JOURNAL OF FOOD COMPOSITION AND ANALYSIS 2, 298–316 (1989)

The Copper Content of Foods Based on a Critical Evaluation of Published Analytical Data[1]

DEBORAH G. LURIE, JOANNE M. HOLDEN,[2] ANITA SCHUBERT, WAYNE R. WOLF, AND NANCY J. MILLER-IHLI

Nutrient Composition Laboratory, Beltsville Human Nutrition Research Center, USDA, ARS, Building 161, BARC-East, Beltsville, Maryland 20705, U.S.A.

Received November 17, 1988, and in revised form January 9, 1990

Increasing interest in the copper (Cu) intake of Americans has generated a need for the compilation, evaluation, and improvement of data for Cu in foods. In order to estimate dietary Cu intake, accurate and precise Cu values for foods are needed. A system of criteria developed to evaluate the quality of published selenium data has been adapted to evaluate analytical data for Cu in foods. Mean Cu values for each food were calculated from the evaluated data and combined with USDA frequency of consumption data, resulting in a list of 218 major contributors of dietary Cu. The richest sources of Cu are legumes, wheat bran cereals, organ meats, shellfish, and grains. Confidence codes, indicators of the relative degree of confidence the user of the data can have in that mean value, were included. More than half of the mean values for the foods listed are of limited quality or result from a limited quantity of data, indicating a need for improvement in food Cu data. This proposed dynamic system for the compilation and evaluation of Cu data can be used to generate Cu data bases for specific purposes, provide a ranked list of foods which are significant contributors of that nutrient, and establish priorities for further improvements in the data base.

INTRODUCTION

Copper (Cu), an essential nutrient for humans, is required for numerous physiological and biochemical functions (1–3). The recognition of Cu's role as an essential nutrient prompted the establishment of an estimated safe and adequate range of recommended daily intake of 2–3 mg for healthy adult individuals (4). The majority of Cu available to the body comes from dietary intake, including drinking water (5). Studies of the intake of Cu in the United States have indicated lower levels than previously believed (3, 6–8). Recently, studies of the biochemical effects of diets containing low levels of Cu in conjunction with varying levels of other dietary components, including fructose, have demonstrated possible deleterious effects on various biochemical parameters associated with the development of cardiovascular disease (9–11).

Results of these studies have led to increased interest in the dietary intake of Cu by the U.S. population, generating a need for the compilation, evaluation, and improvement of data for foods which are significant contributors of Cu in the diet. A food can be considered to be a significant contributor if it contains a high concentration

[1] Supported in part by National Heart, Lung, and Blood Institute Reimbursable Agreement YOL HV 60041-00.

[2] To whom correspondence and reprint requests should be addressed.

0889-1575/89 $3.00

of Cu or if it is a food with a moderate to low level of concentration but is frequently consumed in amounts large enough to contribute a substantial amount of Cu to the diet. Thus, we have undertaken an effort to compile published Cu data for foods, to evaluate the relative quality of these data, and to identify significant contributors of Cu to the diet.

METHODS

The first step in the process was to develop a system for evaluating published analytical data for Cu in foods and was based on one previously developed for the evaluation of selenium (Se) data. That system encompassed five general categories relative to generating nutrient composition data and included number of samples, analytical method, sample handling, sampling plan, and analytical quality control (12). While these categories were determined to be suitable, the specific criteria within certain categories (analytical method and quality control) required some modification to accommodate the evaluation of Cu data. The Se evaluation system included a rating scale, ranging from 0–3, for each category and specific criteria for each rating within each category. The basis for defining specific criteria for Cu within these two categories was provided by a knowledge of acceptable methodology, including quality control for Cu analysis. While a specific analytical method had been specified for Se, the mention of a specific method for Cu was deleted in order to reflect the acceptability of several analytical methods. It should be noted that, as with the Se evaluation, the evaluation of Cu data placed emphasis on the use of a validated method monitored by quality control materials with measurements above the quantitation limits. A recent survey of commercially available biological materials indicated that there are more than 20 reference materials certified for Cu (13). The appropriateness of the selected materials with regard to sample matrix and Cu level would need to be considered in order to determine a rating for the quality control category. The Se criteria for number of samples, sample handling, and sampling plan were appropriate for Cu without modification. Table 1 provides the detailed description of criteria within categories for the Cu evaluation system. For further details, the reader is referred to Holden *et al.* (12).

Once the criteria within categories were established for Cu data, mean values for individual foods from published reports were evaluated. More than 225 papers including methodology and composition papers were collected from the literature. Consideration was limited to papers published since 1960 which reported Cu levels in foods consumed by the U.S. population. Within each reference, data for individual foods were rated according to the criteria in Table 1. Generally, the ratings for the five categories were averaged to obtain a quality index (QI), an indicator of the quality of an individual mean for a single food (Table 2). When the rating for analytical method was 0 or when any three other ratings were 0's, the QI for the corresponding mean became 0. The QI for an individual food mean was used to determine the acceptability of that value for inclusion in the grand mean for a food. Mean values expressed on a wet weight basis for food items with a QI of one or greater were considered acceptable. Dry weight values which were accompanied by moisture values were converted to the wet weight basis and considered for inclusion in the grand mean. Those dry weight values not accompanied by moisture values were judged unacceptable for this purpose.

TABLE 1

DATA QUALITY CRITERIA

Categories	Rating Scale: 3	2	1	0
Sample Number	>10; SD, SE, or raw data reported.	3 to 10.	1–2 explicitly stated or not specified.	---
Analytical Method	Method documented by a complete published write-up with validation studies for foods analyzed, including use of appropriate SRM where available with results within ±5% of the acceptable range based on the mean value; 95–105% recoveries on food similar to sample analyzed in same or other paper; Cu concentration above quantitation limit of the method.	Some documentation incomplete validation studies for foods analyzed; must include 90–110% recoveries on food similar to sample analyzed (or good recovery but no statistics given), and/or use of other method on sample with good agreement (within 10%).	Partially described; 80–120% recoveries on foods similar to sample or use of comparison method or recoveries on food only somewhat related to sample (animal/plant).	No documentation of method, no ref. or inaccessible ref. given, no validation studies, or recoveries <80% or >120%; or poor agreement (>10%) of test method with comparison method on same sample.
Sample Handling	Complete documentation of procedures including validation of homogenization method, details of food preparation and storage and moisture changes monitored.	Pertinent procedures documented, seem reasonable, but some details not reported.	Only edible portion analyzed.	Totally inappropriate procedures or no documentation of criteria pertinent to food analyzed.
Sampling Plan	Multiple geographical sampling with complete description; sample is representative of brands/varieties commonly consumed or commercially used.	One or two geographic areas sampled; sample is representative.	Sample representative of small % of U.S. and/or origin not clear.	Not described or sample not representative.
Analytical Quality Control	Optimum accuracy and precision of method monitored and indicated explicitly by data.	Documentation of assessment of both accuracy and precision of method; acceptable accuracy and precision.	Some description of minimally acceptable accuracy and precision of method.	No documentation of accuracy and/or precision.

TABLE 2

WORKSHEET FOR APPLESAUCE
(INCLUDES STEWED APPLE)

				Data Quality Criteria Ratings						
		No. of Samples		Analytical	Sample	Sampling	Analytical Quality	Quality[c]	Cu	
Description[a]	Ref.[b]	Actual No.	Rating	Method	Handling	Plan	Control	Index	Values	Comments
									μg/100gm	
applesauce,cnd,drn.	L	1	1	1	2	1	0	1.0	10	duplicates
stewed apple	M	1	1	3	0	0	2	1.2	29	10 analyses, range 23-33
applesauce,cnd,swtn.	N	8	2	1	2	3	1	1.8	28±7[d]	
strained applesauce	O	1	1	3	1	0	0	1.0	3±7	quadruplets
strained applesauce	P	1	1	1	1	0	0	0.6[e]	637	

Summary: Quality Sum[f]=5; Confidence Code[g]=B; Grand mean[h]=17.5μg/gm; Min.-max.[i]=3-29μg/100gm

[a]Authors' unique descriptions of foods analyzed.
[b]While data, including ratings, are authentic the references are coded.
[c]A Quality Index ≥1.0 is required for a datum to be considered acceptable.
[d]Mean ± standard deviation for a single reference.
[e]Unacceptable study.
[f]The sum of the quality indices for the various acceptable references for a food; it serves as the basis of the confidence code
[g]The confidence code is derived from the Quality Sum.
[h]The grand mean is calculated from the acceptable means.
[i]Range of means.

TABLE 3

ASSIGNMENT AND MEANING OF CONFIDENCE CODES

QUALITY[a] SUM	CONFIDENCE CODE	MEANING OF CONFIDENCE CODE
≥6.0	A	The user can have considerable confidence in this value. Two perfect studies would merit a Confidence Code of "A".
3.4 to <6.0	B	The user can have a moderate amount of confidence in this value.
1.0 to <3.4	C	The user can have less confidence in this value due to limited quantity and/or quality of data. A single highly rated study would receive a Confidence Code of "C".

[a]See footnote f, Table 2.

Initially, published analytical data for similar foods were grouped to facilitate the process of compiling data from various sources. After all of the data were evaluated, the individual mean values were more carefully aggregated according to the similarity of the food descriptions, the availability of Cu data for specific forms of the food, e.g., cooked, raw, frozen, or canned, and the proximity of their Cu concentrations. In the case of canned and cooked green beans, the analytical mean values compiled from various references were similar, as expected, since the products themselves are similar. As a result, the means for cooked and canned forms of this food were aggregated. Due to the lack of reported individual values for most studies and/or indicators of variability about the mean, the various acceptable mean values for a specific food item/aggregate were averaged to obtain a grand mean. No attempt was made to weight the individual means that contributed to the grand mean.

Similarly, the various QIs for individual acceptable means within a food aggregate were summed to yield the quality sum (QS) which served as the basis for the assignment of a confidence code (Table 3). The confidence code, either A, B, or C, is an indicator of the relative degree of confidence the user of the data can have in a grand mean value for a food. A confidence code of A indicates considerable confidence, while B indicates moderate confidence, and C indicates limited confidence due to limited data quantity and/or quality. A single mean for a food resulting from one highly rated study can receive only a C confidence code. The code serves as a flag to the user of the data and indicates the need for individual consideration with regard to the intended use. In Table 4, the confidence code is included with the grand mean and food description so that the user can easily determine the relative quality of each mean and the suitability of such data for a specific use.

The third aspect of the project objective, the determination of significant Cu contributors, required the use of food consumption data obtained from the Nationwide

TABLE 4

Copper Content of Selected Foods

FOOD OR AGGREGATE	GRAND MEAN (μg/100g)	MIN	MAX[a]	NO. OF MEANS USED[b]	CONFIDENCE CODE[c]	TOTAL REFS. EVAL.[d]	ACCEPTABLE REFERENCES
BEEF, LAMB, PORK, AND VEAL							
beef, ckd	104	80	136	6	A	3	6, 40, 42
beef, raw	58	12	92	12	A	6	19, 40, 96, 103
pork, ham, ckd/cnd	121	57	210	15	A	2	6, 90
pork, raw	81	11	390	12	A	4	19, 28, 94, 104
lamb, ckd	145	130	171	3	B	4	6, 51
lamb, raw	87	45	129	4	B	2	19, 51
veal, ckd	114	60	180	7	A	3	6, 78
veal, raw	86	43	140	4	B	2	19, 78
liver, pork, ckd	1820	1820	1820	1	C	4	42
liver, beef, ckd	6434	3425	9310	4	A	10	6, 22, *
liver, beef, raw	3880	2780	4600	4	B	4	19, 40, 101, 109
meat loaf, ckd	90	90	90	1	C	1	6
BEVERAGES							
coffee, reg, bev	1	1	1	1	C	2	6
coffee, decaf, bev	1	1	1	1	C	1	6
tea, bev	24	6	80	8	A	6	6, 19, 29, 42, 57, 95
soft drink, carbonated	13	1	38	8	A	3	6, 29, 42
fruit flavored drink	62	4	120	2	B	2	29, *
beers & ales	15	3	38	3	B	5	6, 29, *
wines	22	13	31	4	B	5	6, 36
whiskey	24	18	35	3	B	2	6, 29
BREADS							
bread, white	132	110	147	6	A	5	6, 19, 44
rolls	135	135	135	1	C	1	6
bread, French	210	200	220	2	C	2	47, 88
bread, Italian	200	200	200	2	C	2	47, 88
bread, raisin	215	200	230	2	C	2	47, 88
bagels	180	170	190	3	B	2	47, 89
muffins, bran	130	130	130	1	C	1	42
bread, whole wheat	360	170	600	9	A	8	6, 19, 24, 44, 47, 88
bread, cracked wheat	225	210	240	2	C	2	47, 88
bread, rye	181	170	192	2	C	2	6, 19
biscuits	102	102	102	1	C	1	6
cornbread	60	60	60	1	C	1	6
READY-TO-EAT CEREALS							
shredded bran	965	850	1080	2	C	1	60
bran flakes	533	400	640	3	B	2	19, 60
bran flakes w/raisins	485	485	485	1	C	1	6
Bran Buds[f]	920	920	920	1	C	1	60
Cracklin Bran[f]	670	670	670	1	C	1	60
corn flakes	44	23	53	4	B	3	6, 19, 60
Cheerios[g]	368	340	423	3	B	3	6, 19, 60
granola	623	410	850	4	B	3	24, 42, 60
Life[j]	490	490	490	1	C	1	60
rice, puffed	190	190	190	1	C	1	60
wheat, puffed	430	430	430	1	C	1	60
rice, crisped	137	85	175	3	B	3	6, 19, 60
Special K[f]	280	280	280	1	C	1	60
Team[i]	240	240	240	1	C	1	60
wheat flakes	359	290	447	3	B	3	19, 44, 60
shredded wheat	417	170	561	4	A	5	6, 19, 44, 60
Grape Nuts[h]	370	370	370	1	C	1	60
Total[g]	390	390	390	1	C	1	60
Fruit Loops, Apple Jacks[f]	114	114	114	1	C	1	6
Product 19[f]	180	180	180	1	C	1	60
CHOCOLATE PRODUCTS							
cocoa powder	5000	5000	5000	1	C	1	19
milk chocolate candy	286	70	453	3	B	3	6, 29, *
chocolate bar, fruit/nut	510	510	510	1	C	1	42
syrup, chocolate	430	430	430	1	C	1	19
DAIRY PRODUCTS							
milk, whole	7	3	10	13	A	18	6, 17, 19, 27, 30, 33, 48, 55, 65, 73
milk, lowfat	5	3	8	3	B	3	6, 45, 55
milk, skim	5	2	11	4	B	4	6, 19, 48, 55
buttermilk	7	3	11	2	C	3	6, 55

TABLE 4—*Continued*

FOOD OR AGGREGATE	GRAND MEAN	MIN -	MAX[a] (μg/100g)	NO. OF MEANS USED[b]	CONFIDENCE CODE[c]	TOTAL REFS. EVAL.[d]	ACCEPTABLE REFERENCES
DAIRY PRODUCTS(Continued)							
milk, evaporated	13	9	16	2	C	2	6, 55
yogurt, plain	8	4	12	2	C	2	6, 55
yogurt, fruit	43	7	79	2	C	2	6, 55
milk, chocolate	27	27	27	2	C	2	6, 55
milkshake	95	82	107	2	C	2	6, 58
cream	6	2	10	2	C	2	6, 55
sour cream	19	19	19	1	C	1	55
ice cream, nonchocolate	19	19	19	1	C	3	55
ice cream, chocolate	149	149	149	1	C	1	6
ice cream sandwich	64	64	64	1	C	1	6
ice milk	17	11	23	2	C	2	6, 55
sherbet	27	22	30	2	C	2	19, 55
pudding,chocolate,instant	70	70	70	1	C	1	6
brick cheese	24	24	24	1	C	1	2, 55
Cheddar cheese, Colby	73	27	220	5	A	3	6, 24, 55
Swiss cheese	71	32	110	2	C	2	19, 55
cottage cheese	22	16	28	2	C	4	6, 55
cream cheese	16	16	16	1	C	1	55
American cheese, processed	61	30	110	4	A	5	6, 19, 55, *
FATS AND OILS							
butter	10	3	16	4	A	5	6, 55, 71, *
margarine	5	5	5	2	B	2	6, *
mayonnaise	12	12	12	1	C	1	6
vegetable oil	101	1	320	9	A	9	16,24,29,31,38,55,71
shortening,cu-hydrogenated	284	54	409	3	B	3	31, 38
salad dressing, Italian	5	5	5	1	C	1	6
OTHER GRAIN PRODUCTS							
sweet rolls	103	103	103	1	C	1	6
tortillas, corn	150	130	170	2	C	2	47, 88
tortillas, wheat	138	138	138	1	C	1	6
cake, chocolate	232	232	232	1	C	1	6
cake, yellow	36	36	36	1	C	2	6
cookie, chocolate sandwich	317	317	317	1	C	1	6
cookie, chocolate chip	228	228	228	1	C	1	6
cookie, oatmeal raisin	300	300	300	1	C	1	24
apple pie	54	54	54	1	C	1	6
doughnuts, cake type	121	110	133	2	B	2	6, 44
coffee cake	132	132	132	1	C	1	6
graham crackers	40	40	40	1	C	1	19
saltine, soda cracker	120	90	150	2	C	2	6, 19
crackers, whole wheat	870	870	870	1	C	2	24
corn chip snacks	220	110	330	2	C	2	6, 42
popcorn	181	181	181	1	C	1	6
pancakes	61	50	72	2	C	2	6, 42
egg noodle/mac/spag, ckd	92	79	100	14	A	6	6, 47, 67, 75, 110
corn grits, ckd	12	12	12	1	C	1	6
oatmeal, ckd	99	99	99	1	C	1	6
rice, white, ckd	79	79	79	1	C	1	6
rice, white, raw	210	190	230	2	B	2	72, 102
millet, ckd	330	330	330	1	C	1	24
farina, ckd	26	26	26	1	C	1	6
wheat germ	1143	876	1425	3	C	4	32, 53, 54, 60
LEGUMES							
white beans, dry then ckd	308	285	330	3	B	2	6, 34
split peas, dry then ckd	190	190	190	1	C	1	34
lima beans, dry then ckd	238	205	280	3	B	3	6, 34
pinto beans, ckd/cnd	231	140	272	4	B	3	6, 34, 61
soybeans, ckd/cnd	670	670	670	1	C	1	24
kidney beans, dry then ckd	240	240	240	1	C	1	34
black beans, ckd	290	290	290	1	C	1	24
chickpeas, dry then ckd	470	470	470	1	C	2	34
cowpeas, dry then ckd	320	320	320	1	C	2	34
lentils, dry then ckd	225	200	250	2	C	2	24, 34
Brazil nuts	2382	2382	2382	1	C	3	29
almonds	1411	1411	1411	1	C	3	29
walnuts	1335	1270	1400	2	C	4	19, 29
pecans	1203	1100	1264	3	B	6	6, 19, 29
peanuts	613	348	931	12	A	9	6, 19, 29, 46, 56, 66, 68, 100
sunflower seeds	1770	1770	1770	1	C	3	24
sesame seeds	2080	1610	2470	3	B	2	24

TABLE 4—*Continued*

FOOD OR AGGREGATE	GRAND MEAN (μg/100g)	MIN (μg/100g)	MAX[a] (μg/100g)	NO. OF MEANS USED[b]	CONFIDENCE CODE[c]	TOTAL REFS. EVAL.[d]	ACCEPTABLE REFERENCES
PROCESSED MEATS							
bacon, ckd	110	110	110	1	C	3	6
frankfurter, ckd	60	60	60	1	C	3	6
bologna	69	60	78	2	C	2	6, 28
sausage, ckd	93	93	93	1	C	1	6
salami	103	78	128	2	C	2	6, 28
luncheon meat	50	20	79	2	C	2	19, 28
MISCELLANEOUS							
infant formula, milk	66	9	102	4	A	4	6, 70
infant formula, soy	105	62	149	2	C	2	70, 108
rice cereal, infant	380	380	380	1	C	1	21
cream subst powder	14	14	14	1	C	1	6
gravy	4	4	4	1	C	1	6
sugar, white	29	10	57	3	B	4	6, 29, 42
honey	37	20	70	3	B	3	6, 42
gelatin dessert	5	5	5	1	C	1	6
coffee, regular, powder	771	235	1300	4	B	4	19, 29, 106
MIXED DISHES							
beef stew w/vegetables	57	40	76	4	B	2	6, 74
chicken/turkey pot pie	527	50	55	3	B	2	6, 74
chili con carne w/beans	144	90	210	4	B	3	6, 20, 74
chow mein, pork	57	50	69	4	B	2	6, 74
hamburger on bun, fast food	105	89	133	3	B	2	6, 58
vegetable beef soup, cnd	16	16	16	1	C	1	6
minestrone soup, cnd	115	100	130	2	C	1	42
pork and beans, cnd	186	170	203	2	C	2	6, 19
taco with beef	100	100	100	1	C	1	23
lasagna, hmd	110	110	110	1	C	1	6
macaroni & cheese, pkg	81	60	120	4	A	4	6, 42, 74, e
pasta w/beef/chick/tuna,hmd	88	56	120	2	C	2	6, 74
spag w/meat sauce, hmd	129	109	150	2	C	2	6, 74
spag w/tom sauce, hmd/cnd	74	57	90	2	C	2	6, 74
pizza, cheese	115	90	133	3	B	3	6, 23, 74,
chicken soup w/starch, cnd	10	10	10	1	C	1	6
potato,white,scalloped,hmd	60	60	60	1	C	1	6
tomato soup, cnd	35	35	35	1	C	1	6
POULTRY, OTHER HIGH PROTEIN FOODS							
chicken, ckd	61	40	79	12	A	3	6, 40, 98
chicken, raw	46	11	73	13	A	6	19, 40, 59, 98, 99
turkey, ckd	92	40	185	3	B	3	6, 91
turkey, raw	62	37	114	4	C	2	19, 91
egg, ckd	70	52	90	4	A	2	6, 74
egg, raw	80	53	120	3	B	3	19, 42, 93
peanut butter	630	610	670	3	B	3	6, 19, 56
FISH AND SEAFOOD							
fish, breaded, fried	59	38	92	5	B	2	49, 74
tuna fish, cnd, drained	30	11	51	3	B	7	6, 19, 35
fish sticks	76	76	76	1	C	1	6
salmon, cnd	96	76	116	2	C	3	19, 35
salmon, raw	70	47	93	2	C	2	35, 97
crab, ckd	783	590	1061	3	B	2	62, 92
crab, cnd	390	270	510	2	C	4	19, 92
crab, raw	527	366	740	3	B	2	35, 92
scallops, ckd	270	270	270	1	C	1	42
shrimp, ckd/cnd	216	170	300	3	B	3	6, 19, 35
shrimp, raw	193	193	193	1	C	1	35
oysters, ckd/cnd	44996	10692	79300	2	B	3	62, e
oysters, raw	13415	750	60220	5	A	6	26, 35, 62, e
FRUITS AND VEGETABLES							
coconut, fresh	370	370	370	1	C	2	24
grapefruit	34	27	41	2	C	5	6, 19
orange juice	25	8	50	4	B	10	6, 19, 61
orange	30	4	45	3	B	6	6, 19, e
apple	26	26	26	1	C	11	6
applesauce	17	3	29	4	B	5	6, 19, 25, 59
apricot, dried	280	280	280	1	C	1	24
banana	140	100	210	4	B	6	6, 19, 61
cantaloupe	73	14	240	6	A	6	6,19,43,52,61,107
grape	115	35	250	4	A	5	6, 19, 61, e

TABLE 4—*Continued*

FOOD OR AGGREGATE	GRAND MEAN	MIN (μg/100g)	MAX[a]	NO. OF MEANS USED[b]	CONFIDENCE CODE[c]	TOTAL REFS. EVAL.[d]	ACCEPTABLE REFERENCES
FRUITS AND VEGETABLES(Continued)							
peach, fresh	77	55	100	2	C	3	6, 63
peach, cnd	67	31	125	7	A	5	6, 19, 41, 61, 63
pear, fresh	86	86	86	1	C	4	6
pear, cnd	44	40	50	3	B	3	6, 19, 61
watermelon	21	17	24	2	C	3	6, 19
strawberry	55	55	55	1	C	2	6
fruit cocktail	58	58	58	1	C	1	6
apple juice	17	10	23	2	C	2	6, 19
grape juice	19	7	40	3	B	4	6, 19, 61
potato,white,bkd/bld/cnd	107	68	140	3	B	3	6, 61
potato chips	353	353	353	1	C	1	6
potato, french fried	155	141	177	3	B	3	6, 58, e
potato, white, mashed	63	55	70	2	C	2	6, 61
broccoli, ckd	28	28	28	1	C	2	6
broccoli, raw	51	11	90	2	C	2	19, 61
carrot, raw	83	11	150	5	A	11	6, 19, 61, 64, 72
sweet potato, ckd/cnd	130	63	190	5	A	4	6, 19, 50, 63
sweet potato, raw	190	130	250	2	C	2	50, 63
squash winter, ckd	92	44	140	2	C	1	6, 19
squash summer, ckd	67	67	67	1	C	4	6
tomato, ckd/cnd	92	67	114	5	A	3	6, 41, 45
tomato, raw	93	50	180	7	A	11	6,45,61,64,72,77
tomato juice	76	67	80	3	B	5	6, 61, 77
tomato sauce	106	106	106	1	C	1	6
cabbage salad, coleslaw	17	17	17	1	C	1	6
cabbage, ckd	10	10	10	1	C	1	6
cabbage, raw	40	20	60	2	C	5	19, 61
celery	18	10	25	2	C	4	6, 61
cucumber	51	32	70	2	C	5	6, 61
lettuce	38	10	90	5	A	9	6, 19, 46, 61
mushroom, raw	390	390	390	1	C	2	59
green beans, ckd/cnd	52	18	100	9	A	5	6, 41, 61, 69
corn, cnd	27	11	44	4	B	4	6, 19, 105
corn, cream style, cnd	30	30	30	1	C	1	6
corn, raw	38	30	45	2	C	2	46, 105
mushroom, ckd/cnd	262	260	268	3	B	3	6, 19, 61
onion, ckd/cnd	81	60	102	2	C	2	6, 39
onion, raw	53	35	97	4	A	9	6, 19, 39, 72
green peas, ckd/cnd	101	70	130	4	B	4	6, 19, 76
lima beans, raw	180	180	180	1	C	1	19
mixed vegetables, cnd	38	38	38	1	C	1	6
cucumber pickles, dill	33	33	33	1	C	1	6
jellies, jams, preserves	19	19	19	1	C	2	6

[a] Grand mean of individual mean values taken from acceptable studies; also the minimum and maximum acceptable individual means.

[b] Number of copper values from acceptable references which were used to derive the grand mean value. For some foods, the number of mean values reflects the aggregation of related food items.

[c] Indicator of the relative degree of confidence a user can have in a value; the confidence code is a function of the quality and quantity of available data.

[d] Total number of references evaluated

[e] This grand mean value includes data from Table 5

[f] Kelloggs Company, Battle Creek, MI 49016

[g] General Mills, Inc., Minneapolis, MN 55440

[h] General Foods, Corporation, White Plains, NY 10625

[i] Nabisco, Inc., East Hanover, NJ 07936

[j] Quaker Oats Company, Chicago, IL 60654

ABBREVIATIONS:

bkd	=	baked
bld	=	boiled
cnd	=	canned
ckd	=	cooked
hmd	=	homemade

Food Consumption Survey, 1977–1978 (NFCS, 77–78) (14). Until the results for the Nationwide Food Consumption Survey, 1987–1988, are published, the NFCS, 77–78, is the most recent survey of nationwide food consumption patterns available for all household types and sex-age categories in the U.S. population. Data from the NFCS, 77–78, include specific food descriptions for approximately 3500 foods, 3-day weighted frequencies of consumption for specific foods by 36,255 individuals, and average portion size consumed. The frequency of consumption for a specific food indicates the number of eating occasions at which the food was consumed by the survey participants (15). It should be noted that foods included in this NFCS, 77–78, file represented edible forms. Foods not normally consumed raw, (e.g., liver) or without further processing, (e.g., enriched flour), did not appear.

In an attempt to limit the task to manageable proportions, the descriptions of foods were reviewed. Similar foods were aggregated and their frequencies of consumption were summed. Frequencies for foods which, by description, represented mixed foods of uncertain formulation, e.g., beef with gravy, were not combined with other beef items and were retained as individual items. The aggregation of food descriptions with accompanying frequency data was similar to the aggregation of food descriptions for the analytical data, so that the two data sets could be merged. Consumption data for nonchocolate candies, sugar syrups and toppings, and salad dressings were eliminated due to the low frequencies for individual items, as well as the limited availability of Cu data for these categories. Frequency data for infant foods were not included.

Foods/food aggregates with 3-day frequencies of 300 or greater were selected for a subset. This subset accounted for 90% of the total food counts recorded by subjects in the survey. The most frequently consumed food items in the NFCS, 77–78, such as whole milk, white bread, and beef had 1-day frequencies of 34,565, 26,825, and 14,025, respectively, for the survey population. In addition, the evaluation of published analytical data indicated a small number of foods (e.g., oysters and legumes), which contain relatively high levels of Cu. Despite the fact that the frequencies for these foods were below 300, they were included.

In order to account for the combined effect of frequency and portion weights, the average portion weights of individual foods were multiplied by their respective frequencies to obtain the gram weights consumed by the population. For aggregates, the gram weights of individual foods were summed. The ratio of the gram weights of foods included in the subset to the total grams of food consumed in the survey was 89%. Specifically, tabulation by food group indicated a range of 78–96%. Thus, this subset of foods/food aggregates represents the majority of the foods consumed by the survey population. Therefore, it is probable that these foods supply the majority of nutrients in the diet based on the gram weight consumed. Next, the grand Cu means for foods/food aggregates which had been calculated from the evaluated analytical data were multiplied by their respective NFCS, 77–78, weights of foods as described above. This process yielded the amount of copper contributed by each food for the total population surveyed. Then, the food/food aggregates were ranked by their Cu contribution. The amount of Cu contributed by the foods not included in this subset was judged to be a small percentage of population intake.

After the food/food aggregates were ranked the authors noticed that values for several highly ranked foods (beef liver, oysters, fruit-flavored drinks, and french fries) had confidence codes of C. Since the rank of a food as a copper contributor is determined, in part, by its copper value, it is critical that copper values for high ranking foods be supported by adequate data. Also, widely disparate literature values for several lower ranking foods including margarine, macaroni and cheese, and beer indicated a need for confirmatory analyses.

Limited additional Cu data were generated by the Inorganics Section, Nutrient Composition Laboratory, for the foods listed above in order to improve or verify mean values. Two to four samples of each product were purchased in local supermarkets, cooked if appropriate, and homogenized in a Cuisinart food processor according to predetermined protocol. Where the brand of item was relevant, samples were carefully selected to represent the major brands in the U.S. market. Samples were prepared in triplicate using an HN03/H202 wet ash digestion procedure and analyzed by atomic absorption spectrometry using a Perkin–Elmer Model 603 (16). Analytical accuracy and precision were monitored by the use of National Institute of Standards and Technology (NIST) (formerly National Bureau of Standards) reference materials, NIST SRM 1567 Wheat Flour (certified value: 2.0 ± 0.3 μg/g) and NIST RM 8431 Mixed Diet (reference value: 3.36 ± 0.33 μg/g). The results were 2.17 ± 0.10 and 3.48 ± 0.26 μg/g, respectively.

RESULTS

Cu is widely distributed in the foods Americans consume. Table 4 provides a list of foods, including both raw and cooked forms of some foods, for which acceptable data exist. These data include grand means for each food as well as the minimum and maximum acceptable means reported in the literature. The number of acceptable means used in the calculation of the grand mean for a food/food aggregate is listed. In some cases the number of acceptable means includes mean values for similar forms of a food which have been aggregated under a single, more general descriptor. Individual means which passed the screening for acceptability were equally weighted. The total number of references which were evaluated for each food has been included. Also, included are the references for individual acceptable means so that the user may retrieve individual studies for review. A confidence code for the mean for each food, indicating the relative degree of confidence a user can have in that value, is provided. The confidence code is a function of both the quality and the quantity of available data. It should be noted that only 14% of the confidence codes for the 218 foods are A and 24% are B, while 62% are C. In general, the large number of C confidence codes is an indicator of the paucity of Cu data. For 120 of the foods, only a single reference was deemed acceptable. The maximum QI [QI (quality index) equals QS (quality sum) for a single acceptable reference] that an individual reference could achieve would be 3, qualifying a single study for a confidence code of C (Table 3). In fact, the average QI for foods with a single reference is 1.8. This is attributable to the large amount of FDA's Total Diet Study data which have been included. Relatively high ratings were given to FDA's analytical results due to the use of a validated analytical method, monitoring of batch-to-batch accuracy and precision, and nationwide sampling. While data from other studies may have been evaluated for some of these foods, those data were determined to be unacceptable for reasons previously mentioned and were not used in the computation of the grand mean.

Of the 218 core foods, twenty-six provide 65% of the total Cu intake (Table 5). These include beef liver (rank 1) and oysters (rank 3) which have low frequencies of

TABLE 5

FOODS REPRESENTING 65% OF COPPER CORE FOOD INTAKE RANKED BY CONTRIBUTIONS TO U.S. DIETS

Rank	Food Item	Copper Content Mean	Min.	-	Max.	Conf. Code	Number of Means[c]	Cumul. %[d]
		------ug/100g[a]------						
1	Liver, beef, ckd	6434	3425	-	9310	A	4	8.7%
2	Beef, ckd	104	80	-	136	A	6	15.4%
3	Oysters, ckd/cnd	44996	10693	-	79300	B[b]	2	21.7%
4	Bread, white	132	110	-	146	A	6	27.0%
5	Tea beverage	24	6	-	80	A[b]	8	30.6%
6	Potato, French fried	155	141	-	177	B	3	33.2%
7	Pork, ham, ckd/cnd	121	57	-	210	A	15	35.6%
8	Potato, white, bkd/bld/cnd	108	68	-	115	B	3	38.1%
9	Bread, whole wheat	360	170	-	600	A[b]	9	40.5%
10	Soft drink, carbonated	13	1	-	38	A[b]	8	42.9%
11	Fruit flavored drink	62	4	-	120	B[b]	2	44.7%
12	Milk, whole	7	3	-	10	A	13	46.4%
13	Chicken, ckd	61	11	-	79	A[b]	12	48.0%
14	Peanut butter	630	610	-	670	B	3	49.6%
15	Banana	141	100	-	210	B	4	51.2%
16	Potato, white mashed	63	55	-	70	C	2	52.6%
17	Orange juice	25	8	-	50	B[b]	4	54.1%
18	Spaghetti w/tomato sauce&meat	130	109	-	150	C	2	55.5%
19	Rolls	135	135	-	135	C	1	57.0%
20	Tomato, raw	93	50	-	180	A	7	58.3%
21	Egg noodle, mac, spag, ckd	92	79	-	100	A	14	59.6%
22	Rice, white, ckd	79	79	-	79	C	1	61.1%
23	Egg, ckd	70	52	-	90	A	4	62.1%
24	Chili con carne w/beans	144	90	-	210	B	4	63.3%
25	Pinto beans, ckd/cnd	231	140	-	272	B	4	64.2%
26	Oatmeal, ckd	99	99	-	99	C	1	65.5%

[a]Edible portion.
[b]Foods which have maximum values greater than four times the minimum value.
[c]Number of copper values from acceptable references which were used to derive the grand mean value. For some foods, the number of mean values reflect the aggregation of related food items.
[d]Cumulative percentage of the daily copper intake/person from 218 core foods, (see text).

consumption but high levels of concentration. The top ranking foods also include foods which are not as rich in Cu but are consumed so frequently that they become important contributors of Cu such as tea, potatoes, whole milk, and chicken. Other good sources of Cu include other organ meats, grains, and cocoa products.

Table 6 includes the new analytical copper values determined for selected high-ranking foods (beef liver, oysters, etc.) and some lower ranking foods with disparate values. Also included are the previous mean values as well as the recalculated means after the addition of these new data. The new analytical data for each food were averaged and were assigned ratings prior to their addition to the previously evaluated data.

It should be noted that the new analytical data, if used alone, could achieve no higher confidence code than a C. However, as a result of the input of a limited amount of high quality data, it was possible to upgrade the initial confidence codes for the foods analyzed.

Currently, the variability in the Cu content of a food is not considered in the determination of the confidence code. In Table 5, seven foods which have maximum values greater that four times the minimum value have been flagged. This flagging indi-

TABLE 6

EFFECTS OF ADDITIONAL ANALYTICAL DATA ON MEAN VALUES FOR SELECTED FOODS

	Previous Mean[a]	Adjusted Mean[b]	Nutrient Composition Laboratory Values[c]
	µg/100g		
1. Liver, beef, ckd.	6500	6434	3425,9310
2. Potato, French fried	159	155	125,170
3. Macaroni & cheese (from box mix)	81	81	77,86
4. American cheese	62	61	57,64
5. Grapes	125	115	84,76,87
6. Milk chocolate candy	263	286	270,402
7. Oysters, ckd.	79300	44996	4050,7640[d] 2640,28410[e]
8. Oysters, raw	15353	13415	2870,2300[d] 1390,9000[e]
9. Margarine	5	5	5,5
10. Fruit flavored drink	120	62	4,6,1
11. Beer, reg.	22	15	4,2,3
12. Butter	11	10	9,9
13. Orange	23	30	48,42
14. Egg white, raw	5	14	20,27
15. Egg yolk, raw	10	88	158,174

[a]Based on the evaluation of literature values.
[b]Recalculated to include Nutrient Composition Laboratory values.
[c]Two to four samples of each product were purchased from local supermarkets, cooked if appropriate, and analyzed by AAS.
[d]Pacific oysters
[e]Chincoteague, Maryland oysters

cates the wide range of analytical values which contribute to their respective means and serves as a caution to users. All of these foods have confidence codes of A or B. The evaluation system permits the inclusion of values from individual references which demonstrate acceptable procedures for analytical method, sample selection, and sample preparation. In general, authors presented limited or no documentation of procedures for monitoring day-to-day accuracy and precision. In fact, the majority of the ratings for analytical quality control were zero. Without quality control data, it was difficult to evaluate the accuracy of a mean from an individual reference.

The tabulation of individual means from various references, as previously described, to determine a grand mean for a food, provides a range of values which can be viewed as a rough estimate of variability about that mean. For many foods the range is based on less than eight individual means, each representing limited individual analyses. This estimate of variability, albeit rough, can be used to calculate the number of analytical samples per food required to estimate a mean nutrient level with a specified level of statistical confidence (103, 111).

However, this estimate of variability (determined from the literature compilation) includes analytical variability as well as the inherent variability in the Cu content of the food. Since these sources cannot be separated without quality control data, it is difficult to assess the inherent variability in the Cu content of specific food/food aggregates. For those foods (e.g., oysters) where good quality control procedures have been reported, divergent analytical data indicate considerable inherent variability in Cu levels. If published data included documentation of quality control procedures which ensure the accuracy and precision of measurements, then the inherent variability in Cu levels for foods could be quantified. Such information could be utilized to provide better estimates of Cu values to be used in studies of Cu intake and metabolism.

CONCLUSIONS

The evaluation of Cu data for foods resulted in a list of 218 foods/food aggregates which contribute the majority of the Cu to the diet. A systematic evaluation of analytical data can provide the basis for the identification of food items for future analyses. A review of the grand means and confidence codes for various foods indicates that additional high-quality data are needed for several food groups. Breads and other grain products, good sources of Cu frequently consumed by the population, should be of first priority. The increased consumption of commercial and home-prepared mixed dishes indicates a need for improved copper data for these foods. Limited data are available for many cheeses, yogurt, and frozen desserts. Furthermore, the current trend toward increased consumption of good copper sources such as seafood products and legumes will require the availability of improved copper data for those foods. Finally, the availability of minimum and maximum values, providing a rough indication of Cu variability (analytical, geography, formulation), indicates the need for more extensive measurements of Cu values for important dietary contributors.

The assignment of indicators of data quality and the inclusion of references for individual means allow the user to make an informed decision regarding data applications. The dynamic nature of the evaluation system facilitates the updating process and allows for the system's modifications as the state of the data improves. The authors welcome any constructive comments regarding ways in which this system for evaluating data can be improved. In particular, ideas for weighting the various acceptable means in order to determine the best estimate of the copper level in a specific food need to be discussed and tested.

REFERENCES

1. FIELDS, M. (1985). Newer understanding of copper metabolism. *Int. Med.* **6**, 91–95.
2. DAVIS, G. K., AND MERTZ, W. (1987). Copper. In *Trace Elements in Humans and Animal Nutrition* (W. Mertz, Ed.), pp. 301–350. Academic Press, New York.
3. TURNLUND, J. R. (1988). Copper nutriture, bioavailability, and the influence of dietary factors. *J. Amer. Diet. Assoc.* **88**, 303–308.
4. National Research Council (1989). *Recommended Dietary Allowances*, 10th ed. Committee on Dietary Allowances, Food and Nutrition Board, Commission on Life Sciences, National Research Council, National Academy Press, Washington, DC.
5. SMITH, J. C., JR. (1987). Indices for assessing copper nutriture in animals and humans. In *Biology of Copper Complexes* (J. R. J. Sorenson, Ed.), pp. 115–126. Humana Press, New Jersey.
6. PENNINGTON, J. A. T., YOUNG, B. E., WILSON, D. B., JOHNSON, R. D., AND VANDERVEEN, J. E. (1986). Mineral content of foods and total diets: The selected minerals in foods survey, 1982 to 1984. *J. Amer. Diet. Assoc.* **86**, 876–890.
7. Human Nutrition Information Service, USDA (1987). *Nationwide Food Consumption Survey, Continuing Survey of Food Intakes by Individuals, Women 19–50 Years and their Children 1–5 Years, 4 Days.* Report No. 85-4. Nutrition Monitoring Division, Human Nutrition Information Service, USDA, Hyattsville, MD 20782.
8. HOLDEN, J. M., WOLF, W. R., AND MERTZ, W. (1979). Zinc and copper in self-selected diets. *J. Amer. Diet. Assoc.* **75**, 23–28.
9. REISER, S., SMITH, J. C., JR., MERTZ, W., HOLBROOK, J. T., SCHOLFIELD, D. J., POWELL, A. S., CANFIELD, W. K., AND CANARY, J. J. (1985). Indices of copper status in humans consuming a typical American diet containing either fructose or starch. *Amer. J. Clin. Nutr.* **42**, 242–251.
10. KLEVAY, L. M., INMAN, L., JOHNSON, L. K., LAWLER, M., MAHALKO, J., MILNE, D. B., LUKASKI, H. C., BOLONCHUK, W., AND SANDSTEAD, H. H. (1984). Increased cholesterol in plasma in a young man during experimental copper depletion. *Metabolism*, **33**(12), 1112–1118.
11. FIELDS, M., FERRETTI, R. J., SMITH, J. C., JR., AND REISER, S. (1984). The interaction of type of dietary carbohydrates with copper deficiency. *Amer. J. Clin. Nutr.* **39**, 289–295.
12. HOLDEN, J. M., SCHUBERT, A., WOLF, W. R., AND BEECHER, G. R. (1987). A system for evaluating the quality of published nutrient data: Selenium, a test case. In *Food Composition Data, A User's Prospective* (W. R. Rand *et al.*, Eds.), *Food and Nutrition Supplement*, Vol. 12, pp. 174–193.
13. MURAMATSU, Y., AND PARR, R. M. (1985). Survey of currently available reference materials for use in connection with the determination of trace elements in biological and environmental materials. International Atomic Energy Agency Publication No. RL/128.
14. Human Nutrition Information Service, USDA (1983). *Food Intakes: Individuals in 48 States, Year 1977–78.* Nationwide Food Consumption Survey, 1977–78. Report No. 1-1. Consumer Nutrition Division, Human Nutrition Information Service, USDA, Hyattsville, MD 20782.
15. PAO, E. M., FLEMING, K. H., GUENTHER, P. M., AND MICKLE, S. J. (1982). *Foods Commonly Eaten by Individuals: Amount per Day and per Eating Occasion.* Home Economics Research Report No. 44. Human Nutrition Information Service, USDA.
16. WOLF, W. R. (1981) In *Human Nutrition Research Symposia in Agricultural Research,* (G. R. Beecher, Ed.), Vol. 4, pp. 175–196. Allanheld, Osmun and Co., New Jersey.
17. DORN, R., PIERCE, J. O., II, CHASE, G. R., AND PHILLI, P. E. (1973). Cadmium, copper, lead and zinc in blood, milk, muscle and other tissues of cattle from an area of multiple-source contamination. *Trace Subst. Environ. Health* **7**, 191–203.
18. JACOB, R. A., AND KLEVAY, L. M. (1975). Determination of trace amounts of copper and zinc in edible fats and oils by acid extraction and atomic absorption spectrophotometry. *Anal. Chem.* **47**(4), 741–743.
19. GORMICAN, A. (1970). Inorganic elements in foods used in hospital menus. *J. Amer. Diet. Assoc.* **56**, 397–403.
20. NOLLER, B. N., AND BLOOM, H. (1978). Methods of analysis for major and minor elements in foods. *Food Technol. Australia* **30**(1), 11–19, 22–23.

21. DEEMING, S. B., AND WEBER, C. W. (1979). Trace minerals in commercially prepared baby foods. *J. Amer. Diet. Assoc.* **75,** 149–151.

22. MILNE, D. B., SCHNAKENBERG, D. D., JOHNSON, H. L., AND KUHL, G. L. (1980). Trace mineral intake of enlisted military personnel. *J. Amer. Diet. Assoc.* **76,** 41–45.

23. APPLEDORF, H., AND KELLY, L. S. (1979). Proximate and mineral content of fast foods. *J. Amer. Diet. Assoc.* **74,** 35–40.

24. FREELAND-GRAVES, J. H., EBANGIT, M. L., AND BODZY, P. W. (1980). Zinc and copper content of foods used in vegetarian diets. *J. Amer. Diet. Assoc.* **77,** 648–653.

25. EVANS, W. H., DELLER, D., LUCAS, B. E., JACKSON, F. J., AND READ, J. I. (1980). Observations on the determination of total copper, iron, manganese, and zinc in foodstuffs by flame atomic-absorption spectrophotometry. *Analyst* **105,** 529–543.

26. CAPAR, S. G. (1977). Atomic absorption spectrophotometric determination of lead, cadmium, zinc, and copper in clams and oysters: Collaborative study. *J. Assoc. Off. Agric. Chem.* **60**(6), 1400–1407.

27. JONES, J. W., GAJAN, R. J., BOYER, K. W., AND FIORINO, J. A. (1977). Dry ash–voltammetric determination of cadmium, copper, lead, and zinc in foods. *J. Assoc. Off. Agric. Chem.* **60**(4), 826–832.

28. KIRKPATRICK, D. C., AND COFFIN, D. E. (1975). Trace metal content of various cured meats. *J. Sci. Food Agric.* **26,** 43–46.

29. SCHROEDER, H. A., NASON, A. P., TIPTON, I. H., AND BALASSA, J. J. (1966). Essential trace metals in man: Copper. *J. Chronic Dis.* **19,** 1007–1034.

30. SMITH, A. C. (1968). Rapid methods for determining copper content of milk. *J. Dairy Sci.* **50**(5), 664–668.

31. LIST, G. R., EVANS, C. D., AND KWOLEK, W. F. (1971). Copper in edible oils, trace amounts determined by atomic absorption spectroscopy. *J. Amer. Oil Chem. Soc.* **48,** 438–441.

32. GARCIA, W. J., BLESSIN, C. W., AND INGLETT, G. E. (1972). Mineral constituents in corn and wheat germ by atomic absorption spectroscopy. *Cereal Chem.* **49,** 158–167.

33. BAETZ, R. A., AND KENNER, C. T. (1975). Determination of trace metals in foods using chelating ion exchange concentration. *J. Agric. Food Chem.* **23**(1), 41–45.

34. MEINERS, C. R., DERISE, N. L., LAU, H. C., CREWS, M. G., RITCHEY, S. J., AND MURPHY, E. W. (1976). The content of nine mineral elements in raw and cooked mature dry legumes. *J. Agric. Food Chem.* **24**(6), 1126–1130.

35. GORDON, D. T., AND ROBERTS, L. G. (1977). Mineral and proximate composition of Pacific coast fish. *J. Agric. Food Chem.* **25**(6), 1262–1268.

36. DYER, R. H., AND ANSHER, A. F. (1977). Analysis of German wines by gas chromatography and atomic absorption. *J. Food Sci.* **42**(2), 534–536.

37. COX, R. J., EITENMILLER, R. R., AND POWERS, J. J. (1977). Mineral content of some California wines. *J. Food Sci.* **42**(3), 849–850.

38. EVANS, C. D., LIST, G. R., AND BLACK, L. T. (1971). Char-ashing of glyceride oils preliminary to the atomic absorption determination of their copper and iron contents. *J. Amer. Oil Chem. Soc.* **48,** 840–842.

39. LOPEZ, A., AND WILLIAMS, H. L. (1979). Essential elements in fresh and in canned onions. *J. Food Sci.* **44,** 887–891.

40. LAWLER, M. R., AND KLEVAY, L. M. (1984). Copper and zinc in selected foods. *J. Amer. Diet. Assoc.* **84**(9), 1028–1030.

41. HENRIKSEN, L. K., MAHALKO, J. R., AND JOHNSON, L. K. (1985). Canned foods: Appropriate in trace element studies. *J. Amer. Diet. Assoc.* **85**(5), 563–568.

42. MCNEILL, D. A., ALI, P. S., AND SONG, Y. S. (1985). Mineral analyses of vegetarian, health, and conventional foods, magnesium, zinc, copper and manganese content. *J. Amer. Diet. Assoc.* **85**(5), 569–572.

43. EITENMILLER, R. R., JOHNSON, C. D., BRYAN, W. D., WARREN, D. B., AND GEBHARDT, S. E. (1985). Nutrient composition of cantaloupe and honeydew melons. *J. Food Sci.* **50,** 136–138.

44. ZOOK, E. G., GREENE, F. E. AND MORRIS, E. R. (1970). Nutrient composition of selected wheats and wheat products. VI. Distribution of manganese, copper, nickel, zinc, magnesium, lead, tin,

cadmium, chromium, and selenium as determined by atomic absorption spectroscopy and colorimetry. *Cereal Chem.* **47**(6), 720–731.

45. LOPEZ, A., AND WILLIAMS, H. L. (1981). Essential elements in fresh and canned tomatoes. *J. Food Sci.* **46,** 432–444.

46. WOLNIK, K. A., FRICKE, F. L., CAPAR, S. G., BRAUDE, G. L., MEYER, M. W., SATZGER, R. D., AND KUENNEN, R. W. (1983). Elements in major raw agricultural crops in the United States. Other elements in lettuce, peanuts, potatoes, soy beans, sweet corn, and wheat. *J. Agric. Food Chem.* **31**(6), 1244–1249.

47. RANHOTRA, G. S., GELROTH, J. A., NOVAK, F. A., BOCK, M. A., WINTERRINGER, G. L., AND MATTHEWS, R. H. (1984). Nutritive value of selected variety breads and pastas. *J. Amer. Diet. Assoc.* **84**(3), 322–327.

48. BRUHN, J. C., AND FRANKE, A. A. (1977). Trace metal and protein concentrations in California market milks. *J. Food Prot.* **40**(3), 170–173.

49. GALL, K. L., OTWELL, W. S., KOBURGER, J. A., AND APPLEDORF, H. (1983). Effects of four cooking methods on the proximate, mineral, and fatty acid composition of fish fillets. *J. Food Sci.* **48,** 1068–1074.

50. LOPEZ, A., WILLIAMS, H. L., AND COOLER, F. W. (1980). Essential elements in fresh and in canned sweet potatoes. *J. Food Sci.* **45,** 675–678.

51. ONO, K., BERRY, B. W., JOHNSON, H. K., RUSSEK, E., PARKER, C. F., CAHILL, V. R., AND ALTHOUSE, P. G. (1984). Nutrient composition of lamb of two age groups. *J. Food Sci.* **49,** 1233–1239.

52. TAPER, L. J., MCNEILL, D. A., AND RITCHEY, S. J. (1985). Yields and nutrient content of selected fresh fruits. *J. Amer. Diet. Assoc.* **85**(6), 718–720.

53. The Millfeed Manual (1967). Miller's National Federation, Chicago.

54. WAGGLE, D. H., LAMBERT, M. A., MILLER, G. D., FARRELL, E. P., AND DEYOE, C. W. (1967). Extensive analyses of flours and millfeeds made from nine different wheat mixes. II. Amino acids, minerals, vitamins and gross energy. *Cereal Chem.* **44,** 48–60.

55. WONG, N. P., LACROIX, D. E., AND VESTAL, J. H. (1977). Mineral content of dairy products. *J. Amer. Diet. Assoc.* **72,** 288–291.

56. GALVAO, L. C. A., LOPEZ, A., WILLIAMS, H. L. (1976). Essential mineral elements in peanuts and peanut butter. *J. Food Sci.* **41,** 1305–1307.

57. KENNEY, M. A., AND THIMAYA, S. (1983). Copper content of tea. *J. Amer. Diet. Assoc.* **82**(5), 509–510.

58. APPLEDORF, H. (1974). Nutritional analysis of foods from fast-food chains. *Food Technol.* **28,** 50–55.

59. HOLAK, W. (1983). Determination of copper, nickel, and chromium in foods. *J. Assoc. Off. Agric. Chem.* **66**(3), 620–624.

60. ALLEN, K. G. D., AND KLEVAY, L. M. (1980). Copper and zinc in selected breakfast cereals. *Nutr. Rep. Int.* **22**(3), 389–394.

61. JOHNSON, P. E., STRAUS, C., AND EVANS, G. W. (1977). Metallocalorie ratios for copper, iron, and zinc in fruits and vegetables. *Nutr. Rep. Int.* **15**(4), 469–475.

62. ANTHONY, J. E., HADGIS, P. N., MILAM, R. S., HERZFELD, G. A., TAPER, L. J., AND RITCHEY, S. J. (1983). Yields, proximate composition and mineral content of finfish and shellfish. *J. Food Sci.* **48,** 313–316.

63. ELKINS, E. R. (1979). Nutrient content of raw and canned green beans, peaches, and sweet potatoes. *Food Technol.* **33,** 66–70.

64. LEVEILLE, G. A., BEDFORD, C. L., KRAUT, C. W., AND LEE, Y. C. (1974). Nutrient composition of carrots, tomatoes, and red tart cherries. *Fed. Proc.* **33**(1), 2264–2266.

65. MURTHY, G. K., RHEA, U. S., AND PEELER, J. T. (1972). Copper, iron, manganese, strontium, and zinc content of market milk. *J. Dairy Sci.* **55**(12), 1666–1674.

66. HALLOCK, D. L., MARTENS, D. C., AND ALEXANDER, M. W. (1971). Distribution of P, K, Ca, Mg, B, Cu, Mn, and Zn in peanut lines near maturity. *Agron. J.* **63,** 251–256.

67. RANHOTRA, G. S., GELROTH, J. A., NOVAK, F. A., BOCK, M. A., AND MATTHEWS, R. G. (1985).

Retention of selected minerals in enriched pasta products during cooking. *Cereal Chem.* **62**(2), 117–119.

68. WALKER, W. M., AND HYMOWITZ, T. (1972). Simple correlations between certain mineral and organic components of common beans, peanuts, and cowpeas. *Commun. Soil Sci. Plant Anal.* **3**(6), 505–511.

69. LOPEZ, A., AND WILLIAMS, H. L. (1985). Essential elements and cadmium and lead in fresh, canned, and frozen green beans (*Phaseolus vulgaris* L.). *J. Food Sci.* **50,** 1152–1157.

70. MURTHY, G. K., AND RHEA, U. S. (1971). Cadmium, copper, iron, lead, manganese, and zinc in evaporated milk, infant products, and human milk. *J. Dairy Sci.* **54**(7), 1001–1005.

71. KLEVAY, L. M., VO-KHACTU, K. P., AND JACOB, R. A. (1975). The ratio of zinc to copper of cholesterol-lowering diets. In *Trace Subst. Environ. Health, 9th Conf.* (D. D. Hemphill, Ed.), pp. 131–138. Univ. of Missouri, Columbia, MO.

72. WOLNIK, K. A., FRICKE, F. L., CAPAR, S. G., MEYER, M. W., SATZGER, R. D., BONNIN, E., AND GASTON, C. M. (1985). Elements in major raw agricultural crops in the United States. 3. Cadmium, lead, and eleven other elements in carrots, field corn, onions, rice, spinach, and tomatoes. *J. Agric. Food Chem.* **33,** 807–811.

73. LOPEZ, A., COLLINS, W. F., AND WILLIAMS, H. L. (1985). Essential elements, cadmium, and lead in raw and pasteurized cow and goat milk. *J. Dairy Sci.* **68,** 1878–1886.

74. WYATT, C. J., MACBRIDE, D. E., AND OWSTON, C. (1985). Nutrients in prepared food items. *Nutr. Rep. Int.* **32**(3), 597–608.

75. RANHOTRA, G. S., GELROTH, J. A., AND NOVAK, F. A. (1986). Nutrient profile of pasta products commercially produced in the United States. *Nutr. Rep. Int.* **33**(5), 761–768.

76. LOPEZ, A., WILLIAMS, H. L., AND COOLER, F. W. (1986). Essential elements and cadmium and lead in fresh and canned peas. *J. Food Sci.* **51**(3), 604–607.

77. LOPEZ, A., WILLIAMS, H. L., AND COOLER, F. W. (1986). Essential elements in tomatoes and fresh and canned tomato juice. *J. Food Sci.* **51**(4), 1071–1072.

78. ONO, K., BERRY, B. W., AND DOUGLASS, L. W. (1986). Nutrient composition of some fresh and cooked retail cuts of veal. *J. Food Sci.* **51**(5), 1352–1357.

79. MCHARD, J. A., FOULK, S. J., NIKDEL, S., ULLMAN, A. H., POLLARD, B. D., AND WINEFORDNER, J. D. (1979). Comparison study of four atomic spectrometric methods for the determination of metallic constituents in orange juice. *Anal. Chem.* **51**(11), 1613–1616.

80. TALBOT, V. (1986). Seasonal variation of copper and zinc concentrations in the oyster *Saccostrea cuccullata* from the Dampier Archipelago, Western Australia: Implications for pollution monitoring. *Sci. Total Environ.* **57,** 217–230.

81. SCHMITT, C. J., AND FINGER, S. E. (1987). The effects of sample preparation on measured concentrations on eight elements in edible tissues of fish from streams contaminated by lead mining. *Arch. Environ. Contam. Toxicol.* **16,** 185–207.

82. LOEWE, R., LORENZ, K., AND RANUM, P. (1985). Mineral nutrient variability of commercially grown wheats and wheat flours. *Cereal Foods World* **30**(5), 347–450.

83. HENDZEL, M. R., FALLIS, B. W., AND DEMARCH, B. G. E. (1986). Interlaboratory comparison of analyses for heavy metals in clam tissue. *J. Assoc. Off. Anal. Chem.* **69**(5), 863–868.

84. KELSAY, J. L., FRAZIER, C. W., PRATHER, E. S., CANARY, J. J., CLARK, W. M., AND POWELL, A. S. (1988). Impact of variation in carbohydrate intake on mineral utilization by vegetarians. *Amer. J. Clin. Nutr.* **48,** 875–879.

85. STEPNICK-GROPPER, S. A., GREEN, N. R., AND ACOSTA, P. B. (1987). Mineral content of selected Florida wines. *Nutr. Rep. Int.* **35**(5), 1105–1109.

86. HOUDAYER, A., HINRICHSEN, P. F., MARTIN, J. P., AND BELHADFA, A. (1987). Pixe trace element analysis of a selection of wines. *Canad. J. Spectrosc.* **32**(1), 7–13.

87. LOPEZ, A., WILLIAMS, H. L., AND COOLER, F. W. (1986). Essential elements in tomatoes and fresh and canned tomato juice. *J. Food Sci.* **51**(4), 1071–1072.

88. RANHOTRA, G. S., GELROTH, J. A., NOVAK, F. A., AND MATTHEWS, R. (1985). Minerals in selected variety breads commercially produced in four major cities. *J. Food Sci.* **50,** 365–368.

89. RANHOTRA, G. S., GELROTH, J. A., AND NOVAK, F. A. (1985). Nutritional composition of bagels commercially produced in the United States. *Cereal Foods World* **30,** 209–210.

90. JOHNSON, W. A., AND DEETHARDT, D. E. (1983). Nutrient content and edible yield of selected cuts of cooked pork. *J. Food Sci.* **48,** 1352–1353.

91. ZENOBLE, O. C., AND BOWERS, J. A. (1977). Copper, zinc, and iron content of turkey muscles. *J. Food Sci.* **42,** 1408–1412.

92. LOPEZ, A., WILLIAMS, H. L., AND WARD, D. R. (1981). Essential elements in raw, boiled, steamed, and pasteurized crabmeat. *J. Food Sci.* **46,** 1128–1131.

93. KIRKPATRICK, D. C., AND COFFIN, D. E. (1975). Trace content of chicken eggs. *J. Sci. Food Agric.* **26,** 99–103.

94. MOSS, M., HOLDEN, J. M., ONO, K., CROSS, R., SLOVER, H., BERRY, B., LANZA, E., THOMPSON, R., WOLF, W., VANDERSLICE, J., JOHNSON, H., AND STEWART, K. (1983). Nutrient composition of fresh retail pork. *J. Food Sci.* **48,** 1767–1771.

95. BURKE, K. E., AND ALBRIGHT, C. H. (1971). Atomic absorption spectroscopy for determination of ppm quantities of copper and nickel in tea. *J. Assoc. Off. Agric. Chem.* **54,** 658–662.

96. MARCHELLO, M. J., MILNE, D. B., AND SLANGER, W. D. (1984). Selected macro and micro minerals in ground beef and longissimis muscle. *J. Food. Sci.* **49,** 105–106.

97. PILLAY, K. K. S., THOMAS, C. C., JR., AND HYCHE, C. M. (1973). Neutron activation analysis of some of the biologically active trace elements in fish. *Conf. Trace Subst. Environ. Health* **7,** 415–420.

98. MEINERS, C., CREWS, M. G., AND RITCHIE, S. J. (1982). Yield of chicken parts: Proximate composition and mineral content. *J. Amer. Diet. Assoc.* **81,** 435–439.

99. HAMM, D., SEARCY, G. K., AND SMITH, F. G. (1981). Bird to bird variation within processing lots for mineral elements, proximate constituents and parts. *Poult. Sci.* **60,** 327–331.

100. MARTENS, D. C., HALLOCK, D. L., AND ALEXANDER, M. W. (1969). Nutrient distribution during development of three market types of peanuts. II. B, Cu, Mn, and Zn contents. *Agron. J.* **61,** 85–88.

101. KORSRUB, G. O., MELDRUM, J. B., SALISBURY, C. D., HOULIHAN, B. J., SASCHENBRECKER, P. W., AND TITTIGER, F. (1985). Trace element from cattle, swine, and levels in liver and kidney from poultry slaughtered in Canada. *Canad. J. Comp. Med.* **49,** 159–163.

102. MASIRONI, R., KOIRTYOHANN, S. R., AND PIERCE, J. O. (1977). Zinc, copper, cadmium, and chromium in polished and unpolished rice. *Sci. Total Environ.* **7,** 27–43.

103. HOLDEN, J. M., LANZA, E., AND WOLF, W. (1986). Nutrient composition of retail ground beef. *J. Agric. Food Chem.* **34,** 302–308.

104. MARCHELLO, M. J., SLANGER, W. D., AND MILNE, D. B. (1985). Macro and micro minerals from selected muscles of pork. *J. Food Sci.* **50,** 1375–1378.

105. LOPEZ, A., WILLIAMS, H. L., AND COOLER, F. W. (1985). Essential elements, cadmium and lead in fresh and canned corn (*Zea mays* L.). *J. Food Sci.* **50,** 1360–1361.

106. SHAH, K. R., FILBY, R. H., AND DAVIS, A. H. (1971). Determination of trace elements in tea and coffee by neutron activation analysis. *Intern. J. Environ. Anal. Chem.* **1,** 63–73.

107. COWGILL, U. M. (1981). The chemical composition of bananas: Market basket values, 1968–1980. *Biol. Trace Elem. Res.* **3,** 33–34.

108. SUDDENDORF, R. F., AND COOK, K. K. (1984). Inductively coupled plasma emission spectroscopic determination of nine elements in infant formula: Collaborative study. *J. Assoc. Off. Agric. Chem.* **67,** 985–992.

109. OSHEIM, D. L., AND ROSS, P. E. (1985). Atomic absorption spectrophotometric determination of liver copper: Collaborative study. *J. Assoc. Off. Agric. Chem.* **68,** 44–45.

110. RANHOTRA, G. S., GELROTH, J. A., NOVAK, F. A., AND BOCK, M. A. (1982) Retention of selected minerals in cooked pasta products. *Nutr. Rep. Int.* **26,** 821–825.

111. COCHRAN, W. G. (1977). *Sampling Techniques,* 3rd ed., pp. 77–78. Wiley, New York.