VARIABILITY OF MINERALS IN FOODS

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ABSTRACT

Dietary guidance to the public stresses foods or food groups as specific sources of minerals such as calcium in dairy products, iron in meats and legumes, and potassium in oranges and bananas. Dietary guidance also identifies foods that are low in some minerals (such as sodium, potassium, calcium, cooper, and iron) for patients with specific disease conditions. However, the levels of minerals and other substances in foods vary because of inherent (e.g., age and species of plants and animals), environmental (e.g., animal diets, climate, soil type), and processing (e.g., fortification, food additives, cooking method) factors. the distributions of minerals in foods are not generally Gausian, but vary based on unique features of both the is affected by levels of salt added during processing and may vary from brand to brand of t he same foods, while sodium in unprocessed milk, fruits, vegetables, nuts, and meats tends to be low and stable. Iodine in milk is affected by feed supplements of iodine, the use of iodophor sanitizing solutions by the dairy industry, and the use of the iodine-contained red food dye, erythrosine. Iron and zinc in breakfast cereals are greatly affected by levels of fortification. Levels of iron, copper, and zinc in some shellfish and in liver are affected by levels of these minerals in animal diets and by the age of the animals. Some acidic foods (like tomatoes and sauerkraut) may leach minerals from metal containers with prolonged contact. formulated products (entrees, desserts, condiments) vary in their ingredients from brand to brand, and thus have different mineral composition. although it is difficult to identify all the causes of mineral variation in finished food products, it is useful to have some measure of variation (such as standard deviation or coefficient of variation) with published mean values to determine the reliability of the data.

INTRODUCTION

When dietitians and nutritionists use food composition data to plan and evaluate diets or to assist patients and clients with modified diets, they usually search for mean values (values that represent a central tendency or typical concentration) of nutrients in foods. The presence of a measure of nutrient variability, such as a standard deviation (SD) or coefficient of variation (CV), is useful to help nutrition professionals assess the reliability of mean values and provide practical dietary advice and guidance. High variability of nutrients in foods may limit the use of mean values in certain situations.

Nutrient variability is of particular importance if it occurs in foods that are relied upon as the major sources of a nutrient (because of either high concentrations or frequent use) for a specific population. If mean nutrient values in food composition tables are unreliable because of high variation, dietary intakes of nutrients calculated from such values may be unreliable. Nutrient variability is also of concern for patients on restricted or modified diets who are trying to limit or increase their intake of a nutrient. For example, an individual may be consuming an abundance of foods thought to be Asodium free@ and indulging in one or two Alow sodium@ foods that are within their dietary limits. If the variability of sodium in foods is large and it tends to err on the high side, then the patient may be ingesting more sodium than dietary calculations (based on mean values) suggest.

Causes of Mineral Variation in Foods

The causes of mineral variation in foods include inherent, environmental, and processing factors. Inherent factors refer to age, maturity, genus, species, variety, and cultivar. Environmental factors include feed type and composition; soil and water composition; climate-related factors (rainfall, temperature, humidity, amount of sunlight); use of pesticides, and use of medications. Examples of processing factors include storage time and temperature; preservation methods (freezing, drying, canning); packing media; contact with containers (plastic, paperboard, glass, metal, wax); cooking methods (boiling, frying, roasting); substances added or removed; and use of food additives.

Secondary sources of variability such as the sampling design used to collect foods for analysis, sample preparation in the laboratory, analytical methods, and statistical treatment of the data (e.g., handling of outliers) affect the values reported for nutrients in foods, but do not affect the actual levels of nutrients in foods. These secondary factors may account for differences in results between laboratories when chemists analyze what appears to be the Asame@ product for minerals. Analytical variability is measurable, and, with the use of standard reference materials is controllable.

Although it is difficult to identify all the causes of mineral variation in finished food products, it is useful to have some measure of variation (such as SD or CV) with published mean values to determine the reliability of the data. Dietary guidance to the public stresses foods or food groups as specific sources of minerals such as calcium in dairy products, iron in meats and legumes, and potassium in oranges and bananas. Dietary guidance also indicates which foods are low in sodium for patients with hypertension, and for some disease conditions, patients are given advice about foods low in potassium, calcium, copper, and iron. This paper presents some information on the variability of minerals in core foods of the U.S. food supply (1-5).

METHODS AND MATERIALS

Between 1982 and 1991, there were 37 analysis of the levels of 11 minerals in 234 core foods of the U.S. food supply (1-3). Between 1991 and 1995, there were 13 individual measures of 10 minerals in 260 foods (4-5). These foods were collected by inspectors of the Food and Drug Administration District Offices, and they were analyzed by chemists at the Kansas City District Office Laboratory. The foods were clearly identified for collection purposes, but brand names for industry-prepared and restaurant-prepared foods were not specified. Thus, the results for industry and restaurant foods represent a mixture of different brand-name products. Analytical variation was minimized by the use of standard quality control measures (chemical standards, duplicate analysis, standard reference materials, fortified samples) and the consistent use of the same laboratory, sample preparations, analytical methods, chemists, and technicians. Information related to food collections, sample preparations, analytical methods, detection limits, and quality control are found in references 1 through 5.

RESULTS AND DISCUSSION

Space limitations prevent presentation of all the data and discussion of the many issues concerning mineral variability. This paper focuses on the variation of minerals in foods considered to be sources of the minerals (i.e., foods that provide at least 10% of the Daily Value (DV) per serving portion) and on the distributions of several minerals in selected foods. DVS are used for nutrition labeling and are the suggested daily intakes for nutrients based on an energy intake of 2,000 kilocalories per day.

Sources of Minerals

The number of foods providing at least 10% DV per serving portion, based on the data from 1982 to 1991 (1-3), are shown in Table 1. It appears that sodium, phosphorus, and iodine are more generally distributed in the core foods of the US food supply; that zinc, potassium, manganese, iron, and selenium are more moderately distributed; and that copper, magnesium, and calcium are less well distributed. Recommended intakes for nutrients that are more widely distributed tend to be easier to meet because there is a greater probability of including the sources in the diet. Results of dietary assessments show that some population subgroups do not meet daily requirements for calcium, magnesium, and copper, but requirements for phosphorus and sodium are almost always met. Even though iron appears to have a moderate distribution, it is still difficult for some groups to meet recommended dietary allowances because requirements are high relative to energy needs, e.g., women of child-bearing age have an iron requirement of 18 mg/day and an average caloric intake of only 1,500 to 2,000 kilocalories.

Table 1. Number of Foods Providing at Least 10% DV for 11 Minerals Per Serving Portion*

Mineral	Number of Foods	(Percent)	DV (mg)
Iodine	81	(35%)	0.150
Phosphorus	61	(26%)	1000
Sodium	58	(25%)	2400
Selenium	48	(21%)	0.070
Iron	43	(18%)	15
Manganese	40	(17%)	3.5
Potassium	31	(13%)	3500
Zinc	28	(12%)	15
Calcium	20	(9%)	1000
Magnesium	19	(8%)	400
Copper	16	(7%)	2

*Based on results of 36 analysis of 234 foods (1-3).

Coefficients of Variation (CVs)

The average and ranges of CVs for foods containing at least 10% DV per serving portion (in increasing order of average values) are shown in Table 2. Variability is important because several of these minerals are considered to be of public health concern. For example, sodium-restricted diets may be prescribed for hypertension or kidney disease; increased intakes of potassium from food sources are recommended with some diuretic medications. There is increasing concern about the ratio of calcium and phosphorus in the diet, and evidence that average intakes of iron, calcium, magnesium, zinc, and copper may be low for some segments of the population. In addition, certain disease states require dietary restriction of potassium, iron, or copper.

It is difficult to identify the specific causes of nutrient variability for prepared foods because the inherent, environmental, processing, cooking, and analytical variables are compounded. This is especially true for mixed dishes which contain varying levels of ingredients, each with its own causes of nutrient variability. As indicated in Table 2, levels of sodium were more variable than levels of phosphorus, potassium, or magnesium as indicated by the higher average CVs and wider ranges of CVs for sodium. Sodium variability in processed foods is due primarily to different levels of salt added by different manufacturers, while phosphorus, potassium, and magnesium variabilities are more related to inherent causes (e.g., genetics) and processing effects (e.g., use of food additives). Variability of some minerals (e.g., iron and zinc in breakfast cereals) may reflect different fortification levels. Selenium variability in plant foods is probably related to the selenium content of the soil in which the plants were grown. Some geographic areas are known to have high or low selenium content. Selenium variability in animal foods is related to the selenium content of the plants on which they feed. Iodine variability in foods is largely due to the presence of iodine-containing food additives (both direct and indirect). Because of their high variability, data on the iodine content of foods should be used with caution.

Table 2. Average and Ranges of CVS for Foods Containing at Least 10% DV Per Serving Portion*

Mineral	CV Mean	CV (Range)
Phosphorus	15%	(6-28%)
Potassium	16%	(7-27%)
Magnesium	17%	(6-37%)
Sodium	21%	(6-78%)
Calcium	22%	(13-36%)
Zinc	22%	(10-50%)
Copper	24%	(13-49%)
Iron	28%	(12-90%)
Manganese	28%	(11-66%)
Selenium	37%	(19-100%)
Iodine	158%	(35-416%)

*Based on 36 analysis of 234 foods (1-3).

<u>Concentration Versus Variability</u>

A few examples of mineral concentration versus variability are provided for sodium, calcium, and iron (1-3). Foods with the highest concentrations of sodium per serving portion and with the most variable concentrations of sodium among the 234 core foods are shown in Tables 3 and 4, respectively. The six foods with the highest concentrations of sodium (Table 3) provided from 36 to 68% DV of this mineral, and the CVs for these foods ranged from 10 to 27%, i.e., these high sources were relatively stable and reliable. The six foods with the most variable concentrations (and thus less reliable sources) of sodium contained 11 to 34% DV and had CVs ranging from 34 to 78%.

Table 3. Highest Sources of Sodium+

Food	Sodium (mg/serving)	CV(%)	%DV*
Fried chicken frozen dinner	1626	19	68
Chili con carne, canned	1112	10	46
Ham, cured	1088	13	45
Chicken pot pie, frozen	1058	15	44
Beef bouillon, canned	890	27	37
Chicken noodle soup, canned	853	22	36

+Based on analysis of 234 foods (1).
*DV = 2,400 mg.

The six foods with the highest concentrations of calcium per serving (Table 5) provided 28 to 34% DV and had CVs of 13 to 22%. These foods were dairy products or contained dairy products and appear to be stable and reliable sources of calcium. The six foods most variable in calcium content (Table 6) provided 11 to 23% DV and had CVs of 27 to 37%. These foods included spinach, collards, shrimp, and three foods containing some dairy products. The highest CV was only 37% which indicates that these sources of calcium are also relatively stable.

Table 4. Most Variable Sources of Sodium+

Food	Sodium(mg/serving)	CV(%)	%DV*
Italian salad dressing	344	78	14

Beef and vegetable stew, homemade	532	54	22
Whole wheat bread	300	52	13
Potatoes, scalloped	260	38	11
Spaghetti w/ meat sauce, homemade	397	38	17
Vegetable beef soup, canned	805	34	34

+Based on analysis of 234 foods (1).
*DV=2,400 mg.

Table 5. Highest Sources of Calcium+

Food	Calcium (mg/serving)	CV(%)	%DV*
Lowfat yogurt, plain	341	15	34
Milk shake, chocolate	303	13	30
Cheese pizza, frozen	285	21	29
Skim milk	279	17	28
Lowfat milk	279	22	28
Buttermilk	277	13	28

+Based on analysis of 234 foods (2).
*DV=1,000 mg.

Table 6. Most Variable Sources of Calcium+

Food	Calcium (mg/serving)	CV(%)	%DV*
Chicken noodle casserole, homemade	206	37	21
Spinach, canned	120	36	12
Tomato soup, canned	126	35	13
Shrimp, breaded, fried	109	33	11
Collards, boiled	116	32	12
Lasagna, homemade	234	27	23

+Based on analysis of 234 foods (2).
+DV=1,000 mg.

Tables 7 and 8 present the foods with the highest and most variable concentrations, respectively, of iron per serving. The percent DVs for the highest sources (Table 7) ranged from 25 to 107%, and the CVs for these foods ranged from 12 to 43%. The four highest sources were all breakfast cereals, and the variability of iron in these products is probably related to the presence of iron fortification and the levels of fortification. The other two high sources were beef/calf liver and chili con carne (which contains both meat and beans as sources of iron). The most variable sources of iron (Table 8) contained 11 to 24% DV and had CVs ranging from 44 to 90%. Three of these foods were breakfast cereals, and their iron variability was probably related to the presence and levels of iron fortification. Also included in this group with high variability were spinach, baked potato, and red beans.

Table 7. Highest Sources of Iron+

Food	Iron (mg/serving)	CV(%)	%DV*
Raisin bran cereal	19.20	43	107
Farina	10.51	41	58
Oat ring cereal	7.06	34	39
Fruit-flavored cereal	6.19	20	34
Beef/calf liver, fried	5.78	18	32

Chili con carne, canned	4.44	12	25

+Based on analysis of 234 foods (3).
*DV=18 mg.

Table 8. Most Variable Sources of Iron+

Food	Iron (mg/serving)	CV(%)	%DV*
Corn grits	2.90	90	16
Spinach, boiled	4.23	74	24
Granola w/ raisins	2.57	62	14
Potato, baked	1.90	50	11
Red beans, boiled	1.95	46	11
Oatmeal, cooked	2.25	44	13

+Based on analysis of 234 foods (3).
*DV=18 mg.

Distributions of Minerals

The distributions of minerals in foods are not generally Gausian (i.e., normal), but vary based both on unique features of the foods and on potential sources of minerals for each food. For example, sodium in processed foods is affected by levels of salt, soy sauce, garlic salt, and other sodium-containing additives added during processing and may vary from brand to brand of the same food, while sodium in unprocessed (and unsalted) foods such as milk, fruits, vegetables, nuts, and meats tends to be low and stable. Iodine in milk is affected by feed supplements of iodine fed to cattle (especially during the winter when cattle are not grazing outdoors) and the use of iodophor sanitizing solutions by the dairy industry. Previous work (6-7) has shown that the iodine content of whole milk varies from 2 to 94 µg per 100 grams. The iodine content of some foods may also be altered by the use of iodized salt as one of the ingredients. Iron and zinc in breakfast cereals are greatly affected by levels of fortification. Levels of iron, copper, and zinc in some shellfish and in liver are affected by levels of these minerals in the animal diets (or surrounding waters) and by the age of the animals. Some acidic foods (like tomatoes and sauerkraut) may leach minerals from metal containers with prolonged contact. Formulated products (entrees, desserts, condiments) vary in their ingredients from brand to brand, and thus have different mineral composition. Levels of phosphorus in processed foods are affected by the use of phosphate-containing food additives.

Several results from analysis completed in 1991-95 (4,5) are presented in Table 9 to illustrate the variability of minerals in several basic foods. Milk is a traditional, basic food which is considered a dependable and consistent source of calcium. Although the magnesium and zinc content of milk is stable, the calcium varies by fourfold. (Milk is not a source of iron or copper.)

Table 9. Mean and Range of Selected Minerals in Several Foods, 1991-95*

Food	Calcium Mean Range	Magnesium Mean Range	Iron Mean Range	Zinc Mean Range	Copper Mean Range
	(mg/100 g)				
Whole milk	95 26-116	10.1 6.9-11.6	0.01 0.00-0.07	0.36 0.25-0.41	.001 .000-.006
Beef/calf liver fried	5 4-6	23.1 20.8-25.1	6.19 4.55-7.98	5.45 3.35-6.30	10.56 4.77-20.8

Shrimp, boiled	122 34-219	43.8 16.7-88.0	1.79 0.18-5.19	1.62 0.72-3.46	.217 .090-.354
Spinach, fresh/ frozen, boiled	95 54-149	42.5 21.9-64.1	2.37 1.08-6.40	0.45 0.26-0.66	.080 .055-.164
Collards, fresh/ frozen, boiled	132 52-199	21.6 11.8-35.2	0.82 0.51-1.03	0.23 0.10-0.45	.060 .019-.188
Cheese pizza, regular crust, from pizza carry-out	224 174-303	27.9 23.5-31.4	2.34 1.66-3.01	1.71 1.50-1.97	.112 .092-.138
Beef chow mein, from Chinese carry-out	18 11-30	12.3 9.1-17.8	1.23 0.68-2.56	1.11 0.85-1.48	.054 .000-.079

*Based on 13 analysis (4,5).

Beef or calf liver is a highly nutritious food, although it is not commonly liked or consumed frequently. Liver is a storage organ with variable levels of minerals. It appears that calcium is not stored here (levels are low and stable). The magnesium concentration is stable, and the concentrations of iron, zinc, and copper are variable with twofold variations for iron and zinc and fourfold variation for copper.

Shrimp, a shellfish that accumulates some minerals, is a nutritious, although somewhat expensive, food that is liked and commonly consumed. Variations of six-fold for calcium, fivefold for magnesium, 29-fold for iron, fivefold for zinc, and fourfold for copper occur in this food.

Spinach and collards are both regarded as highly nutritious. Leaves are the metabolically active parts of plants which contain magnesium as part of the chlorophyll molecule and other minerals as enzyme activators. Spinach and collards both exhibit “natural” variability in mineral content. Spinach shows a threefold variation in calcium, magnesium, zinc, and copper and a six-fold variation in iron. Collards show a fourfold variation in calcium and zinc, three-fold variation in magnesium, twofold variation in iron, and tenfold variation in copper content.

The following are additional examples of mineral variation from the 1991-95 data (4,5). The iron content of raisin bran cereal ranged from 13.2 to 55.0 mg/100g due to different levels of fortification. This is a fourfold variation in a food regarded as an excellent source of iron. Fruit-flavored, sweetened cereal exhibited a threefold variation in iron content (8.00-24.1 mg/100 g) and a twofold variation in zinc (8.74-21.1 mg/100g) concentration, which are probably due to different levels of fortification.

The sodium content of fast-food french fries showed a tenfold variation in sodium content (67-640 mg/100 g) likely due to different restaurant practices in salting this product. The six-fold variation in the iron content of tomato juice (.19-1.18 mg/100 g) and twofold variation in the iron content of sauerkraut (.29-.71 mg/100 g) may illustrate potential leaching of minerals by acidic foods from metal containers or utensils during processing or packaging. The iron content of homemade cornbread varied from 0.16 to 3.60 mg/100 g illustrating that a mixed dish made repeatedly with the same recipe may differ in mineral content probably due to the different nutrient content of the ingredients.

The mineral content of cheese pizza from carry-out pizza restaurants showed stability, while the mineral content of carry-out beef chow mein from Chinese restaurants varied most likely due to different ratios of meat to other ingredients in the product obtained from different restaurants (Table 9).

CONCLUSIONS

Database compilers should consider the variability of minerals in foods before determining if means, medians, or modes are the most representative values for a database. Frequency distributions are useful for assessing the variability of nutrients in foods and may assist database compilers in identifying outliers and deriving representative values. Values with high variability should be used with caution when assessing nutrient intakes or providing dietary guidance. Reliance on foods as nutrient sources could be misleading if the nutrient levels are highly variable. Dietitians and nutritionists who use food composition data to assess individual diets or provide dietary guidance to patients should consider nutrient variability to effectively meet the objectives of their intended use of the data.

Database users who are unfamiliar with the variability of food composition data may express dismay when they discover the less than perfect presence (i.e., high variability and low reliability) of some minerals in some foods. Although analytical variation can and should be monitored, mineral variability due to inherent, environmental, or processing factors cannot be controlled, and needs to be measured and expressed (as SD or CV) with published food composition data. When high variability is discovered in food sources of minerals (e.g., those containing at least 10% DV of a mineral), caution in dietary guidance messages to the public may be warranted.

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