IN ADDITION to analyzing foods for their content of water, protein, fat, carbohydrate, and minerals, the modern food chemist must determine their vitamin content. Methods for doing this are still difficult and tedious, though the recent discovery of several of the vitamins in pure forms will be a great help. This article gives lists of foods that are exceptionally good sources of vitamins A, C, D, thiamin, riboflavin, and nicotinic acid. The author also tells how the vitamin content of foods is affected by various conditions of production, storage, processing, and cooking, and suggests some practical ways to prevent undue vitamin losses.

Some twenty-odd years ago the public responded to its introduction to vitamins with a single question: "What good are they?" This question was dramatically and convincingly answered by the production of deficiency diseases in experimental animals receiving diets lacking these important nutrients. Interest immediately centered in discovering vitamin-containing foods which could prevent or cure such deficiency diseases in man, and a long series of tedious experiments was begun in which one food after another was tested on laboratory animals to determine its importance as a vitamin carrier.

Qualitative tables were set up showing what vitamins were present in certain foods, but these soon proved insufficient. It had become evident that vitamins play an important part in health and well-being, and it was seen to be essential not only to learn where to find them but to ascertain in what quantities they are available. And so from the original crude biological tests more carefully controlled meth-
ods were gradually devised and units were adopted for measuring the exact vitamin content of a food. Just as it was once arbitrarily decided to let the weight of a grain of wheat be the unit upon which to build the English system of weights, so in the present case it was agreed that a certain defined response in laboratory animals would indicate the presence of 1 unit of vitamin. This is the biological method of measurement.

Meanwhile, the chemical identification of several of the vitamins has aroused interest in finding chemical methods of measurement. The amounts of vitamin A, carotene, and ascorbic acid in foods are now being determined chemically by several investigators, with varying degrees of success.

Knowledge of the vitamin content of foods is essential in analyzing human dietaries and is necessary in providing a practical means of establishing vitamin requirements and in recommending foods that will best meet these requirements.

As the list of vitamin-containing foods grew, it became apparent that each vitamin has its own characteristic distribution. An attempt is made here to point out the more important sources of the different vitamins (255, 363) and to indicate some of the factors that influence and limit the vitamin content of foods.

**NATURAL OCCURRENCE OF VITAMINS**

**VITAMIN A**

Vitamin A activity was early associated with highly pigmented foods, particularly those having a deep green or yellow color. This association became extremely puzzling when it was discovered that vitamin A itself is an almost colorless substance that occurs only in a limited number of animal and marine foods. It was some time before scientists recognized that certain yellow-orange pigments, which are contained in many plant and some animal foods, are changed over into vitamin A in the body. These substances, belonging to a class of pigments known as carotinoids, are precursors of the vitamin, and are often referred to as provitamin A. The yellow-orange color of provitamin A may be masked in some foods by the presence of chlorophyll (the green coloring matter in plants), or by other pigments such as lycopene (the red coloring matter in tomatoes). The depth of color of a green or yellow plant food is often a rough indication of the amount of provitamin A that it contains. For example, yellow corn is richer in provitamin A than white corn; sweetpotatoes contain more than potatoes; and green leaves are a better source of this pigment than bleached leaves. On the other hand, there are a few very highly colored foods, such as cranberries and beets, that display little or practically no vitamin A activity.

Although animal foods may contain besides vitamin A some provitamin A which influences their color, depth of color in animal foods is never a dependable index of their vitamin A activity. For instance, although egg yolks generally contain these vitamin A-active pigments in varying amounts, by controlled feeding of the hen it is readily possible to produce highly pigmented egg yolks that contain practically no

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1 Italic numbers in parentheses refer to Literature Cited, p. 1075.
vitamin A activity. It is equally easy to produce pale-colored yolks that are exceedingly rich in vitamin A.

Foods in which vitamin A and provitamin A occur are listed in table 1.

<table>
<thead>
<tr>
<th>Type of food</th>
<th>Excellent sources</th>
<th>Good sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal products</td>
<td>Fish-liver oils, liver, fish roe, egg yolk, butter, cheese.</td>
<td>Cream, kidney, oysters, whole milk, red salmon.</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Kale, spinach, dandelion greens, dock, escarole, chard, lamb's quarters, turnip tops, green lettuce, collards, water cress, Chinese cabbage, broccoli, mustard greens, beet greens, carrots, sweet potatoes, yellow squash, sweet peppers, red tomatoes, green peas, green beans.</td>
<td>Green asparagus, okra, Brussels sprouts, globe artichokes, yellow tomatoes.</td>
</tr>
<tr>
<td>Fruits</td>
<td>Apricots, papayas, mangos, prunes, yellow peaches.</td>
<td>Avocados, guavas, cantaloups, blackberries, black currants, blueberries, bananas, pineapples, green and ripe olives, dates, deep-yellow juice oranges, yellow corn meal.</td>
</tr>
<tr>
<td>Cereal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**VITAMIN D**

The natural distribution of vitamin D appears to be limited to a comparatively few animal and marine foods; as yet there is insufficient evidence to establish its occurrence in foods of plant origin. Cod-liver oil had been outstanding as an effective cure for rickets even before the recognition of vitamin D, a deficiency of which was found to be the cause of this disease. For many years after the discovery of vitamin D, cod-liver oil was the richest known source of this vitamin. Now it is known that a number of other fish-liver oils, such as those of halibut, tuna, salmon, sardine, and swordfish, outrank cod-liver oil in vitamin D activity, some of them being many times richer in this vitamin than cod-liver oil.

On the other hand, some foods of plant origin contain a substance that is changed into vitamin D upon irradiation with ultraviolet light. Animal foods contain a similar substance which can be activated by irradiation. The ultraviolet rays may be furnished either by the sun or by so-called sun lamps. This method of supplying vitamin D through the irradiation of foods is known as the Steenbock process, from the name of its discoverer. Since one of these provitamin D substances exists in the human body, it is possible to supply an individual with vitamin D by exposure of the body to ultraviolet light.

In addition to foods enriched with vitamin D by the Steenbock irradiation process, the following animal products are natural sources of the vitamin: ²

Excellent sources: Fish-liver oils and egg yolk (from hens on diet high in vitamin D).
Good sources: Salmon, sardines, eggs, and butter.
Small amounts: Liver, cream, whole milk, and oysters.

² These foods and those listed as sources of the other vitamins have been classified on the basis of equal weights. Consequently their vitamin value in the diet depends not only upon vitamin content but also upon the quantities eaten. A food which contains only a fair amount of vitamins may become a good or an excellent source if liberal quantities are used. Likewise, a food having a very high concentration of vitamin may be included so infrequently or in such small amounts that it offers no real vitamin contribution.
Methods for determining the amounts of vitamin E in foods have not been so well worked out as for some of the other vitamins, and less is known about its quantitative distribution. It appears to occur in a great many foods, at least in small quantities. The germ portion of the wheat grain is an especially rich source, while vegetable oils, green leaves, and eggs contain considerable amounts. Scientists at the University of California, who have been interested in vitamin E for a number of years, have published a report in which they discuss its general distribution (348).

ASCORBIC ACID (VITAMIN C)

In his efforts to alleviate scurvy among sailors, James Lind, a surgeon in the British Navy, in 1747 found orange and lemon juices effective in curing this condition. By 1795, well over a century before ascorbic acid was discovered, the British Navy was regularly administering lime juice to sailors for the prevention of scurvy. Today citrus fruits are universally recommended, and tomatoes, although containing less ascorbic acid than most citrus fruits, have proved to be a popular and very valuable source of this vitamin.

In some countries it has been said that the potato has been extremely valuable in decreasing the incidence of scurvy. Potatoes are not a particularly rich source of ascorbic acid, but considering the relatively large quantities in which they are generally used, they may contribute important amounts of this vitamin to the diet. Foods containing ascorbic acid are listed in table 2.

<table>
<thead>
<tr>
<th>Type of food</th>
<th>Excellent sources</th>
<th>Good sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal products</td>
<td>Liver, brain</td>
<td>Kidney</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Collards, turnip greens, mustard greens, kale, water cress, spinach, dandelion greens, sweet peppers, kohlrabi, rutabagas, turnips, Brussels sprouts, cauliflower, cabbage, broccoli, asparagus, fresh and canned tomatoes, green peas, corn salad, radishes.</td>
<td>Endive, cucumbers, potatoes, sweet potatoes, green beans, parsnips, rhubarb, leeks, onions, globe artichokes.</td>
</tr>
<tr>
<td>Fruits</td>
<td>Guavas, mangos, oranges, lemons, grapefruit, tangerines, currants, strawberries, gooseberries, raspberries, cantaloupes.</td>
<td>Pineapples, cherries, cranberries, papayas, bananas, peaches, apples, avocados, watermelon.</td>
</tr>
<tr>
<td>Seeds</td>
<td>Sprouted seeds.</td>
<td></td>
</tr>
</tbody>
</table>
nuts—thiamin occurs in many animal and marine foods. A curious observation, which is as yet without explanation, indicates that lean pork is an exceptionally rich source.

Since the chemical isolation of thiamin has made possible its use as a standard for vitamin B1 assay, methods for determining the quantity in foods have greatly improved. In order to extend the meager reliable information regarding the thiamin content of foods, the Bureau of Home Economics tested some 90 foods for thiamin content during 1938–39.

A list of foods containing thiamin in varying amounts is given in table 3.

### Table 3. Food sources of thiamin (vitamin B1)

<table>
<thead>
<tr>
<th>Type of food</th>
<th>Excellent sources</th>
<th>Good sources</th>
<th>Fair sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal products</td>
<td>Lean pork, chicken, kidney, liver.</td>
<td>Egg yolk, brains, lean beef, lean mutton, fish roe, codfish, sardines, whiting.</td>
<td>Fresh milk (whole or skim).</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Green peas, green lima beans.</td>
<td>Potatoes, sweet corn, sweetpotatoes, Brussels sprouts, cauliflower, cabbage, mushrooms, spinach, turnip greens, water cress, garden cress, lettuce, collards, kale, onions, leeks, tomatoes, wax and green beans, parsnips, beets, carrots.</td>
<td>Turnips, broccoli, kohlrabi, eggplant.</td>
</tr>
<tr>
<td>Fruits</td>
<td>Wheat germ, corn germ, rye germ, rice polishings, wheat bran, oats, whole-grain wheat, rye, barley, brown rice, peanuts, soybeans, cowpeas, navy beans, dried peas.</td>
<td>Prunes, avocados, pineapples, oranges, grapefruit, tangerines, dates, figs, plums, pears, apples, cantaloupes.</td>
<td>Bananas, watermelons, raspberries, blackberries.</td>
</tr>
<tr>
<td>Seeds</td>
<td>Germ portion of wheat, rice polishings, peanuts, soybeans.</td>
<td>Hazel nuts, chestnuts, brazil nuts, walnuts, almonds, pecans.</td>
<td></td>
</tr>
</tbody>
</table>

**RIBOFLAVIN (VITAMIN G)**

Riboflavin, one of the more recently isolated vitamins, has an extremely wide natural distribution. Milk, eggs, meat, green leafy vegetables, whole cereals, and legumes all furnish liberal quantities. Glandular meats such as liver, kidney, and heart are better sources than the muscle meats, and dark meats contain more than light ones.

Food sources of riboflavin are given in table 4.

### Table 4. Food sources of riboflavin (vitamin G)

<table>
<thead>
<tr>
<th>Type of food</th>
<th>Excellent sources</th>
<th>Good sources</th>
<th>Fair sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal products</td>
<td>Liver, kidney, heart, lean muscle meats, eggs, cheese, dried (whole or skim), condensed, and evaporated milk.</td>
<td>Fresh (whole or skim) milk, buttermilk, whey.</td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td>Turnip tops, beet tops, kale, mustard greens.</td>
<td>Peas, lima beans, spinach, water cress, collards, endive, broccoli, green lettuce, cabbage, cauliflower, carrots, beets.</td>
<td>Bananas, cured figs, grapefruit, oranges, apricots, guavas, papayas, muskmelons, apples.</td>
</tr>
<tr>
<td>Fruits</td>
<td></td>
<td>Pears, avocados, prunes, mangosteen, peaches.</td>
<td></td>
</tr>
<tr>
<td>Seeds</td>
<td>Germ portion of wheat, rice polishings, peanuts, soybeans.</td>
<td>Whole-grain wheat, dried legumes.</td>
<td></td>
</tr>
</tbody>
</table>

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6 See footnote 4, p. 288.
NICOTINIC ACID (PELLAGRA-PREVENTIVE FACTOR)

Probably no vitamin-deficiency disease is more prevalent in the United States than pellagra, yet the factor or factors effecting its cure are still only partly understood. Only recently has the value of nicotinic acid in the prevention and treatment of this disease been recognized.

The Public Health Service has made a rather extensive study of foods which have pellagra-preventing properties. Over a period of years, certain foods have been found by trial to be more or less effective in preventing or curing pellagra in human beings. Those known to be most effective are lean meats, chicken, liver, green leafy vegetables, legumes, and tomato juice.

A list of good to fair sources of nicotinic acid follows:

Animal products: Liver, salmon, rabbit, fresh and corned beef, lean pork, chicken, buttermilk, egg yolk, skim milk (fresh and dried), evaporated milk, and haddock.

Vegetables: Green peas, collards, turnip greens, kale, tomato juice, cowpeas, soybeans, green cabbage, spinach, and mustard greens.

Seeds: Wheat germ, peanut meal, and green (dried) peas.

OTHER VITAMINS

Vitamin K, the antihemorrhagic factor, is known to occur in large quantities in green leaves. Withering or yellowing of the leaves appears to have no effect on the vitamin. Flowers, roots, and seeds contain much less than green leaves (253).

Experiments with laboratory animals have proved the existence of several vitamins other than those discussed, but practically nothing is known concerning their importance in human nutrition.

FACTORS AFFECTING VITAMIN CONTENT OF FOODS

A great many factors affect the vitamin content of foods. Some are environmental influences which can be only partly controlled; others are the result of artificial processes carried out in the attempt to preserve and prepare foods for human consumption. Such factors are universally recognized, but their specific influences on the different vitamins in various classes of foods are still little understood.

The physiological functions of the vitamins, although by no means clearly understood, undoubtedly determine the site of vitamin concentration in plants and animals. In plants ascorbic acid is always present in greatest amounts in the growing parts, and both ascorbic acid and vitamin A are more concentrated in the protective covering, or skin, and in the fleshy portion directly beneath the skin than in the inner flesh.

In animal foods likewise, the vitamins occur in greater concentration in certain body tissues. Liver is the storehouse for many of the vitamins and is thus richer in these nutrients than are muscle meats. Riboflavin occurs in larger quantities in dark meat than in light meat.

VARIETY, SOIL, AND CLIMATE

The variety of plant and the type of soil are factors influencing vitamin content (1068, 1146). Over these, man has only partial control.

\footnote{See footnote 4, p. 288.}
He is frequently restricted to certain varieties of fruits and vegetables best adapted to a given region. The weather conditions and the seasons further influence vitamin formation. An interesting observation made by members of the Bureau of Plant Industry indicates that oranges picked from outside branches well exposed to sunlight contain more ascorbic acid than shaded fruit grown on the same tree.

**DEGREE OF MATURITY**

The stage of maturity of many plant foods also has an effect on vitamin content \( (358) \). For example, the vitamin A, thiamin, and ascorbic acid content of tomatoes increases with maturity. In corn, the vitamin A increases until the seed is fully ripened, while ascorbic acid decreases with maturity and ripening. Likewise, as green peas mature the ascorbic acid content diminishes. The Bureau of Plant Industry found that green oranges contain more ascorbic acid than the fully ripened fruit. Spinach, snap beans, and rhubarb show no significant change in ascorbic acid value as they become mature \( (1146) \).

**FEEDING PRACTICES AND BREED**

The vitamin value of animal products such as milk and eggs is dependent to a considerable extent upon the diet of the cow and hen \( (273, 275, 385, 1056) \). At present many poultry and dairy managers recognize the value of feeding vitamin-rich foods for the production of vitamin-rich eggs and milk. Pasture-fed cows give milk that is richer in all the vitamins than stall-fed animals, and plenty of sunshine for the cows assures milk richer in vitamin D.

As the period of lactation progresses, the vitamin A content of milk decreases \( (385) \), while the quantity of thiamin remains practically constant. Eggs at the beginning of the laying season contain more vitamin A than those produced later by hens receiving the same diet during the entire period \( (1056) \).

There is also evidence that the breed of cow may slightly influence the vitamin content of milk \( (410) \).

**PRESERVATION AND STORAGE**

Very little of our food comes directly from the garden to the table. Much of it is canned, frozen, or dried for later use, when it may be either unavailable fresh or prohibitive in price for the average individual. A large part of the unprocessed food may be delayed for a considerable time in getting to market, held in the market itself, or kept in our own pantries and refrigerators before it is finally prepared and served.

This unavoidable temporary storage of food is always accompanied by certain vitamin losses \( (358, 1146) \). Type and condition of the food and the length and temperature of storage all influence the degree of loss. Riboflavin, nicotinic acid, and vitamins D and E appear to be little affected during storage; but vitamin A and thiamin are gradually lost, and there may be serious destruction of ascorbic acid.

The effect of storage on ascorbic acid, of all the vitamins, is best understood. As soon as fruits and vegetables are gathered, certain changes take place in their structure that allow a gradual destruction of ascorbic acid. Certain enzymes that are present hasten this
VITAMIN CONTENT OF FOODS

Destructive action. Thus, delays in marketing or the holding of vegetables like spinach, beans, and peas in household refrigerators or pantries too long before they are used may result in considerably decreased ascorbic acid content. Any bruising, peeling, cutting, chopping, or shredding of the food breaks down the cell walls, frees the enzymes mentioned, and thus accelerates ascorbic acid loss through oxidation (362). This explains the recommendation to prepare chopped fruit and vegetable salads immediately before use. The acid in such foods as tomatoes, citrus fruits, and rhubarb helps to preserve ascorbic acid, and extracted juice from these may be stored in the refrigerator for 2 or 3 days and still retain considerable quantities of this vitamin.

Freezing

There is very limited information on the effect of freezing and freezing operations on vitamins other than ascorbic acid (358, 360, 586). As a matter of fact, freezing itself appears to have no destructive action upon the vitamin content of foods. Losses sometimes attributed to freezing generally occur before the foods are frozen or are a result of improper handling during and after freezing. For example, the manufacturing operations concerned with shelling, washing, and blanching of lima beans and peas have often been found to result in a loss of as much as 50 percent of the ascorbic acid. Slow freezing, slow thawing, or storage of the frozen product above 0°F. (a temperature lower than zero is preferable (587)) adversely affects the vitamins. Frozen foods, especially vegetables such as peas, beans, and spinach, rapidly lose ascorbic acid if allowed to stand after thawing, and it is generally recommended that cooking be started while they are still in the frozen condition. Fruits which are to be used uncooked should be served immediately after thawing.

Drying

Foods lose vitamin A, thiamin, and particularly ascorbic acid during drying (358), and if the dehydration process is prolonged, these vitamin losses may be serious. Several investigators have found sun drying more destructive than artificial dehydration. Sulfur dioxide, frequently used in commercial practice, tends to prevent the destruction of vitamin A and possibly of ascorbic acid, but does not conserve thiamin. In fact, thiamin is readily destroyed when sulfur dioxide is present.

Drying, however, is not always destrucive. The riboflavin values of dried and evaporated milks would indicate no appreciable destruction of this vitamin. Extremely meager evidence suggests no appreciable loss of vitamins D and E and nicotinic acid in foods due to drying.

Canning

Most vitamin losses in canning are due to oxidation (358, 362, 641). Consequently the aim in canning methods devised to preserve vitamin content should be to exclude air from the hot food just as much as possible. The so-called open-kettle method of canning with subsequent transfer of the hot food to containers permits greater vitamin
destruction than methods in which the foods are processed directly in the jars. Removing the air from the containers before processing further helps to keep down vitamin loss by oxidation. It also minimizes the loss of vitamins during storage of the canned material.

As in cooking, acid foods retain more of their vitamin content during canning than nonacid ones. After canning, citrus fruits and tomatoes, for example, are still excellent sources of ascorbic acid, even though this is the most easily destroyed of the vitamins.

**COOKING**

Today the art of cooking is more than the production of a tasty dish attractively served; it also includes the conserving of food values (358, 362). While certain vitamin losses during cooking are unavoidable, considerable quantities of these valuable protective substances are needlessly thrown away every day.

Under certain conditions, the oxygen in the air changes vitamins into other substances that do not have the protective properties of vitamins. This process of oxidation is accelerated by heat. Thus, stirring air into foods while they are cooking or sieving them while they are still hot is a frequent cause of vitamin destruction (577). An alkaline substance like soda, frequently used to preserve green color in vegetables, also intensifies oxidation, which has a destructive effect on all of the vitamins. Acid, on the other hand, either when added or naturally occurring as in tomatoes and many fruits, helps to protect the vitamins in food during cooking.

In the case of ascorbic acid, oxidation is accelerated by an enzyme referred to as ascorbic acid oxidase (623) and also by certain metals such as copper. The enzyme is inactivated by heat; thus, for the conservation of ascorbic acid, it is desirable to employ a method of cooking that rapidly raises the temperature of the food to the boiling point. It was found, for example, that about one-fourth of the ascorbic acid of cabbage was destroyed before boiling and very little after the boiling point was reached, although a considerable quantity was dissolved in the cooking water (427).

Ascorbic acid, thiamin, riboflavin, and nicotinic acid all dissolve readily in water; therefore the water in which foods are cooked may acquire considerable amounts of these vitamins. The more water that is used, the greater will be the amount of vitamin dissolved out of the food. It has been pointed out that the cooking water which remains after preparing certain vegetables may be as rich a source of ascorbic acid as tomato juice (1146). It is recommended that cooking be done in as little water as possible, and that the water drained from cooked vegetables be served in gravies, sauces, or soups; otherwise, valuable food substances will be lost. The insolubility of vitamins A, D, and E in water prevents loss of these vitamins in this way.

Either steaming or the so-called waterless method of cooking dissolved out less of the water-soluble vitamins than boiling. On the other hand, the more rapid process of boiling helps somewhat to prevent ascorbic acid destruction. These methods of cooking appear to have no significant destructive effect on the vitamins other than ascorbic acid and, to a lesser extent, thiamin. Long cooking processes such as stewing permit greater vitamin losses. Frying is probably
the most destructive of the ordinary cooking methods and may result in a complete loss of ascorbic acid, considerable loss of thiamin, and significant destruction of vitamin A. Limited experiments indicate that baking causes somewhat less destruction (246, 359, 362, 1205).

Far too little is yet known about the effects of various methods of cooking on the vitamin content of different foods. Ascorbic acid, as the most easily destroyed of the vitamins, has been most intensively studied, but even with it much is still to be learned concerning the effects of various processes.

Most of the foods of man receive some treatment before they reach his dinner table. It is from these cooked, canned, frozen, dried, and stored foods that much of his vitamin requirement must be supplied. In order to establish these requirements and meet them adequately nutritionists realize the great need for extending the present meager knowledge concerning the vitamin losses which occur as a result of these various treatments.

**SUGGESTIONS FOR SAVING VITAMINS**

So far as the homemaker is concerned, present knowledge might be summed up in the following practical suggestions for the preservation of vitamin values in cooking and serving foods:

- Don’t stir air into foods while cooking.
- Don’t put them through a sieve while still hot.
- Don’t use soda in cooking green vegetables.
- In boiling foods, raise the temperature to the boiling point as rapidly as possible.
- Use as little water as possible.
- Don’t use long cooking processes such as stewing when shorter methods are feasible.
- Don’t throw away the water in which vegetables have been cooked. Use it in making gravies, sauces, and soups.
- Don’t fry foods valuable for their content of vitamins A, B₁, or C.
- Prepare chopped fruit and vegetable salads just before serving.
- Start cooking frozen foods while they are still frozen.
- Serve raw frozen foods immediately after thawing.