG. Accuracy and efficiency of estimating nutrient values in commercial food products using mathematical optimization. J Food Comp Anal, 7:223-239, 1994.
14. Schakel S, Buzzard IM, and Gebhardt S. Procedures for estimating nutrient values for food composition databases. J Food Comp Anal, 10: 102-114, 1997.
15. Holden J, Eldridge A, Beecher GR, Buzzard IM, Bhagwat S, Davis C, Douglass L, Gebhardt S, Haytowitz D, Schake S. Carotenoid content of US foods: An update of the database. J Food Comp Anal, 12: 169-196, 1999.
16. Schakel S, Harnack L, Wold C, Van Heel N, Himes J. Incorporation of trans-fatty acids into a comprehensive nutrient database. J Food Comp Anal, 12: 323-331, 1999.
17. Schakel SF. Maintaining a nutrient database in a changing marketplace: keeping pace with changing food products-a research perspective. J Food Comp Anal, 14:315-322, 2001.
18. Van Heel N, Pettit J, Rice BL, Smith SM. Meeting expanding needs for nutrient specificity: the NASA case study. J Food Comp Anal, 16:299-303, 2003.
19. Schakel S, Pettit J. Expansion of a nutrient database with the "new" vitamin E. J Food Comp Anal, 17: 371-378, 2004.
20. Schakel S, Schauer R, Himes J. Development of a glycemic index database for dietary assessment. J Food Comp Anal, 21:S50-S55, 2008.
21. Thor MY, Harnack L, King D, Jasthi B, Pettit J. Evaluation of the comprehensiveness and reliability of the chromium composition of foods in the literature. J Food Comp Anal, 24: 1147-1152, 2011.
22. Jasthi B, Pettit J, Harnack L. Addition of Gluten Values to a Food and Nutrient Database. J Food Comp Anal, 85:103330, 2020.
23. Lorenzana Peasley J, Harnack L, Anater A, Lopes T, de Brito J, Schmitz K. Adapting a US dietary analysis software and nutrient database for use in Brazil. J Food Comp Anal, 121: 105364, 2023.