

Report

Progress in development of an integrated dietary supplement ingredient database at the NIH Office of Dietary Supplements

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Abstract

Several activities of the Office of Dietary Supplements (ODS) at the National Institutes of Health involve enhancement of dietary supplement databases. These include an initiative with US Department of Agriculture to develop an analytically substantiated dietary supplement ingredient database (DSID) and collaboration with the National Center for Health Statistics to enhance the dietary supplement label database in the National Health and Nutrition Examination Survey (NHANES). The many challenges that must be dealt with in developing an analytically supported DSID include categorizing product types in the database, identifying nutrients, and other components of public health interest in these products and prioritizing which will be entered in the database first. Additional tasks include developing methods and reference materials for quantifying the constituents, finding qualified laboratories to measure the constituents, developing appropriate sample handling procedures, and finally developing representative sampling plans. Developing the NHANES dietary supplement label database has other challenges such as collecting information on dietary supplement use from NHANES respondents, constant updating and refining of information obtained, developing default values that can be used if the respondent cannot supply the exact supplement or strength that was consumed, and developing a publicly available label database. Federal partners and the research community are assisting in making an analytically supported dietary supplement database a reality. © 2005 Elsevier Inc. All rights reserved.

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1. Introduction

Dietary supplement use in the US is high; with at least 50% of the population claiming that they have used dietary

supplements at one time or another (Radimer et al., 2004). Sales in the dietary supplement industry in 2002 were over \$18 billion (Nutrition Business Journal, 2003). Yet tools to validly document and quantify intakes are lacking, and the public health impact of dietary supplements is unknown. To quantify public use of dietary supplements and the public health impact involved, validated,

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standardized instruments are needed to collect data on intakes; the composition of dietary supplements must be documented; and valid approaches to merging dietary intakes of food and dietary supplements to obtain estimates of total intakes must be found (Dwyer et al., 2003a, b).

The Dietary Supplement Health and Education Act (DSHEA) of 1994 defined dietary supplements, assured American consumers access to dietary supplement products, and established a regulatory framework administered by the Food and Drug Administration (FDA). DSHEA treated dietary supplements as foods, not as drugs, and it specified rules for the contents of a dietary supplement label.

In addition, DSHEA established the Office of Dietary Supplements (ODS) at the National Institutes of Health (NIH) in the Office of the Director. The mission of the ODS is to strengthen knowledge and understanding of dietary supplements by evaluating scientific information, stimulating and supporting research, disseminating research results, and educating the public to foster an enhanced quality of life and health for the US population. The components of interest in dietary supplements include nutrients, as well as potentially bioactive botanicals and other constituents such as contaminants and pesticide residues. Since dietary supplement use is high in the US, there is a pressing need to develop an analytically substantiated dietary supplement ingredient database (DSID) to validate dietary supplement label data and to obtain sound estimates of total dietary intakes of nutrients and other food constituents.

ODS has recently issued its ODS Strategic Plan that will guide its work from 2004 to 2009 (Office of Dietary Supplements, 2004). The Strategic Plan and information about other ODS programs are available from the ODS website (<http://ods.od.nih.gov>).

This paper describes some of the current work of the ODS and partners in other federal agencies relating to documenting the composition of dietary supplements for a dietary supplement database. The goal is to develop quantitative estimates for nutrients and other bioactive components in dietary supplements, to release and maintain an on-line database for dietary supplements, and to assess the variability and/or possible bias in stated values for dietary supplements.

2. Challenges in developing a DSID

One key part of the ODS strategy is to develop an analytically supported dietary supplement compositional database which is called the DSID. ODS and its partners are meeting the challenges to make this a reality: The DSID database is supported by chemical analyses of the ingredients of public health importance in dietary supplements.

2.1. Categorizing products in the database

Appropriate sampling methodology requires a logical system for categorizing dietary supplements and provides a basis for selecting products for analysis. Categorization affects the estimation of values for related products. One major problem is deciding how to select representative samples of product types. Conventions such as source/origin, use in meals or categories of foods that are rich sources of certain nutrients have long been accepted and employed for categorizing food products. Drug databases also employ conventions for grouping drugs, such as by intended or end use, by function, or by the chemical name of the drug (USP, 2005, <http://www.nlm.nih.gov/medlineplus/druginformaiton.html>, <http://sfghean.ucsf.edu/barnett/DBS/drugs.asp> {accessed July 11, 2005}). Many schemes are possible for categorizing dietary supplements for research purposes, but no conventions have yet been identified and widely agreed upon. These include origin, brand/manufacturer, end use, chemical content, and, for commercial purposes, market share. There are many possible logical groupings, and myriad classifications are used, each designed for different purposes. The logic of these categorization schemes is not always clear, and categorizations are often based on convenience with decisions based on subjective rather than objective criteria. The implications for research of the current state of affairs is that comparison between studies is difficult, variability of nutrients within categories is often great, and the categories are often neither homogeneous nor mutually exclusive. To move the field forward, principles for the categorization of dietary supplements for research purposes are needed. These should include, at a minimum: (1) identification and standardization of useful classification schemes for major research uses; (2) the development of explicit rationale and logic for the categorization criteria; (3) homogeneity; and (4) mutually exclusive categories.

2.2. Identifying components of public health interest to populate the database

A cooperative agreement has been in place for many years between the National Heart, Lung and Blood Institute (NHLBI) and the US Department of Agriculture (USDA). Agricultural Research Service (ARS) to update nutrient values for USDA food composition tables, to assemble information on constituents for special food and dietary supplement composition tables, and to develop analytical methods for other constituents of interest in foods. Because the standard reference database contains data on foods, and because its procedures have been thoroughly tested, ODS is augmenting this agreement by providing supplementary funding to the NHLBI/ARS project to develop and populate a dietary supplement database.

Dietary supplements contain many nutrients and other components. It is impossible to analyze all of these

components at once, and in any event some of the constituents are not of public health interest or concern. Therefore, it is important to identify the most critical components to include in the database using a priority ranking system based on the nutrients or other components of greatest public health interest.

2.2.1. Criteria for selecting components for analysis

Four criteria were used as the basis for deciding on critical components of public health interest to be studied first in developing a DSID. They were: exposure/frequency of consumption, public health significance of the constituent, federal agency interest, and availability of methods and reference materials. Exposure/frequency of consumption was determined from dietary supplement use/exposure data collected in the National Health and Nutrition Examination Survey (NHANES) in 1999–2000. Public health significance of the constituent was assessed in terms of frequency of use in NHANES 1999–2000 and other factors as well. For example, priority was given to constituents for which Dietary Reference Intakes had been established (Dwyer, 2004). Those identified as being of public health significance in the Third National Nutrition Monitoring Report (Federation of American Societies for Experimental Biology, 1995) or that were mentioned in the Healthy People 2010 report (US Department of Health and Human Services, 2000) were also utilized in determining priorities of public health significance. Constituents with biomarkers for which biochemical assessment of nutrient status was possible and with nutritional status monitoring biomarkers that were feasible and available in NHANES were also used in establishing priorities. Other nutrients of public health interest included those that are limiting or excessive in diets, or other constituents that posed potential safety concerns.

An example of Federal agency interest is dietary supplement components being evaluated by the NIH in evidence-based reviews, or being planned for inclusion in large-scale clinical trials. Components with ongoing studies mentioned in the NIH Computerized Access to Research on Dietary Supplements (CARDS) and Human Nutrition Research Information Management (HNRIM) system, identified in a survey of NIH Institute and Center directors, and high priority constituents of other federal agencies, such as FDA, the Centers for Disease Control and Prevention, and USDA were also given consideration.

With regard to availability of methods and reference materials, preference was given to analytes for which there are methods from the Association of Official Analytical Chemists International (AOAC) or the US Pharmacopoeia (USP) monograph series, or for which generally accepted methods used in the analysis of conventional foods and infant formulas exist (AOAC International, 2003; USP-28-NF-23, 2004). It was expected that these could be easily adopted for use with dietary supplements. If a reference material was available or could be readily developed for a component, it was preferred.

Table 1
Dietary supplement ingredient database priorities

Phase 1: highest priority

Folic acid/folate
Calcium
Vitamin E
Zinc
Vitamin A
Vitamin C
Iron
Magnesium
Selenium
Vitamin B6
B carotene
Vitamin D
Vitamin B12
Omega 3 fatty acids (DHA, ALA, lipids)
Potassium
Sodium
Iodine

Phase 2: high priority

Thiamin
Riboflavin
Niacin
Vitamin K
Pantothenic acid
Copper
Lycopene
Biotin
Chromium
Lutein
Phosphorus
Manganese
Ginkgo biloba
Caffeine
Soy isoflavones (phytoestrogens)
Molybdenum

Note: Within each phase, all ingredients are of the same priority.

The decision-making scheme employed was adopted from that of Kepner and Tregoe (1981). Factors that should be taken into account in the ranking of an item were identified and scored. The factors were then assigned a weight based on their relative importance to each other and the scores were multiplied by their respective weights, sorted, and ranked to yield a priority list.

Table 1 presents the final list of priorities determined by the interagency working group. The qualitative factors were summarized, scored, the results were then discussed by the group, and a final decision was made by consensus.

2.2.2. Priorities for tabulating components

Priorities for current compositional research are listed in Table 1. Phase 1 constituents will be addressed first, and as time and resources permit, constituents in phase 2 will also be addressed.

Note that most of the constituents listed are nutrients. Nutrients in dietary supplements are relatively straightforward to analyze, their active components are known, they are also found in foods, analytical methods for assaying

them are often validated, and although matrices vary, analytical methods are usually easy to validate. Finally, the benefits and public health importance of nutrient-containing dietary supplements are generally known.

Botanicals are more problematic to quantify for several reasons. The active components are largely unknown, analytical methods are not developed, the chemical forms in which they occur are not necessarily the same as the forms occurring in foods, efficacy is often not established, and the public health relevance of consuming the products is still unknown. For these reasons the components to be analyzed in phases 1 and 2 tend to be more heavily weighted toward nutrients than botanicals.

2.3. Quantifying priority components

Next the priority nutrients–ingredients–components must be quantified. One characteristic that distinguishes dietary supplements from conventional foods is that few publicly available chemically determined data exist for them. Therefore, only values that are declared on the label are available. The production of data to populate a DSID based upon chemical analysis requires the use of validated analytical methodology and the use of appropriate reference standards. For these methods, ODS has initiated a complementary effort, the Dietary Supplements Methods and Reference Materials Program (Saldanha et al., 2004).

To assure data quality, the present state of analytical methodology and available reference materials are being evaluated for their potential use in contracts to generate information for the DSID. Ingredient priorities for the DSID include vitamins and minerals, both multi and single ingredient) and caffeine. Other classes of dietary supplements such as botanicals and herbals will also be considered, but at a later time. Analytical methods from the AOAC International and USP have been considered along with available reference materials from the National Institute of Standards and Technology (NIST) and other sources that have assigned values for the priority ingredients. Assuring the quality of analytical data to provide accurate information about the levels and types of components in dietary supplements will allow public health professionals to have greater confidence in the data when they combine dietary intake data from foods and dietary supplements to determine the total impact of dietary supplements on the nation's health.

2.3.1. Analytical methods

Standardized publicly available and validated methods are often lacking for the chemical analysis of dietary supplements. To assure quality of the resulting data, the present states of analytical methodology and available reference materials have been evaluated for potential use in contracts to generate information for the DSID.

ODS is partnering with the FDA, and the AOAC International to remove these barriers. It is working with the methods validation program of AOAC International to

develop analytical methods that are appropriate for dietary supplements, and make them available. Through the AOAC methods program, analytical methods are being validated for ephedra, aristolochic acids, β -carotene, chondroitin sulfate, glucosamine (potassium and sodium sulfate), St John's wort constituents, Ginkgo constituents, and saw palmetto constituents. AOAC has issued a call for methods for *s*-adenosylmethionine (SAmE), vitamin E, Coenzyme Q 10, Panax ginseng (Asian), Quinquefolius ginseng (American), Eleuthero (Siberian Ginseng), Kava kava, yohimbe, and cranberry extract. Future candidates for the methods program include (but are not limited to) aconite, black cohosh, milk thistle, valerian, green tea, garlic, goldenseal, Vitex (chaste tree), skullcap, pygeum (African plum), l-carnitine, biotin, and feverfew.

Numerous analytical methods for vitamins and minerals in foods are available from AOAC International (Sullivan and Carpenter, 1993), and specific methods for some vitamin and multivitamin supplements are available from USP (USP-26-2003). It is anticipated that the AOAC methods can be readily adapted for vitamin and mineral supplements. Supplement matrices for these nutrients are different from, but usually far less complex than those for foods. Verification of the accuracy of the AOAC methods for the supplement matrices should, therefore, be fairly straightforward. The USP methods consist of families of tests designed to validate the integrity of the sample and provide analytical values. In general, the USP tests for specific vitamins and minerals are less rigorous than the AOAC methods because the integrity of the sample has been previously verified by another set of tests. Use of only the USP tests for vitamins and minerals, without full verification, would not be appropriate for all supplements. Like the AOAC methods, verification of the accuracy of the USP methods for specific supplement matrices will be required. In general, the methods developed by both organizations provide excellent background information and should make methods development relatively straightforward. Using previously defined criteria for qualitative, quantitative and economic analyses (Holden et al., 2001), the USDA ARS Food Composition Laboratory group has reviewed the current status of analytical methods for nutrients and evaluated them. Those meeting all three criteria were classified as "robust", those meeting two of the criteria as "limited", and those failing to meet two or more criteria as "inadequate". In general, methodology for the minerals is robust or adequate. In contrast, adequacy for the vitamins is mixed, especially for some of the B vitamins due to lack of agreement on generally accepted methods.

2.3.2. Standard reference materials (SRMs)

Reference materials are used as a tool for confirming that an individual laboratory's analytical method provides accurate results. They can be used as part of a laboratory or supplement manufacturer's quality assurance program to support the reliability of the day-to-day use of such a

method. A certified reference material (CRM) is a “reference material, accompanied by a certificate, one or more of whose property values are certified by a procedure which establishes traceability to an accurate realization of the unit in which the property values are expressed, and for which each certified value is accompanied by an uncertainty at a stated level of confidence” (International Organization for Standardization, 1993). NIST, which is the national metrology institute of the US and housed in the US Department of Commerce, defines CRMs that are called SRMs. Analytical chemists can measure a component in a chemical-composition SRM or other reference material at the same time as they measure that same component in the sample material that they are testing, and if the results from the SRM are comparable to assigned values stated on the SRM Certificate of Analysis, confidence is enhanced that the answer for the unknown test material is correct as well (Sharpless et al., 2004). Available reference materials from the NIST and other sources that have assigned values for priority dietary supplement ingredients have also been examined. There are some reference materials such as infant formula available with assigned values for the priority ingredients, but these are all food-based materials and not specifically dietary supplements.

Thus, SRMs are lacking for many ingredients in dietary supplements. Therefore, it is necessary to develop SRMs or CRMs for dietary supplements that laboratories can use for quality assurance. ODS and NIST have partnered with assistance from the private sector to prepare an SRM for a multivitamin–mineral supplement. This SRM is now being certified and made available for use in establishing the DSID. NIST is also developing SRMs for ephedra, ginkgo, saw palmetto, St John’s wort, bitter orange, green tea, beta carotene, and alpha tocopherol. It is also updating its cod liver oil SRM to show individual fatty acids.

2.3.3. Analytical accuracy required

The analytical accuracy that is needed must also be determined. For certain ingredients of dietary supplements, including some of the vitamins and minerals of high public health importance, such as folic acid, calcium, and vitamin D, it is important to get better evidence about total intakes from dietary sources. For botanicals, the needed analytical accuracy depends on the substance.

2.4. Identifying qualified laboratories

The capacity, capabilities, and interests of existing testing laboratories must be identified. Some laboratories are more familiar with analyzing foods than dietary supplements. Using products identified as consumed in NHANES 1999–2000, we have identified several issues of interest. For example, we examined whether methods appropriate for foods are also appropriate for the chemical analysis of dietary supplements. Also of interest are whether labels reflect the actual contents of dietary

supplements, and how much variability there is among production lots and by many other characteristics. The USDA plans to issue a notice of its interest in identifying suitable laboratories for analysis of dietary supplement samples. It issued a request for proposals in 2004, and will review and rate the proposals by the end of 2005. Selected laboratories will receive test materials and proceed to test the samples. USDA will review the results for accuracy and precision and select the most highly qualified laboratories.

2.5. Sample handling

The next step is to develop appropriate dietary supplement sample processing and handling protocols. A group of experts on laboratory methods will be convened to review protocols that have been proposed by active laboratories for dietary supplements. Issues such as encapsulation, homogenization, and other problems posed by matrices will be considered and protocols will be developed or approved as needed.

2.6. Developing an analytical survey of products

The ultimate goal for the DSID is to report the results of a systematic survey of dietary supplement composition, including chemical analyses of the individual ingredients in supplements and indicators of data quality. Preliminary sampling plans for products have been developed in collaboration with the National Agricultural Statistical Service (NASS) of USDA. The percent daily values (DVs) for products in different groups have been categorized. For example, for multivitamin products reported in the NHANES 1999–2000, the three top percent DV levels of folic acid for such products (from declared values on the label) were 75%, 100%, and 250%, respectively, with greater than 80% of the products labeled at 100% DV. In contrast, the most common percent DV levels for iron in multivitamins were 100% (with over 60% of all values falling at that level) 50%, and 150%. For calcium in multivitamins, the most common level consisted of 16% DV (approximately 40% of products), with 20% DV and 45% DV being the next most common. The plan for the pilot study is to choose representative multivitamin products for each of six nutrients (folic acid, vitamins E, C, A, iron and calcium), for each of the most commonly occurring % DV levels. Five to 10 representative multivitamin/mineral products will be analyzed to estimate the mean composition of critical nutrients and to determine the within and between lot variability. These six critical nutrients were chosen because their analysis will involve a number of different analytical challenges. Analytically determined values will then be compared to labeled values. This information will support the exploration of the relationship between label declaration values and actual analytical data. Once these results are evaluated, additional questions will be explored as these may affect the ultimate sampling plan. The questions include: how does dietary

supplement composition change over time, and which nutrients/constituents change the most? It will also be important to explore how to overcome any significant challenges posed by nutrients or components. These and other pilot studies will answer basic questions about the concept and the sampling process, and will lay the groundwork for the full-scale analytical survey of products.

2.7. Developing representative sampling plans

An appropriate sampling plan must be developed to populate the dietary supplement database. The sampling plan should consider the marketing sectors through which the products are sold. Products will be chosen from all distribution channels. Dietary supplements differ somewhat from food products in that the distribution channels are quite different. The distribution channels include mass market retail sales in supermarkets and drugstores, natural and health food stores, and other stores, as well as multilevel marketing and direct sales over the internet, by mail order, and by alternative medical practitioners. The products in these various markets may be quite different (Nutrition Business Journal, 2003).

3. Challenges in developing the NHANES dietary supplement label database

Dietary supplement use in the US is being documented by collection of dietary supplement information in NHANES, the nation's population-based survey to assess the health and nutritional status of adults and children in the US. Information on dietary supplement use is vital for achieving the goals of NHANES, which include the relationships between diet, nutritional status and health over time; monitoring trends in health risk behaviors and environmental exposures over time; and exploring emerging public health issues. NHANES is a nationally representative sample of non-institutionalized civilians in the US. About 5000 people are surveyed each year in 15 communities nationwide, with public data releases every 2 years.

3.1. Collection of information on dietary supplement use from NHANES respondents

Information on dietary supplement use (frequency, amount, and duration) is collected during the household interview in NHANES. The information obtained about dietary supplements includes vitamins, minerals, other dietary supplements (both prescription and non-prescription), and antacids taken in the last month. Those respondents who say that they have taken dietary supplements are then asked to provide the containers, and about two-thirds of the respondents do so. Supplement containers are viewed and label names recorded. The interviewer records the product name, strength of ingredient for some

vitamins and minerals, and other information. During the household interview, details on supplement use, such as how long the product has been used, how often it was taken over the last month, and how much was taken are established.

3.2. Development and updating of the NHANES label survey database

A dietary supplement database has been developed to store nutrient information taken from dietary supplement labels collected in NHANES, and this is the basis for the dietary supplement label database information. Working from the label information obtained from NHANES respondents, NHANES nutritionists obtain additional label data for the dietary supplement database through letters to manufacturers and distributors, company websites, other internet sources, and the [Physician's Desk Reference \(2004\)](#). Changes in supplement composition are tracked and entered into the database when reformulations are identified.

4. Developing defaults for dietary supplement products

Another facet of the work is to create default values, age and sex specific when possible, that can be used if the respondent cannot supply the exact supplement or strength that was consumed, so that some information can be captured. The defaults are based upon the frequency of supplements reported in the most up-to-date 2-year NHANES cycle that is available, as well as on manufacturer information on sales. For example, for an individual who reports use of "vitamin C", the default is 500 mg. Suggested default matches for adults include matching multivitamins to multivitamin/multimineral, vitamin A to 8000 IU, vitamin B6 to 100 mg, vitamin D to 400 IU, vitamin E to 400 IU, folic acid to 400 mcg, calcium to 500 mg, iron to 65 mg, and zinc to 50 mg. Because NHANES uses a nationally representative sampling procedure, defaults developed with NHANES data may be useful in surveys that are not able to collect data with this level of detail. Surveys that collect brand-specific supplement names can also use the database to access the nutrient content of a supplement. The supplement-specific nutrient information contained in the database can be assigned to individuals who report having taken a specific or generic supplement. These nutrients can then be combined with dietary nutrient intake to calculate total nutrient intake.

4.1. Developing a publicly available label database

A publicly available database is being developed which will make the information collected in NHANES more accessible to researchers and others. It will contain the same products as the NHANES 1999–2000 data in an SAS format and will be available at: <http://www.cdc.gov/nchs/>

about/major/nhanes/NHANES99.00htm. A spreadsheet format will allow easy access to the data, sorting, and importing of information into other databases. The public web-based NHANES dietary supplement database will consist of three separate excel worksheets—a supplement information sheet, an ingredient information sheet, and a blend information sheet. Two uses of the database are to obtain ingredients reported on the dietary supplement label, and to obtain defaults for surveys that collect generic dietary supplement data.

5. A practical example

The challenges involved in estimating dietary supplement intakes are considerable. For example, if calcium intake affects bone density, then the contribution of food, supplement, and antacid sources must be determined and each has its challenges. For food, fortification with calcium is currently difficult to identify because databases may not be complete. In some age groups, such as among postmenopausal women, antacids like TumsTM are the major sources of calcium for many women. Information about antacid use is collected in NHANES, but it may not be in other surveys, and therefore this very significant source of calcium may be missed. Supplement use information is collected in NHANES but as an interval over the past 30 days and only label values as reported by the manufacturer are available. So total dietary intakes of calcium, unless great care is taken, may be very inexact, especially in older women or others who take a number of supplements and use fortified foods. The situation is further complicated by the fact that there are no good biomarkers for calcium intake. These and other issues involving the collection of information about dietary supplement intake, the processing and estimation of total intakes are discussed at length elsewhere (Dwyer et al., 2003a–d).

6. Conclusions

Analytical data that provide accurate information about the levels and types of components in dietary supplements will permit public health professionals to have greater confidence when they combine dietary intake data from foods and from dietary supplements to determine the total intake of dietary components on the nation's health. Progress toward an analytically supported DSID is going forward on two parallel tracks. Presently, the NHANES label-based dietary supplement database is being updated and gradually the DSID at USDA will be populated using analytically verified values. The ultimate goal is to develop an analytically supported dietary supplement database which can be used in NHANES and other national surveys, by researchers and others in the scientific community. The assistance of partners across the federal government and the participation of the research community and industry are helping to make an analytically supported dietary supplement database a reality.

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