

Report

Consequences of changes in the Dietary Reference Intakes for nutrient databases

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Abstract

The purpose of this work is to describe how the release of the new Dietary Reference Intakes (DRIs) for the United States and Canada has necessitated changes in the US Department of Agriculture National Nutrient Database for Standard Reference (SR). New DRIs are reviewed to determine if the units for reporting vitamin intakes have changed and also to determine if the Tolerable Upper Intake Level (UL) is based on a different form of the vitamin than the Recommended Dietary Allowance (RDA). If the units have changed, decisions are made about how to change to the new units. If the form of the vitamin used for the UL is different from the form used for the RDA, consideration is given to reporting values for different forms of the vitamin. Since the release of the first new DRIs in 1997 several changes have been made to the SR. Folate is now reported in dietary folate equivalents as well as total folate. Folic acid is listed in the database because this is the form that is used to assess intake at the UL. Vitamin A is reported in retinol activity equivalents instead of retinol equivalents and reflects reduced bioactivity of the provitamin-A-carotenoids. Retinol is listed in the database because it is the form that is used to assess intake at the UL. Vitamin E is reported as mg of α -tocopherol instead of mg α -tocopherol equivalents. Milligrams of α -tocopherol in fortified foods were recalculated from IU values based on the form of the vitamin added, either RRR- α -tocopherol or *all rac*- α -tocopherol. Additional changes will need to be made to the database for niacin and vitamin B₁₂. The DRIs are the basis for determining the adequacy of diets. Therefore it is necessary for nutrient databases to conform to the DRIs to facilitate accurate monitoring of the adequacy of diets.

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1. Introduction

The Dietary Reference Intakes (DRIs) for the United States and Canada have been updated in a series of reports beginning in 1997 (Institute of Medicine (IOM), 1997, 1998, 2000, 2001, 2002, 2004). In addition to changes in recommended levels of intake, for some nutrients the units of expression and/or the definition of the nutrient has been changed. In some cases, the form of the nutrient used to determine the Tolerable Upper Intake Level (UL) is different from the form used to determine the Estimated Average Requirement (EAR) and the Recommended Dietary Allowance (RDA). The DRIs are the basis for determining the adequacy of diets. Therefore it is necessary

for nutrient databases to conform to the DRIs to facilitate accurate monitoring of the adequacy of diets of individuals as well as population groups. For almost all users of nutrient databases, it is crucial that variables are expressed in the same form and units as the most current dietary recommendations (Murphy, 2001). This paper describes the changes that have been made in the USDA National Nutrient Database for Standard Reference (SR) for folate, vitamin A and vitamin E in response to changes made to these nutrients in the DRIs. Changes will be made for vitamin B₁₂ and niacin.

Currently there are 6839 foods in SR, Release 17 (SR17) (US Department of Agriculture (USDA), 2004b). There are up to 125 nutrient and food component values for each food. All food items do not have complete nutrient profiles for all nutrients. More than 2600 of the foods are used by USDA's Food Surveys Research Group to create the Food

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and Nutrient Database for Dietary Surveys (FNDDS) (USDA, 2004a). It is required that these food items have complete nutrient profiles for the 61 food components or nutrients that are used to assess nutrient intake. If analytical data do not exist for any of the 61 nutrients in these foods, the staff of the Nutrient Data Laboratory (NDL) will calculate a nutrient value from available data. This is not necessarily done for all of the other foods in SR. For many brand name foods in the database there may only be data for the nutrients that are required for nutrition labeling. Therefore these foods would not be affected by the changes made to folate, vitamin A and vitamin E.

2. Folate

Folate was the first nutrient to be updated in SR in response to changes in the DRIs. In the past, the RDA for folate was expressed as μg of total folate. With the release of the DRI for B vitamins in 1998 (IOM, 1998), the EAR and the RDA for folate were expressed as μg dietary folate equivalents (DFE) (Table 1).

Folate is the generic term used to refer to the various chemical forms of this water-soluble vitamin. Folic acid occurs rarely in foods but is the form used to fortify foods and dietary supplements. Most naturally occurring folates, called food folate, are pterylpolyglutamates that have a side chain composed of multiple glutamic acid units joined in peptide linkages. DFEs take into account the greater bioavailability of synthetic folic acid compared to the naturally occurring food folates. To calculate DFEs one must know the micrograms of folic acid present as well as micrograms of food folate.

$$\mu\text{g DFE} = \mu\text{g food folate} + (\mu\text{g folic acid} \times 1.7).$$

The microbiological method that is generally used for folate analysis measures total folate; it does not distinguish between food folate and added folic acid. This is not a problem for unenriched foods. However, for enriched grain products that have folic acid added, a total folate value does not allow for the calculation of DFEs.

Several research laboratories have published HPLC methods that can separate folic acid and the most abundant folate forms naturally present in foods (Konings, 1999; Gregory, 1984; Doherty and Beecher, 2003). These laboratories do not analyze foods on a routine basis. Commercial laboratories that use HPLC are usually measuring folic acid, not the food folates.

Table 1
Units for reporting Recommended Dietary Allowances for the US

RDA	Folate	Vitamin A	Vitamin E
1968	mg	IU	IU
1974	μg	$\mu\text{g RE}$	IU
1980	μg	$\mu\text{g RE}$	mg α -TE
1989	μg	$\mu\text{g RE}$	mg α -TE
1998–2001	$\mu\text{g DFE}$	$\mu\text{g RAE}$	mg

Because of the problem with lack of methodology to separate the forms of folate, for foods containing added folic acid there are two ways used to calculate the different forms. If data exist for a food before it was fortified, this food folate value may be subtracted from the analytical value for total folate after fortification to estimate the folic acid value. The other way is to determine total folate by the tri-enzyme microbiological method and determine folic acid by the microbiological method without the addition of enzymes (Chun et al., 2006). Total folate value minus the folic acid value equals food folate. This is not ideal. Ideally there would be a robust collaborated HPLC method that measured folic acid and food folate separately. Currently the basis for Nutrition Labeling for folate is micrograms (Food and Drug Administration (FDA), 1993), not DFEs. Therefore there is little incentive to develop commercial methods to separate food folate and folic acid.

Another difference in the DRI for folate is that the UL is for folic acid from fortified food or supplements, exclusive of food folate. Because folic acid rarely occurs naturally in foods, the folic acid value in SR can be used for determining the amount of added folic acid contributing to the UL.

With the release of SR14 (USDA, 2002), values for food folate, folic acid, and folate in DFE were reported in addition to total folate. There are about 200 items in SR for which there are values for total folate but not for DFE. These are predominately brand name items. All food items used for the FNDDS will have data for all folate variables.

3. Vitamin A

Over the years, several different units have been used for expressing vitamin A activity (see Table 1). International units (IU) were first used to describe vitamin A activity and are still used as the basis for Nutrition Labeling (FDA, 1993). In the 1974 RDA (National Research Council (NRC), 1974) the unit for expressing vitamin A was changed to retinol equivalents (RE). Vitamin A activity was based on the equivalent weight of retinol. Considering conversion and absorption, the overall utilization of β -carotene was one-sixth that of retinol. α -carotene and cryptoxanthin have half the activity of β -carotene. In the latest DRI for vitamin A released in 2001, the vitamin A activity of β -carotene was recognized as being half of what was previously believed (IOM, 2001). The unit of expression was changed to μg retinol activity equivalents (RAE).

$$1 \text{ IU} = 0.3 \mu\text{g retinol or } 0.6 \mu\text{g } \beta\text{-carotene} \\ \text{or } 1.2 \mu\text{g other provitamin A carotenoids,}$$

$$1 \text{ RE} = 1 \mu\text{g retinol or } 6 \mu\text{g } \beta\text{-carotene} \\ \text{or } 12 \mu\text{g other provitamin A carotenoids,}$$

$$1 \text{ RAE} = 1 \mu\text{g retinol or } 12 \mu\text{g } \beta\text{-carotene} \\ \text{or } 24 \mu\text{g other provitamin A carotenoids.}$$

In SR15 (USDA, 2003a), values for vitamin A reported as RE were dropped and vitamin A activity was reported as RAE. IU values continue to be reported in the database because that is the unit used for the basis for Nutrition Labeling.

For some food groups the conversion to RAE is simple. If vitamin A activity is being contributed by only provitamin A carotenoids, the IU value can be divided by 20 or the RE value divided by 2 to get RAE. These food groups include plant foods such as fruits, vegetables, spices, nuts, seeds, and legumes. For food groups, such as meats, where all of the vitamin A is being contributed by retinol, the IU value can be divided by 3.33 and the RE value and RAE value are the same.

However, it is difficult to convert units for vitamin A when a food contains both provitamin A carotenoids and retinol. Table 2 shows the calculation from RE to RAE for cheddar cheese. For those foods that are used in food surveys there was an estimate of the amount of vitamin A contributed by carotene in RE (assumed to be β -carotene). Subtracting RE of carotene from total vitamin A RE gives an estimate of the amount of retinol in the food. The carotene value is divided by 2; retinol in RE equals retinol in RAEs. These values are added together and the result is 268 RAE.

In SR 16 (USDA, 2003b), analytical data for individual carotenoids, α -carotene, β -carotene, β -cryptoxanthin, lycopene, and lutein plus zeaxanthin, were added to the database. For foods used in the FNDDS, if analytical data were not available, values for the carotenoids were imputed. In the future, if the conversion factors for vitamin A activity change it will be relatively easy to make the adjustment to the new units using the retinol and individual carotenoid values.

There continue to be a few analytical methodology problems for vitamin A. HPLC methods exist for the separation of individual carotenoids but, other than a few scattered values in the literature, our main source of individual carotenoid data is analyses done for National Food and Nutrient Analysis Program. Also, at most commercial analytical laboratories the limit of quantitation (LOQ) for retinol is 15–30 μ g. With the recognition that carotenoid activity is less than previously thought, the amount of retinol in a food becomes more important and a lower LOQ is needed.

For vitamin A, the UL is based on preformed vitamin A (retinol), and the contribution from carotenoids is not considered. Retinol is a variable reported in the database and can be used to determine the contribution to the UL.

Table 2
Calculation of vitamin A in μ g RAE for cheddar cheese

Vitamin A	278 RE		
Carotene	-20 RE	$20 \text{ RE}/2 =$	10 RAE
Retinol	258 RE	$258 \text{ RE}/1 =$	+258 RAE
			268 RAE

There are about 600 items in the SR database where there is a vitamin A value in IU, but no value for RAE. These are primarily brand name items. Any items that are used for the FNDDS will have a value for RAE, either analytical or imputed if analytical carotenoid and retinol data are not available.

4. Vitamin E

Vitamin E has also had several different units for the expression of activity (see Table 1). In the 1980 RDA (NRC, 1989), units for expressing vitamin E were changed from IU to α -tocopherol equivalents (α -TE) taking into account the activity of not only α -tocopherol, but also β -, γ -, and δ -tocopherol and tocotrienols.

The 2000 RDA and EAR (IOM, 2000) for vitamin E are based only on RRR- α -tocopherol (the form found in food) and the 2R-stereoisomeric forms of α -tocopherol that occur in fortified foods and supplements. The other tocopherols and tocotrienols do not contribute toward meeting the vitamin E requirement.

Oils are the major contributors of vitamin E to the diet. In most foods, α -tocopherol is the predominant tocopherol, however in some oils, including the highly consumed corn and soybean oils, γ -tocopherol occurs in the largest amounts (see Fig. 1). For safflower oil that contains predominately α -tocopherol with only a small amount of γ -tocopherol, the difference between mg of α -tocopherol and mg α -TE is negligible, 34.1 mg versus 34.4 α -TEs. For soybean oil that contains a large amount of γ -tocopherol, the vitamin E value will be 8 mg α -tocopherol instead of 16 mg α -TE. The IOM report states for a typical American diet, intake in α -tocopherol is approximately equal to 80% of intake in α -TE. It is important to recognize that the figure of 80% applies to diets not individual foods.

There are 2 forms of vitamin E that may be added to foods. RRR- α -tocopherol, also called d- α -tocopherol, is the natural source of vitamin E. All-*rac*- α -tocopherol, or dl- α -tocopherol, is the synthetic form of vitamin E. For nutrition labeling, vitamin E values are reported as a percent of the Daily Value based on 30 IU (FDA, 1993). To

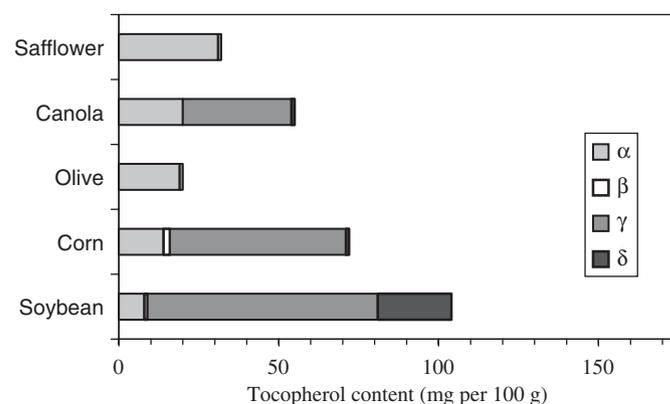


Fig. 1. Tocopherol content of various oils.

convert from IU to mg of α -tocopherol, there are different conversion factors used for the synthetic form of vitamin E versus the natural form:

$$\begin{aligned} \text{mg } \alpha\text{-tocopherol} &= \text{IU of all } \textit{rac}\text{-}\alpha\text{-tocopherol} \\ &\quad (\text{synthetic vitamin E}) \times 0.45 \\ &= \text{IU of RRR-}\alpha\text{-tocopherol} \\ &\quad (\text{natural vitamin E}) \times 0.67. \end{aligned}$$

Currently there are a limited number of foods fortified with vitamin E. The descriptions that appear on the ingredient label for breakfast cereals, infant formulas and a breakfast drink include: “vitamin E acetate,” or “ α -tocopherol acetate,” or “ α -tocopheryl acetate.” These descriptions do not tell whether natural or synthetic vitamin E was added. To determine which compound was added, one must contact the company. In general, synthetic vitamin E is the form being added to food. However, currently there are a few infant formulas and “nutrition/energy” bars that have natural vitamin E added. Some products are now putting “dl- α -tocopheryl acetate” or “d- α -tocopheryl acetate” or “natural vitamin E” on their ingredient list.

To further complicate matters for vitamin E, the UL has a different basis than the EAR and RDA. The UL is based on vitamin E as a supplement or food fortificant and all forms of supplemental α -tocopherol are used as the basis of establishing the UL. To compare intakes to the UL, IU of synthetic vitamin E are multiplied by 0.90 instead of the 0.45 used when converting for vitamin E activity for the RDA and EAR.

In SR16 (USDA, 2003b), values for α -TE were dropped and vitamin E values as milligrams of α -tocopherol were expanded, by analysis or imputation, to all food items used by the FNDDS. In the future there will be another variable included in the databases to address the added vitamin E.

5. Niacin and vitamin B₁₂

DRI changes for vitamin B₁₂ and niacin have not yet been addressed in the database.

The EAR, RDA and UL are all based on micrograms of vitamin B₁₂. However, there is an asterisk on the EAR and RDA that says, “For adults 51 years and older it is advisable for most of this amount to be obtained by consuming foods fortified with vitamin B₁₂ or a B₁₂ containing supplement.” (IOM, 1998) Another variable should be added to the database for micrograms of added vitamin B₁₂. The foods containing added vitamin B₁₂ are similar to those with added vitamin E: breakfast cereals, infant formulas, and nutrition/energy bars, as well as, foods designed for vegetarian diets.

For niacin, the EAR and RDA are based on niacin equivalents. UL is based on niacin taken as a supplement or food fortificant. The RDA for niacin has been based on niacin equivalents for many years, but in the database preformed niacin is reported. This is another variable that

may be added to the database, but at this time it is not a high priority. The UL being based on niacin as a food fortificant presents another problem. Unlike added vitamin E and B₁₂, added niacin is distributed in many foods because of the use of enriched grain products as ingredients. Analytical methods for niacin do not distinguish between the natural and added forms. Therefore, estimating the amount of added niacin will require estimating the amount of added and natural niacin in enriched grain products, such as enriched flour, cornmeal, rice, and noodles and then using recipes and formulations to determine the amount of natural and added niacin in all the food products that contain them. Adding the variable for added niacin will require calculations for an extensive list of foods.

6. Conclusion

Nutrient databases must reflect the changes made in DRIs. Adding variables to the database in response to changes in units, as well as using different forms of the nutrient for the UL, presents several challenges:

- methods may not exist to distinguish added forms of the nutrient from natural forms, e.g., niacin,
- research methods may exist to distinguish among the forms of the nutrient, but the methods have not been tested collaboratively and may not be used by commercial laboratories, e.g., folate,
- ingredient labeling may not be specific enough to identify the form of the nutrient added, e.g., vitamin E.

The DRI publication “Guiding Principles for Nutrition Labeling and Fortification” (IOM, 2003) proposes changing the units used for Nutrition Labeling for vitamin A, vitamin E, and folate to those used for the DRI. This would be an advantageous change for nutrient databases.

References

- Chun, J., Martin, J.A., Chen, L., Lee, J., Ye, L., Eitenmiller, R.R., 2006. A differential assay of folic acid and total folate in foods containing enriched cereal-grain products to calculate μg dietary folate equivalents (μg DFE). *Journal of Food Composition and Analysis* 19, 182–187.
- Doherty, R.F., Beecher, G.R., 2003. A method for the analysis of natural and synthetic folate in foods. *Journal of Agriculture and Food Chemistry* 51, 354–361.
- Food and Drug Administration (FDA), 1993. Food labeling: reference daily intakes and reference daily values. Part IV, Final rule. *Federal Register* 58, 2206–2228.
- Gregory, J.F., 1984. Determination of folacin in foods and other biological materials. *Journal of Association of Official Analytical Chemists* 67, 1015–1019.
- Institute of Medicine (IOM), 1997. *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D and Fluoride*. National Academy Press, Washington, DC.
- Institute of Medicine (IOM), 1998. *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B₆, Folate, Vitamin B₁₂,*

- Pantothenic Acid, Biotin, and Choline. National Academy Press, Washington, DC.
- Institute of Medicine (IOM), 2000. Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids. National Academy Press, Washington, DC.
- Institute of Medicine (IOM), 2001. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. National Academy Press, Washington, DC.
- Institute of Medicine (IOM), 2002. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. National Academy Press, Washington, DC.
- Institute of Medicine (IOM), 2003. Dietary Reference Intakes Guiding Principles for Nutrition Labeling and Fortification. National Academy Press, Washington, DC.
- Institute of Medicine (IOM), 2004. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. National Academy Press, Washington, DC.
- Konings, E.J.M., 1999. A validated liquid chromatographic method for determining folates in vegetables, milk powder, liver, and flour. *Journal of AOAC International* 82, 119–127.
- Murphy, S.P., 2001. Changes in dietary guidance: implications for Food and Nutrient Databases. *Journal of Food Composition and Analysis* 14, 269–278.
- National Research Council (NRC), 1989. Recommended Dietary Allowances, 10th ed. National Academy Press, Washington, DC.
- National Research Council (NRC), 1974. Recommended Dietary Allowances, Eighth ed. National Academy Press, Washington, DC.
- US Department of Agriculture (USDA), Agricultural Research Service, 2002. USDA National Nutrient Database for Standard Reference, Release 14. US CD-ROM Stock Number: 001-000-04699-3. Government Printing Office, Washington, DC.
- US Department of Agriculture (USDA), Agricultural Research Service, 2003a. USDA National Nutrient Database for Standard Reference, Release 15. US CD-ROM Stock Number: 001-000-04708-6. Government Printing Offices, Washington, DC.
- US Department of Agriculture (USDA), Agricultural Research Service, 2003b. USDA Nutrient Database for Standard Reference, Release 16. Nutrient Data Laboratory Home Page, <http://www.nal.usda.gov/fnic/foodcomp/Data/SR16/sr16.html>.
- US Department of Agriculture (USDA), Agricultural Research Service, 2004a. USDA Food and Nutrient Database for Dietary Studies, 1.0. Food Surveys Research Group Home Page, <http://www.barc.usda.gov/bhnrc/foodsurvey/home.htm>.
- US Department of Agriculture (USDA), Agricultural Research Service, 2004b. USDA Nutrient Database for Standard Reference, Release 17. Nutrient Data Laboratory Home Page, <http://www.nal.usda.gov/fnic/foodcomp/Data/SR17/sr17.html>.