FOOD COMPOSITION

by Charlotte Chatfield and Georgian Adams

FOOD-COMPOSITION tables are the basis for all dietary calculations, and they are used to determine the adequacy of existing diets as well as to devise better ones. The tables summarize facts patiently collected over many years from hundreds of scattered sources. Here is an account of what information they give, how they are made up, and what their shortcomings are. The article also includes lists of foods rich in three minerals of major importance—calcium, phosphorus, and iron.

On the basis of studies to determine the body's requirements for energy, proteins, minerals, and vitamins, standards may be formulated for guidance in planning our diets or in evaluating our food habits. Before these requirements and standards can be translated into actual practice, however, we must know what foods supply the essential nutrients.

To this end, food-composition data are necessary. This implies that the foods themselves must be analyzed to determine their content of moisture, protein, fat, carbohydrate, calcium, phosphorus, iron and other minerals, and the several vitamins as well. This involves an enormous amount of detailed work, and it has taken many years to bring our knowledge of foods to its present state. A great many analysts working in various laboratories throughout the country have contributed to this knowledge, but even now the study cannot be considered complete. As a step beyond the analytical work, the analyses from these hundreds of sources must be assembled, evaluated, and finally summarized in tables for convenient reference.

The importance of definite knowledge of the chemical composition of foods has long been recognized. The first analyses of American foods were made as long ago as 1844, when Shepard determined the mineral constituents of Indian corn and sweetpotatoes (1036), and of rice, rice flour, and other rice products (1035). In subsequent years

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2 Italic numbers in parentheses refer to Literature Cited, p. 1075.
many foods were studied by workers in various laboratories, and in
1896 Atwater and Bryant (51) published an extensive compilation on
the proximate composition—the term commonly used for an analysis
that is approximate, or not complete in all details—of American food
materials. Their tables, giving figures for the moisture, protein, fat,
carbohydrate, and ash (mineral) content of a great many foodstuffs,
summarized the data on American foods on record up to July 1895.
They included in addition many unpublished analyses made in con-
nection with nutrition investigations and other studies.

Our knowledge in the field of nutrition has greatly increased since
those tables were published, and emphasis in diet practice has shifted
from mere calorie counting to consideration of adequate protein,
mineral, and vitamin intake, but data on the foods themselves are still
basic to dietary plans.

In fact, the Atwater and Bryant tables, known to many as Bulletin
28, have been a standard of reference ever since their publication.
Tables in many texts on foods and in dietetic manuals have been
based in rather large measure on these early figures. These values are
still fairly representative, particularly for the natural unprocessed
foods that have not significantly changed in composition with the
development of new varieties and new cultural methods. Within
more recent times new summary tables on the proximate composition
of fresh fruits and vegetables (200, 201) have been issued by the
Department of Agriculture. These are largely based on analyses
since 1900 and supersede the corresponding sections in the Atwater
and Bryant compilation, confirming or modifying their data and
providing in addition figures for many fruits and vegetables not
included in their list.

Actually, of course, foods are variable in composition, and no two
tables based on different sets of analyses will be exactly alike. For a
given kind of food there will be variations depending on such factors
as variety and maturity differences, climate, storage, and nature of
the analytical sample. Thus, juice from Concord grapes contains on
an average about 16 percent of sugar, while that from raisin grapes
averages about 25 percent. Young, green sweet corn averages about
5 percent of sugar and 9 of starch. As the corn matures the starch
content increases rapidly, so that fresh corn that has arrived at the
stage designated as old may contain as little as 2 percent of sugar
and as much as 26 of starch. In potatoes stored at temperatures
below 40° or 50° F., there is a conversion of some of the starch into
sugar, while fresh corn and peas held at room temperature rapidly
lose their sweetness as sugar is used up in the respiratory process.
These few examples serve to illustrate how the composition of a single
food may vary. Moreover, if natural foods are subjected to processing,
further variations will be introduced.

Since foods are not constant in composition it is customary in
many food tables (references 51, 200, and 201 are examples) to report
the maximum and minimum values found for each food as well as
the averages. These maximum and minimum values do not represent
the actual limits of variation which can occur, but merely the range
in composition in the particular samples studied. They serve to tell
the reader that the food is variable, and that the average does not

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necessarily give the exact composition of any particular sample. The average serves, however, as a working estimate of the composition of the food.

In actual practice food tables are used in making calculations to determine the nutritive value of the diet as a whole or in determining what the individual foods contribute to the diet. For example, the nutritionist may want to determine how much protein, how much calcium, how much of the other minerals, and how much of the vitamins a given population group is getting according to its dietary habits; the dietitian may need to plan a diet that will furnish just so many calories and contain so many grams of carbohydrate, protein, and fat; and the layman may need to know merely in a general way what foods can be relied on as good sources of the various minerals and vitamins.

It is not necessary either for diet calculations or for general information on relative food values to know how variable in composition each food may be, but it is essential to have for all foods representative average values that will provide a reasonably good basis for calculations. Such averages or general estimates of the proximate composition and fuel value of a great number of common foods have been summarized in convenient form for publication.

Tables that have been compiled cover practically all classes of foods and extend to many items not included in the earlier bulletins. Many of the values reported are the same as those in the older tables, but many others are newly derived. This is particularly true for processed foods, for which new figures were needed in line with present-day standards and processes. The data given cover the gross or proximate composition of foods, that is, their moisture, protein, fat, carbohydrate, and ash content, and their fuel or calorie value. Tables of proximate composition do not give such details as the kinds of protein present in a food, the quantities of different minerals, or the vitamin content.

**WHAT FOOD-COMPOSITION TABLES CONTAIN**

Moisture is a constituent of all foods and represents essentially the amount of free water present. It is determined as the amount of substance lost in drying the material under specified conditions of analysis. That which is not moisture constitutes the “solids” and is made up of protein, fat, carbohydrate, and ash. Thus fresh fruits contain 75 to 90 percent of moisture, the remainder being chiefly sugar. Certain leafy vegetables such as beet greens, spinach, or lettuce may contain as much as 90 to 95 percent of moisture, and certain fruit forms such as tomatoes, summer squash, and cucumbers are also largely water, averaging about 95 percent. Fluid whole milk, however, averages only 87 percent of moisture, since it has measurable amounts of protein, fat, and sugar held either in true solution or in fine suspension. At the other extreme, dry beans and peas, cereals, and nuts have a moisture content of 5, 10, or 15 percent, and such foods as sugar and lard contain almost no moisture. The moisture contents of other foods lie between these extremes.

Proteins, unlike carbohydrates and fats, characteristically contain the element nitrogen. It is customary, therefore, to determine the
total amount of nitrogen in a food, and then to multiply this by an appropriate factor, such as 6.25, which gives a working estimate of the total amount of crude protein. Other factors than 6.25 are sometimes used, depending on the type of protein present.

The food tables show that our richest sources of protein are cheese, meats, eggs, certain nuts, and dry legumes. Within this group the protein runs from 10 to 35 percent. Cereals are the next richest source of protein, while the fresh fruits and vegetables, except for beans and peas, contain about 1 percent or less. The figures for crude protein, however, express only the total amount of protein present and give no indication of its quality, that is, the efficiency with which it meets the body’s needs.

Fats are soluble in ether, and the fat content of foods is determined, therefore, as the portion extracted by ether. The term “ether extract” is sometimes used in place of fat. Data indicate that the vegetable oils and lard stand at one extreme of fat content, being 100-percent fat, while fresh fruits and vegetables, with a few exceptions, are at the other extreme, containing less than 1 percent. Avocados and olives are exceptions among the fruits; certain kinds of avocados contain as much as 25 percent of fat and the usual ripe pickled olives about 19 percent. Among the vegetables, dry soybeans average about 18 percent of fat. Nuts as a group are rich in fat, the content varying from 33 percent in coconuts to 70 or more in pecans. Meats are exceedingly variable in fat content, the amount being determined chiefly by the fatness of the entire animal and by the way it is cut and trimmed.

Aside from moisture, protein, and fat, carbohydrate is the only other constituent of foods that may occur in large quantities. Here again, however, the amount varies, from 100 percent or nearly that in purified sugars or starches down to negligible amounts in meats. Several kinds of carbohydrate occur in foods. Sugars, dextrins, and starches, forms of carbohydrate readily utilized by the body, are of chief importance. Crude fiber, on the other hand, represents the indigestible residue from plant foods; it is not present in any of the animal foods. “Total carbohydrate by difference” is usually reported in food tables and represents the solids left after deducting protein, fat, and ash. The term includes organic acids and any undetermined solids as well as carbohydrate. Sugar, starch, and fiber are often reported separately, thus giving information about the nature of the carbohydrate present.

The amount of mineral matter in foods is indicated in a general way in the tables by the component designated as ash, the material left after the organic portion is burned away. From the nutritional standpoint, values for total ash are not so important as data on the individual mineral elements, such as calcium and iron, for example, which need special consideration in diet plans.

For the constituents other than minerals, average values in published tables give a basis for making fairly good estimates of the quantities present in the total diet. Such estimates cannot be exact because of variations in the composition of foods, but for practical purposes they do very well when the diet is taken as a whole.
MINERAL CONTENT OF FOODS

Dietary estimates for minerals are much less satisfactory than those for other constituents because of the limitations of present knowledge concerning them. Calcium, phosphorus, and iron have been studied more than other elements because of their known significance as measures of the adequacy of the diet, and information about them, though meager in comparison with that on proximate composition, is of first importance to nutritionists. Enough is known to indicate what foods are especially good as sources of each of these elements, and also to indicate that diets are frequently too low in one or more of them. From the information at hand it is possible to plan diets that contain safe allowances of the minerals, even though the estimates of the quantity in any given food are relatively crude approximations.

FOODS RICH IN CALCIUM

The foods regarded as excellent or good sources of calcium are listed below. If they were placed in the order of importance, milk in its various forms (other than butter) would head the list of common foods, and green leafy vegetables would rate among the next best.

**Excellent**

Amaranth
Broccoli
Buttermilk
Cabbage:
- Savoy and nonheaded
- Chinese, nonheaded varieties including tendergreens
Chard
Cheese:
- American or Cheddar
- Swiss
Clams
Collards
Cress, garden
Dandelion greens
Kale
Milk, whole or skimmed; evaporated, condensed, and dried
Molasses
Mustard greens
Orach
Sesame seed
Tendergreens
Turnip tops
Water cress

**Good**—Continued

Burdock, roots
Cabbage, headed, especially green
Carrots
Celeriac
Celery
Cheese, cottage
Chickpeas, whole
Chicory, leaves
Cottonseed flour
Crabs
Cream
Eggs, whole
Egg yolk
Endive or escarole
Figs, dry
Kohlrabi
Leeks
Lettuce, head or leaf
Lobster
Maple sirup
Okra
Oysters
Parsnips
Romaine
Rutabagas
Sorgo sirup
Soybeans, dry or as green vegetable
Soybean flour
Sweetpotato tops
Turnips
Vegetable-oyster or salsy

Certain plant foods, the calcium content of which was high enough to justify inclusion in this list, have been omitted because of their oxalic acid content. Beet greens, dock, rhubarb, spinach, and New Zealand spinach were left out on this account. If a food contains
enough oxalic acid to combine with all of its calcium to form calcium oxalate, the evidence seems to show that the calcium is of little or no use to the body. This may be because the calcium oxalate is already formed in the food; or it may be that the oxalic acid combines with calcium during or after digestion, making it insoluble so that the body cannot utilize it. These same foods, of course, may be valuable for other elements than calcium.

**FOODS RICH IN PHOSPHORUS**

There is a longer list of foods rich in phosphorus, and more food classes or groups are represented. Nearly all of the calcium-rich foods contain significant quantities of phosphorus, and in addition lean meats, fish of all kinds, and several other classes of foods are rich in this element. All animal tissues except fat contain liberal quantities, and many grain products are among the better sources. The following list, though far from complete, will suggest that choosing a diet with enough phosphorus should be comparatively easy:

*Excellent*—Continued

<table>
<thead>
<tr>
<th>Excellent</th>
<th>Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley, whole</td>
<td>Buckwheat flour</td>
</tr>
<tr>
<td>Beans:</td>
<td>Cashew nuts</td>
</tr>
<tr>
<td>Common or kidney, dry, shelled</td>
<td>Celeriac</td>
</tr>
<tr>
<td>Lima, fresh or dry</td>
<td>Cheese:</td>
</tr>
<tr>
<td>Brazil nuts</td>
<td>American or Cheddar</td>
</tr>
<tr>
<td>Buttermilk</td>
<td>Cottage</td>
</tr>
<tr>
<td>Cheese, Swiss</td>
<td>Chickpeas</td>
</tr>
<tr>
<td>Cottonseed flour</td>
<td>Clams</td>
</tr>
<tr>
<td>Cowpeas, or black-eye peas, shelled</td>
<td>Cocoa</td>
</tr>
<tr>
<td>Crabs</td>
<td>Collards</td>
</tr>
<tr>
<td>Eggs, whole</td>
<td>Corn, green, sweet</td>
</tr>
<tr>
<td>Egg yolk</td>
<td>Corn meal, whole ground</td>
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<tr>
<td>Fish</td>
<td>Cress, garden</td>
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<tr>
<td>Liver, any kind</td>
<td>Dasheen or taro</td>
</tr>
<tr>
<td>Lobster</td>
<td>Hazelnuts and filberts</td>
</tr>
<tr>
<td>Meats, lean or medium fat, having more than 12 percent of protein</td>
<td>Kohlrabi</td>
</tr>
<tr>
<td>Milk, whole or skimmed; evaporated, condensed, and dried</td>
<td>Lentils</td>
</tr>
<tr>
<td>Oysters</td>
<td>Meats, fat, having more than 6 percent of protein</td>
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<tr>
<td>Poultry</td>
<td>Millets</td>
</tr>
<tr>
<td>Rice bran</td>
<td>Oatmeal or rolled oats</td>
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<tr>
<td>Rice polish</td>
<td>Orach</td>
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<tr>
<td>Sesame seed</td>
<td>Parsnips</td>
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<tr>
<td>Shrimps</td>
<td>Peanuts</td>
</tr>
<tr>
<td>Soybeans</td>
<td>Peas</td>
</tr>
<tr>
<td>Soybean flour</td>
<td>Pecans</td>
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<tr>
<td></td>
<td>Pistachio nuts</td>
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<tr>
<td></td>
<td>Rice, brown</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Rye flour</td>
</tr>
<tr>
<td>almonds</td>
<td>Walnuts</td>
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<tr>
<td>Artichokes, globe or French</td>
<td>Wheat:</td>
</tr>
<tr>
<td>Bamboo shoots</td>
<td>Flour, graham or whole-wheat</td>
</tr>
<tr>
<td>Barley, pearled</td>
<td>Shredded or puffed</td>
</tr>
<tr>
<td>Beans, mung, dry</td>
<td>Whole grain or meal</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Bran</td>
</tr>
<tr>
<td>Brussels sprouts</td>
<td>Germ</td>
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</tbody>
</table>

**FOODS RICH IN IRON**

Meats, egg yolks, and green leaves are the foods most often accented in lists of iron-rich foods. Whole-grain cereals, although they are not
as high in iron, are among the most useful sources because they can provide much of the necessary iron in low-cost diets that have very limited quantities of the more expensive sources. All of the foods in the following list are regarded as rich sources.

**Excellent**

- Apricots, dried
- Beans:
  - Common or kidney, shelled
  - Lima, shelled, fresh or dry
- Beet greens
- Broccoli leaves
- Chard
- Cowpeas, shelled, dry or fresh
- Dandelion
- Eggs, whole
- Egg yolks
- Heart
- Kale
- Kidney
- Lentils, dry
- Liver
- Meats, lean or medium fat (beef, veal, pork, or lamb), over 15 percent of protein
- Molasses
- Mustard greens
- New Zealand spinach
- Oysters
- Peaches, dried
- Poultry, especially dark meat
- Shrimps
- Sorgo sirup
- Soybeans, dry or as green vegetable
- Spinach
- Tongue
- Turnip greens

**Excellent—Continued**

- Water cress
- Wheat bran

**Good**

- Barley, whole
- Beans, snap or string
- Brains
- Broccoli
- Brussels sprouts
- Cabbage greens or outer leaves
- Collards
- Corn meal, whole ground
- Dates
- Dock or sorrel
- Endive or escarole
- Figs, dried
- Leaf lettuce
- Meats, fat (beef, veal, pork, or lamb), over 10 percent of protein
- Oatmeal or rolled oats
- Peas, green or dried, whole seeds
- Poultry, light meat
- Prunes, dried
- Rye flour, whole
- Seedless raisins, or “currants”
- Sugarcane sirup
- Vegetable-oyster or salsify
- Whole-wheat cereals
- Whole-wheat flour

**OTHER MINERALS IN FOODS**

Numerous mineral elements other than calcium, phosphorus, and iron are required by the body. Some of them, including sodium, potassium, and magnesium, occur in fairly large quantities in foods—that is, in quantities comparable to those of calcium and phosphorus. A fair number of mineral analyses of foods cover these elements, but no summary of these analyses has been made in the Department of Agriculture nor is any contemplated at the present time. This is partly because these elements occur so commonly in foods that nutritionists question whether any freely chosen diets of human beings are deficient with respect to any of them, and partly because authentic analytical data are even more meager for them than for calcium, phosphorus, and iron.

Copper, because of its established nutritional importance, has been determined in a variety of foods. It has been found to occur in measurable amounts in all or nearly all of the natural foods studied. The quantities are very small, barring contamination from spray materials used in combating plant diseases or from industrial sources. Enough is present naturally, however, so that the likelihood of a deficiency of copper seems rather remote except on very restricted
diets in areas where the soil is poor in this element and the bulk of the food supply is produced locally. Such a deficiency may occur in sections where the livestock are subject to the condition known as salt sick, but this has not been established.

Cobalt has only recently been recognized as an element of which a deficiency in the diet may be serious. Only very minute quantities are needed. The effect of such a deficiency in the ration of sheep and cattle is mentioned in the article on Mineral Needs of Man (p. 215). It is remotely possible that in some areas of the world, possibly some in the United States, cobalt deficiencies in human diets may exist; but it seems improbable that freely chosen diets will fail to provide enough of this element unless they are very poor in several other respects.

Manganese is another mineral element for which the body apparently has need. The need is very small, however, and there is no evidence that diets are ever deficient in this element. As a matter of fact, in experimental studies with animals it was found exceedingly difficult to prepare diets that would be free from manganese. Although there have not been many quantitative studies on the amount of this element in foods, the results show that it is widely distributed, occurring in fruits and vegetables, nuts and grains, milk, animal organs, and other foods. Nuts and seeds, including all the cereal grains and the legumes, seem to be among the richer sources.

Zinc is probably necessary in minute amounts in human nutrition, but the evidence on this point is meager. There is little or no danger of a deficiency of this element, since it seems to be present in trace amounts or more in a wide variety of foods.

Various studies have shown that arsenic often occurs in human tissues. On the other hand it is known that only very small amounts of arsenic can be tolerated without toxic effects. In a survey made a few years ago to determine the amount and distribution of arsenic naturally occurring in foods, a great many samples were analyzed. Practically all classes of foods were examined, and it was found that arsenic was much higher in sea foods than in any other class, barring of course those carrying spray residues. Even in the marine products, however, the quantities are so very small that, at the most, arsenic as it occurs naturally in foods can be considered only a trace element.

Chlorine, chiefly in the form of chlorides, is present in relatively large amounts in almost all foods. In addition, table salt, which is sodium chloride, is added freely to our diet.

Iodine is necessary for the proper functioning of the thyroid gland. It is needed in only very small amounts, but unless special provision is made, even these small quantities are often lacking in the diets of people living inland in certain areas where iodine is deficient in the soil and the water. Plants grown on these soils are very low or even altogether lacking in iodine. Foods grown or raised in coastal regions, on the other hand, generally contain more iodine than those grown inland, and in some cases they may even be rich in this element. In coastal areas the soils and the water contain more iodine, and the plants in turn absorb more. In foods of animal origin, such as eggs and milk, for example, the iodine content depends upon the amount
of iodine received by the animal either in natural feed or forage or in
the form of special iodine supplements to the ration. In general,
then, foods cannot be listed as good, fair, or poor sources of iodine,
since actually the iodine content does not depend upon the kind of
food, but rather upon the locality where it is grown, if it is a plant
food, or upon the iodine supplied to the animal if it is a food of animal
origin. The one exception to this is the sea foods, such as marine
fish and shellfish. These are always rich in iodine, obtained from the
sea water.

So little is known at present about the need for bromine, or its
occurrence in foods, that any discussion would necessarily be
unsatisfactory.

Sulfur, while very necessary to the animal body, is generally not
considered in connection with the mineral elements in nutrition. This
seems logical when it is considered that sulfur plays its important
role in the body, not in the form of an inorganic substance but in
complex organic compounds. Moreover, practically all of the sulfur
obtained from food is in organic combination, chiefly as a constituent
of proteins. If the diet contains sufficient protein of the right kind,
this element will be furnished in adequate amounts.

Fluorine, boron, and silicon are found in the body but there has been
no evidence to indicate that they are really necessary for the physiologi-
cal functioning of the animal organism. Their occurrence in foods has
not, therefore, assumed particular importance from the standpoint of
nutrition.

Carbon, hydrogen, and oxygen are never given consideration as
individual elements in studies on foods. They do not occur separately,
but only in combination in complex organic compounds—the proteins,
fats, and carbohydrates. Foods, therefore, are not analyzed for these
elements. Nitrogen, of chief importance as a constituent of proteins,
is likewise not regarded as a mineral element.

**SHORTCOMINGS OF MINERAL ANALYSIS**

Compilations showing the quantities of the more important mineral
elements in many of the common foods have been published (152, 519,
1048), and numerous publications give data from a limited number of
original analyses. Such tables are in wide use for diet calculations.
It is plain that quantitative values are to be preferred to such simple
classifications as have been presented here. But the data now avail-
able on this subject are far from satisfactory, for several reasons.

In the first place, many of the existing analyses were made by
methods now known to give erroneous results. When such data are
discarded, too few findings remain, except for a very few foods, to give
satisfactory estimates. Fewer authentic analyses have been made for
these constituents than for moisture, protein, carbohydrate, fat, and
ash, whereas more analyses are required if the resulting averages are
to be equally good.

The number of determinations should be greater in the case of the
minerals, because variations due to the variety and kind of a certain
food material and differences in sampling or preparation of the food
for analysis frequently affect the minerals much more than they
influence the total solids, protein, or carbohydrate. It is clear that
with wider variations more observations are needed to provide equally
good determinations of the average composition.

Existing data also fall short of present needs because of the character
of the materials that have been studied and the design of the experi-
mental work. Many of the analyses on which averages in such com-
pilations are based, perhaps the majority of them, were made for other
than dietary purposes, and the food samples often were not well
chosen from the standpoint of nutrition. When analyses are made in
connection with studies in agronomy, plant or animal physiology, food
inspection or control, or industrial investigations, the materials
selected for analysis are apt to be quite different from samples that
would be chosen in an experiment designed for deriving average values
for use in diet calculations.

A good example of the need of careful discrimination in making food
analyses can be given in the case of common cabbage. The percentage
of calcium in dark-green cabbage is many times higher than that in
white, but most authors in publishing results of analysis of this
vegetable have failed to tell whether any or all of the dark-green outer
leaves were left in the part sampled. Those who do give this informa-
tion usually neglect to state the variety of cabbage, or to what extent
the inner part was bleached.

Evidence to show how much better the greener leaves are as a source
of calcium is given in a more technical discussion at the end of this
article (p. 283). From the chemist’s or nutritionist’s standpoint the
data available are nevertheless inadequate except to give crude esti-
mates of the average quantity in the several kinds of cabbage that are
consumed. There is enough evidence, however, to warrant advising
consumers to watch for greenness in picking out cabbages at the market
and to see that some of the bright-green outer leaves are left with the
lighter-colored inner part in preparing cabbage for the table. It is
worth while mentioning here that the vitamin A and the iron as well
as the calcium content are higher in the green leaves.

Another vegetable that shows wide variations in calcium content is
the soybean. In this case the variations are associated with variety
and with maturity, and probably to some extent with the soils on
which the plants are grown. On the average, green vegetable soybeans
have enough calcium to rate as good sources of that element, but the
individual variation is so wide that some of the specimens analyzed
would count as excellent and others would fail to rate even as good,
according to the criteria on which the list of calcium-rich foods was
prepared. The degree of variation is shown in the more technical
part of this article.

Most other natural foods probably vary similarly in their mineral
content, but even less is known of the mineral constituents of the
majority of them than of the calcium in cabbage and soybeans.
Highly refined foods like sugar, patent flour, and cooking fats, all low
in minerals, are probably less variable in their mineral content; but
manufactured foods that contain more minerals are usually less
standardized as to processes and formulas, and may vary in mineral
content even more widely than the natural foods.

In view of this variability in composition it must be plain that
tables on the mineral content of foods should be based, not on a few
scattered analyses of poorly described specimens of each item listed, but on well-planned chemical investigations. Better analytical data are needed so that the mineral estimates in food-composition tables will give a more nearly correct means of determining whether a particular diet is satisfactory.

For nutrition purposes, moreover, it is not enough to know how much of each of these elements is present in the food materials. Chemists are now being called on not only to give the quantity of calcium or of iron in different substances but also to supply information that will throw light on the availability of these elements to the body. The relationship between calcium and oxalic acid, already mentioned, is a case in point. More information is needed on the oxalic acid in foods because of its bearing on calcium metabolism. There may be other calcium compounds in foods besides oxalate that the body cannot absorb or metabolize, but so far the chemist has been asked to account only for the total amount of calcium, not to say in what form it exists in the food.

Phosphorus compounds in foods also are dissimilar in their availability to the body. Some work has been done toward finding what kinds of compounds are available and devising chemical methods for distinguishing between them as they occur in foods. Information on this problem, however, is not of first importance from a dietetic standpoint, because nutritionists believe human beings rarely suffer for lack of phosphorus unless the diet is so bad that several other nutrients are deficient at the same time. Other food-composition problems that are far more urgent have prior claims on the chemists' attention.

Iron compounds are by no means alike in their value to the body. Some, the soluble inorganic compounds, are generally admitted to be effective nutritionally while others, complex organic compounds like hematin, are known to be almost if not completely inert. Chemists are attempting to develop methods that will distinguish available iron from iron that the body cannot use, but their efforts so far have not been entirely successful. No one denies that a determination of total iron in a leafy vegetable, for example, may be a very poor measure of the iron that vegetable will contribute to the body. Some progress has been made toward determining what part of the total iron is present in available form in a number of food materials, but much more chemical work in this direction is needed, and to accomplish the end in view, it must be performed in connection with biological experiments.

It has been established by means of experiments with laboratory animals that the quantity of total iron in a good many foods is not a measure of their value as a source of iron to the body. This method usually consists of feeding weighed quantities of the food under investigation as a supplement to the ration of rats first made anemic on a milk diet, and observing the rate of gain in hemoglobin that follows. It has been shown by several investigators that the gains on particular foods are significantly slower than they would be if all of the total iron were physiologically available. This indicates the need for further work to establish satisfactory chemical methods.

Further discussion of this subject from a more technical standpoint follows.
TECHNICAL NOTES ON MINERAL ANALYSIS

CALCIUM IN CABBAGES

The differences in calcium content between inner and outer leaves of cabbage, as shown in figure 1, are wide enough to merit careful consideration by chemists and nutritionists. The variations in calcium are shown in this chart as relatively wider than either those in solids or those in total ash. In fact, the variations in calcium are so great that a logarithmic scale is necessary to show the values for green and bleached leaves in proper perspective. The unshaded area represents the frequency of analyzed samples that were more or less bleached in the cases that were described, or assumed to be bleached in those reported only as "cabbage." Included with these samples are five from red or violet-colored cabbages which on inspection did not appear to differ materially in calcium content from the white or nearly white kinds. The shaded area represents the frequency of analyzed samples that were either dark-green outer leaves or leaves of the non-headed samples. In the upper distribution, based on calcium, it will be noted that the mean of the standard area is eight or nine times the mean of the unshaded and that the extreme is more than 20 times the lower mean.

The similar distributions based on solids and on ash show that there are distinctions between dark-green and bleached leaves in these constituents too; but here the degree of variation is not nearly so great. Attention is called to the position of the two samples of savoy cabbage which, so far as we know, are the only ones of this variety that have been analyzed as the inside portion of the head. This variety is light green in color throughout the head, possibly because it is not tightly headed. At any rate it is not white or completely bleached, and there are several varieties other than savoy which are like it in being loosely headed and light green to the center of the head. The assumption is that other varieties that resemble savoy in color will be similar in calcium content, but actual evidence on this point is lacking.

If calcium, even more than total solids or total ash, is associated with greenness, it seems obvious that a comparison between varieties that are white inside and savoy, as well as other kinds that are light green, should be made in the analytical laboratory. The light-green headed kinds would be distinctly superior, it seems, as sources of calcium, but chemists, horticulturists, and physiologists apparently have not recognized this as a problem; none of the analyses of cabbage made incidentally to their problems has provided a direct answer to the question.

CALCIUM IN SOYBEANS

A study has been made of the available data on calcium variations in immature soybeans, that is, in the green-vegetable stages of certain varieties that agronomists and home economists have selected as suitable to use in this way. This study, based chiefly on the work of two laboratories (1261), covers 78 samples, the majority of which are on 11 varieties picked at intervals during ripening. The investigations on this vegetable are better designed in several respects than those on most foods, and the results here admit of drawing some generalizations. According to these data it appears that varietal and other differences in calcium are so wide that they tend to obscure the changes associated with advancing maturity, but the latter are by no means insignificant.

Results on the entire 78 samples give an average of 0.074 percent of calcium (0.034 to 0.109 percent) on the fresh basis and 0.251 percent of calcium (0.161 to 0.356 percent) on the dry basis. Chemists usually prefer the dry basis on the ground that the dry substance is more nearly constant in composition. The deviations are not quite so wide, relatively, in the data on the dry basis as on the fresh, but even at best these variations are fully as wide as those in total solids on the fresh basis. Total solids average about 30 percent and range from 16 to 38.

Varietal differences are probably chiefly responsible for the wide variations in calcium content as expressed on the dry basis, although maturity has some effect and soil differences and other factors not yet studied may also play some part. The data indicate that as the seed matures the total solids and the calcium on the fresh basis increase rather steadily, while the calcium on the dry basis decreases.
somewhat. Thus the younger, more succulent seeds, having less than 30 percent of solids, average 25 percent of solids and 0.068 of calcium, while the older seeds average 34 percent of solids and 0.080 of calcium in the original material. This increase coincides with a small but significant decrease in the calcium as a percentage of the dry matter.

It is customary in estimating the mineral content of a diet to use a single

Figure 1.—Frequency distributions showing calcium (A), solids (B), and ash (C) of bleached and unbleached samples of the common cabbage (Brassica oleracea capitata). Among these three constituents calcium shows the greatest variation. The mean in each case is the mean of data on the bleached or partially bleached samples (including two of savoy cabbage). For calcium, the mean is 46.0 mg. per 100 gm.; for solids it is 7.6 percent; and for total ash it is 0.72 percent. Frequencies are shown in percentages of these means, using a logarithmic scale. In this way the very high calcium values for unbleached cabbage can be given on the same scale as the low ones for bleached cabbage, and still show the variation in the latter.
calcium figure—expressed as a percentage of the fresh material—to represent any particular vegetable, disregarding all such variations as those under consideration here. The fresh green vegetable might be estimated at one figure and the mature seed in the air-dry form at another, but generally no finer distinction is feasible. Thus a single figure for calcium in green vegetable soybeans, say 0.074 percent, would ordinarily be used for any kind that was not fully mature. A general estimate of 0.251 percent of the dry matter is slightly better as an estimate than the average that disregards differences in maturity or in total solids; but even this small improvement in making estimates has no practical value in calculating a given diet unless either the stage of maturity or the moisture or total solids content of the particular sample is known.

In preparing tables it would seem that the calcium content of each variety might be given separately. This would offer a logical solution to the problem, since varietal differences appear to be of most importance; but there are many varieties that might be used, and data are available for only a very few of them. Further experiments may show that the varieties that tend to have more calcium have certain other characteristics in common; and as evidence is accumulated it may be feasible to present data on several classes of soybeans according to type or variety.

Green vegetable soybeans taken as a whole are apparently no more irregular in their calcium content, relatively, than the bleached leaves of cabbage; but since they are a richer source of calcium, the absolute errors introduced into diet estimates by using a single value for all varieties and stages are potentially much greater. Calculations on a day’s diet that contained a single helping of 100 grams or 3½ ounces of the vegetable could be in error from this source alone by 35 or 40 milligrams, and this would correspond to an error of about 5 or 6 percent of the daily calcium standard for an adult man.

The two examples, cabbage and soybeans, were chosen not as extreme cases but to show, from material at hand, the variability in foods and its bearing first on the preparation of food-composition tables and finally on dietary calculations.

**AVAILABLE IRON**

One method for determining the ionizable iron in foods, using the dipyridyl reagent, gives results in a number of foods that parallel the biological effect, that is, the hemoglobin response, to some extent (512, 1029). The parallel is not complete, however. The gain in hemoglobin is even slower on some foods than would be expected if the body could make good use of all of the iron determined as ionizable by this chemical method (1080). Such lack of correspondence between the quantities that are ionizable and the physiological effect may be due to some other property of the food that hinders the utilization of the iron by the body, or to peculiarities in the biological response of the individual (456, 457). In spite of this lack of agreement, the dipyridyl method may still be suited to measure the kind of iron that the body can utilize when conditions are favorable. In any case, however, further work is needed to develop a more acceptable chemical measure of the quantity of iron that may potentially function as available iron in nutrition.

Nutritionists can now say with some certainty that part of the iron in foods is in effect inert, and that the part that is inorganic and soluble is in a form that, potentially at least, can be utilized by anemic animals. Determinations of ionizable as well as total iron in foods, then, are much to be desired; until further developments, the quantity of ionizable iron in foods, determined by the current modification of the existing method, is the best chemical index we have to the way the food will perform as a source of iron for the body. It has been shown elsewhere in this Yearbook (p. 197) that progress in establishing the iron requirements of human beings can also be advanced when a sharper distinction can be made between iron that is physiologically available and that which is not.