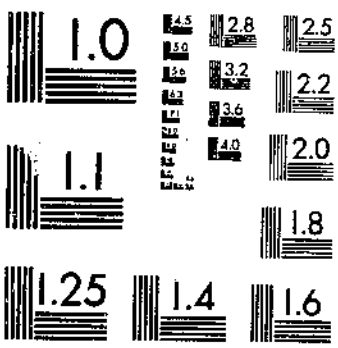
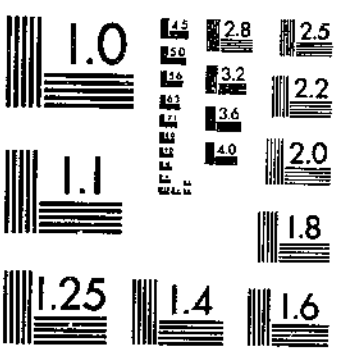
LB:802 (1941)
USDA TECHNICAL BULLETINS
UPDATA
THE VITAMIN A VALUES OF 128 FOODS AS DETERMINED BY THE RAT-GROWTH METHOD
BOOHER, L. E. MARSH, R. L.
1 OF 1

START

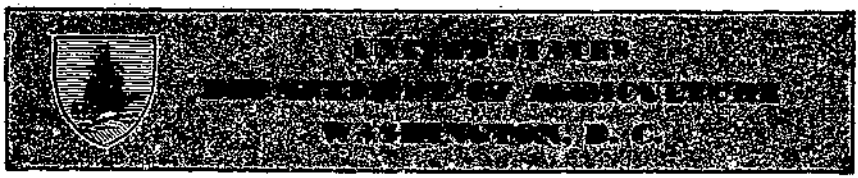


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Technical Bulletin No. 802 • December 1941



The Vitamin A Values of 128 Foods as Determined by the Rat-Growth Method

By LELA E. BOOHER, *senior nutrition chemist*, and ROSEMARY LOUGHLIN MARSH, *assistant home economics specialist, Foods and Nutrition Division, Bureau of Home Economics*[1]

CONTENTS

INTRODUCTION

Vitamin A as such occurs only in foods of animal origin. The vitamin A values of plant foods are due to the presence of one or more of the vitamin-A-active carotenoids, which include alpha carotene, beta carotene, gamma carotene, and cryptoxanthin. Since these four carotenoids can be converted into vitamin A in the livers of man and animals, they are frequently referred to as precursors of vitamin A.

The chief food sources of vitamin A itself (as distinguished from precursors) include fish liver and body oils, mammalian livers and kidneys, adipose tissues of fowls and mammals, livers of poultry, egg yolk, and milk fat.

The richest food sources of the vitamin-A-active carotenoids include green leaves and deep yellow-colored fruits and vegetables, such as carrots, pumpkin, sweetpotato, apricots, yellow peaches, mango, and papaya. In average American diets from 60 to 80 percent of the vitamin A value is derived from vitamin-A-active carotenoids.

Of the four vitamin-A-active carotenoids, beta carotene is much the most prominent in the plant kingdom; alpha carotene and especially

[1] The authors make grateful acknowledgment of the laboratory assistance given by Robert E. Smith, under scientific helper, and Helen L. Roumasset, junior scientific aide.

gamma carotene and cryptoxanthin have a very limited distribution in the natural foodstuffs of man and animals.

Beta carotene is the chief source of vitamin A value in green leaves, carrot roots, and red palm oil. It also occurs in milk fat. Alpha carotene comprises about 10 to 20 percent of the carotene in carrot roots, 30 to 40 of that in red palm oil, 25 of that in bananas, and about 15 percent of the carotene in mountain-ash berries. Gamma carotene is found in small proportions in carrot roots and certain green leaves. Cryptoxanthin is found in egg yolk, green grass, yellow corn, and in the red calyx and fruit of the Chinese lantern plant.

All vitamin-A-active substances possess a polyene chain and at least one beta ionone ring in their structures. No vitamin A activity has ever been observed in substances that do not possess these two chemical configurations.

Vitamin A has been crystallized at very low temperatures from ethyl formate, forming pale-yellow prismatic crystals (*2*).[2] The crystals melt at 63° to 64° C., are optically inactive and isotropic. The average extinction coefficient observed for vitamin A alcohol, $E\frac{1 \text{ percent}}{1 \text{ cm.}}$ at 328 millimicrons was 1,725, equivalent to a molecular extinction coefficient of approximately 49,500.

A second form of vitamin A, designated as vitamin A_2 and differing from the first by the presence of an additional —CH=CH— grouping, has been found to be the predominating form of vitamin A in fresh-water fish (*3*). Vitamin A_2 exhibits definite absorption bands at 280 and 350 millimicrons.

The vitamin-A-active carotenoids are orange-yellow polyene pigments. Because of their high degree of unsaturation they, as well as vitamin A, are readily oxidized by atmospheric oxygen, and all of these carotenoids may be hydrogenated to saturated compounds that are colorless. The vitamin-A-active carotenoids possess the constants shown in table 1.

TABLE 1.—*Constants for vitamin-A-active carotenoids*

Carotenoid	Molecular formula	Melting point	Absorption maxima in petroleum ether
		°C.	mμ
α-carotene	$C_{40}H_{56}$	187	478, 447.5
β-carotene	$C_{40}H_{56}$	183	483.5, 452, 426
γ-carotene	$C_{40}H_{56}$	178	495, 462, 431
Cryptoxanthin	$C_{40}H_{56}O$	169	485, 453

During its first convention in 1931, the Permanent Commission on Biological Standardisation of the Health Organisation of the League of Nations recommended that carotene be "provisionally" adopted as an International Standard of Reference for vitamin A. A composited sample of crystalline carotene served as a standard of reference until further knowledge revealed the fact that this preparation was not a pure substance but a mixture. At its 1934 international conference, therefore, this same Commission adopted 0.6 microgram of a specially prepared sample of pure beta carotene as the

[2] Italic numbers in parentheses refer to Literature Cited, p. 30.

International Standard of Reference for vitamin A. The International Unit of vitamin A is, therefore, the vitamin A activity of 0.6 microgram (=0.0006 mg.) of pure beta carotene. A sample of cod-liver oil carefully assayed in terms of the International Standard under the supervision of the United States Pharmacopoeia Vitamin Advisory Committee is available as a subsidiary standard. The vitamin A values in terms of International Units are, therefore, numerically the same as those in terms of United States Pharmacopoeia units.

The vitamin A values of foods reported in the scientific literature have not been summarized in this bulletin, but are included in a forthcoming publication of the Department of Agriculture entitled "A compilation of the vitamin values of foods in relation to processing and other variants."

By definition then, 1 gm. of pure beta carotene would carry 1.67×10^6 International Units of vitamin A value.

In the conversion of beta carotene into vitamin A in vivo the following equation is theoretically possible:

$C_{40}H_{56}2H_2O$	——>	$2\ C_{20}H_{29}OH$
1 mol, β-carotene		2 mols, vitamin A
536		572 parts by weight
1 gm.		1.067 gm.

If this equation is correct, then the potency of 1 gm. of vitamin A should be $1.67\times10^6/1.067=1.56\times10^6$ International Units.

A biological assay of crystalline carotene made by Dutcher and Guerrant (cited by Holmes and Corbet (*4*)) indicates a potency for vitamin A between 2,265,000 and 3,400,000 International Units per gram. A similar assay made by Emmett (cited by Holmes and Corbet (*4*)) indicates a potency of about 3,000,000 International Units per gram of pure vitamin A. Underhill and Coward (*10*) made biological assays of the anthroquinone-2-carboxylate and of the 2-naphthoate of vitamin A, and found that the potency calculated in terms of vitamin A alcohol corresponded to 3,181,000 and 3,424,000 International Units per gram, respectively. All of these assays indicate a biological potency on the order of 3.0×10^6 International Units per gram of vitamin A, instead of 1.56×10^6 International Units per gram as demanded by the theoretical equation. There is also evidence that alpha carotene, gamma carotene, and cryptoxanthin are half as active as beta carotene.

The chief reason for assuming that the conversion of beta carotene into vitamin A takes place in vivo by symmetrical fission is the superior potency of beta carotene as compared with the potency of alpha carotene, gamma carotene, and cryptoxanthin. If the fission did not occur at the central double bond of carotene, we might expect the reaction to proceed as follows:

$C_{40}H_{56}$ ——	$C_{20}H_{29}OH$ + decomposition products
536	286 parts by weight
1 gm.	0.533 gm.

This reaction would lead to a potency of $1.67\times10^6/0.533=3.1\times10^6$ International Units per gram of vitamin A. This potency for pure vitamin A is as near the biologically estimated potency for vitamin A as could be expected.

The precise chemical processes by which the vitamin-A-active carotenes are converted into vitamin A in the animal body are not fully understood. Since carotene, as such, has been found in the adipose tissue of animals, it would appear that some of the carotene, at least, may not be immediately converted into vitamin A. It is also possible that the animal organism may handle vitamin-A-active compounds in different ways not understood at this time but which yield the more or less constant potencies observed for the different vitamin-A-active compounds.

In making spectrophotometric analyses of vitamin A, the calculations generally assume that 0.3 microgram of vitamin A is equivalent to 1 International Unit, a figure assumed from biological assay work. In making biological assays of food materials, the measurement of physiological potency is made directly by comparison with the physiological potency of pure beta carotene. Such potency even when derived from a mixture of vitamin-A-active substances requires no special calculation and no assumptions with regard to the vitamin A equivalents of the substances. It is still a moot question whether the physiological potency of all vitamin-A-active materials in man can be reckoned from experiments made with vitamin-A-assay rats.

AVAILABLE METHODS FOR THE MEASUREMENT OF VITAMIN A VALUES

The choice of method best suited to the measurement of vitamin A activity depends both upon the nature of the material to be assayed and upon the particular objective the analyst desires to achieve. The available methods of measurement include colorimetric methods, spectrophotometric methods, and biological assay methods.

Colorimetric Methods

The intensity of the yellow coloration in prepared extracts measured against solutions of pure beta carotene or potassium dichromate has been used to estimate the carotene content and indirectly the vitamin A value of foods of plant origin. The accuracy of this method depends upon the care and completeness with which the carotene is extracted from the plant tissue and freed from admixture with xanthophylls and other yellow pigments possessing no vitamin A activity. In order to differentiate the amounts of the several vitamin-A-active carotenoids that might be present, it would be necessary to subject the extract to chromatographic fractionation.

The so-called Carr-Price reaction is based upon the observation that vitamin A in the presence of anhydrous antimony trichloride solution in chloroform yields a blue coloration. The carotenes react under the same conditions to produce a greenish-blue coloration. All substances having the polyene structure give color reactions with such reagents as concentrated sulfuric acid and other anhydrous acids and also with halides of polyvalent metals. Several investigations (*6*, *7*, *11*) of this color reaction have been made as a basis for developing a method for the estimation of vitamin A activity, giving special attention to details and conditions necessary to obtain quantitative results. Whether the blue coloration is measured using a Lovibond tintometer or a spectroscope, the test can only be counted upon to yield a rough

approximation of vitamin A value. When vitamin A and carotenes are present in the same samples, special modifications of the method are essential. The test can be carried out in a very short time, and its chief value lies in exploratory research and in obtaining a rough approximation of the vitamin A values of oils preliminary to their subjection to biological assay.

Spectrophotometric Methods

Each of the vitamin-A-active carotenoids shows characteristic absorption bands in the visible (blue and violet) region of the spectrum. The intensity of absorption depends upon the molar concentration of carotenoid and the depth of solution through which the light passes. The exact position of the absorption bands depends upon the index of refraction of the solvent used. Provided the analyses are conducted according to the most acceptable techniques available, including chromatographic fractionation of the extracts, spectrographic analyses of carotenes in food materials are quite satisfactory.

Vitamin A differs from the vitamin-A-active carotenoids in exhibiting no bands in the visible region of the spectrum. Instead it exhibits a fairly broad absorption band in the ultraviolet region of the spectrum with a definite maximum at 328 millimicrons in chloroform. Under appropriate conditions the intensity of absorption in this band can be used as a quantitative measure of vitamin A content.

Biological Assay Methods

The biological assay methods include the prevention of vitamin-A-deficiency symptoms in animals, the cure of vitamin-A-deficiency symptoms in animals, and animal-growth methods.

The preventive method is based on determination of the smallest supplement of the material under test that will just prevent the appearance of xerophthalmia or some other characteristic sign of vitamin A deficiency. Very little quantitative assay work on foods has been done by this method.

Female rats deprived of vitamin A show abnormal estrus with persistence of cornified cells in the vaginal epithelium. The cure of this condition has been made the basis for attempts to formulate a method for the quantitative determination of vitamin A values (*1*). The difficulty lies in estimating slight responses to small supplements of vitamin-A-active substances and for this reason the method is not well suited to precise measurements of vitamin A values.

The so-called single-feeding method (*5*, *8*) consists of providing young rats, previously depleted of vitamin A to a stage where growth has ceased, with a single dose of the vitamin-A-containing material to be tested. The results are interpreted on the basis of the length of survival and the area under the curve relating body weight to period of survival. In this way it is possible to compare the vitamin A potencies of different materials or of a given material with the potency of a standard of reference. This method possesses the advantage of providing a biological method for measuring the vitamin A values of single samples of perishable materials, probably at some sacrifice of accuracy in comparison with more standardized methods.

The rat-growth method is, of course, subject to variations and inaccuracies due to uncontrollable factors in animal responses. As

ordinarily conducted the rat-growth method is really a combination of rat-curative and rat-growth responses. For the present at least biological assays, of which the rat-growth method has been the most thoroughly standardized, afford the most reliable means for estimating the physiological potency of vitamin-A-active materials. Before employing this method, the analyst should make certain that the basal ration is complete in all respects except for the absence of vitamin A. The method is fairly expensive and time-consuming. When perishable fresh foods are assayed by the rat-growth method using an assay period of 4 or 5 weeks, it is necessary to include several successive batches of the food under test. In the end, therefore, the result is roughly equivalent to assaying a composited sample of several lots.

Since a biological assay method for vitamin A represents the nearest approach to a measurement of the biological value of vitamin A and the precursors of vitamin A, the most highly standardized method within this category, namely the rat-growth method, seemed to be the logical choice for measurement of these values in materials widely represented in human dietaries. The details of this method as used for the present study are presented in the following pages.

METHOD AND MATERIALS USED IN THIS STUDY

Selection and Management of Animals

Young albino rats about 3 weeks of age and weighing between 35 and 40 gm. were kept on a vitamin-A-deficient ration until they showed signs of xerophthalmia and had ceased to increase in weight. The vitamin-A-deficient ration was composed of the following:

	Grams
Extracted casein	180
Cottonseed oil	100
Dried brewers' yeast	150
Salt mixture	40
Cornstarch	530
Total	1,000

In addition, an oil solution of irradiated ergosterol was added to this basal ration in quantities sufficient to provide at least 3 International Units of vitamin D per gram of ration.

The animals were fed the vitamin-A-deficient ration ad libitum and had access to water at all times. The animals were weighed weekly for the first 2 weeks and more frequently thereafter as they approached the stage of stationary weight.

After the animals had remained stationary in body weight for at least 3 days, the members of each litter were separated and housed in individual cages with raised screen bottoms. One rat from each litter (the so-called negative control) was continued on the vitamin-A-deficient ration without supplement of any kind. The remainder of the rats from each litter were apportioned into carefully matched groups and provided three times a week with supplements of reference cod-liver oil or of the food item to be assayed. For most of the assays, two groups of animals were given supplements of the food item to be tested in quantities such that one group received twice the supplement given to the other group. For most assays, two other groups were given United States Pharmacopoeia reference cod-liver oil in supplements corresponding to a daily dosage of 1.0 and 2.0 U. S. P.

units of vitamin A, respectively, or a single matched group was given a daily dose of 1 or 1.5 U. S. P. units of vitamin A.

The reference cod-liver oil was diluted with refined commercial cottonseed oil so that 0.1 ml. or at most 0.2 ml. of the diluted product, administered by mouth from a graduated tuberculin syringe, would provide the requisite quantity of reference standard. The food supplements, in weighed portions, were placed in small receptacles accessible to individual assay rats.

During the experimental period of 4 or 5 weeks, the rats were weighed once each week.

Preparation of Special Ingredients Used in Experimental Vitamin-A-Deficient Ration

VITAMIN-A-FREE CASEIN

To 2 liters of 90-percent (by weight) ethanol in a 5-liter pyrex flask, 500 gm. of dry acid-precipitated commercial casein were added and the mixture refluxed with frequent agitation for 1 hour on a steam bath. The contents of the flask were then transferred rapidly without cooling to a Büchner funnel and filtered with suction. After thorough removal of the hot alcohol, the casein was returned to the flask and the process repeated, using 1.5 liters of the 90-percent ethanol. The casein was refluxed a third time with 1.5 liters of 95-percent (by weight) ethanol and finally washed on the Büchner funnel with 1 liter of fresh hot 95-percent ethanol. The extracted casein was then spread on a suitable tray and air-dried. The dried casein was sieved and stored in a clean, dry, covered jar to be used as needed.

SALT MIXTURE

Modified Osborne and Mendel salt mixture

The following solution was prepared in a large evaporating dish with the use of heat:

Iron citrate	grams	29.5
Water	liters	1.5
Citric acid crystals	grams	444.0

The following were added to the above solution:

KI (0.5 gm. in 250 ml.)	milliliters	40
$MnSO_4 \cdot 4H_2O$ (2.9 gm. in 250 ml.)	do	40
NaF (6.2 gm. in 250 ml.)	do	40
$K_2Al_2(SO_4)_4$ (0.61 gm. in 250 ml.)		
or		
$K_2Al_2(SO_4)_4 \cdot 24H_2O$ (1.13 gm. in 250 ml.)	do	40
Phosphoric acid (85-percent, sirupy)	do	284
Hydrochloric acid (36-percent)	do	517
Sulfuric acid (98-percent)	do	21
$CuSO_4 \cdot 5H_2O$	grams	.425

The following salts were mixed and added slowly (stirring) to the above solution:

Calcium carbonate	grams	539
Sodium carbonate	do	137
Potassium carbonate	do	565
Magnesium carbonate	do	91

The resulting salt mixture was dried and ground. These ingredients in quantities specified make about 1,700 gm. of dry salt mixture.

GROWTH RESPONSE OF ASSAY RATS ON THE VITAMIN-A-DEFICIENT RATION PLUS LIBERAL SUPPLIES OF VITAMIN A

A group of young rats that had reached stationary weights on the vitamin-A-deficient ration were subsequently used to test the suitability of the basal ration for promoting growth when the ration was supplemented with liberal amounts of crystalline carotene.

Carefully matched litter mates of this group, immediately after having attained stationary weight on the vitamin-A-deficient ration, were transferred to a ration composed of dry whole milk and ground whole wheat in the proportions of 1:2 by weight, supplemented with 4.3 gm. of lean beef per rat per day. Salt was added to this ration in the proportion of 2 percent of the weight of the wheat.

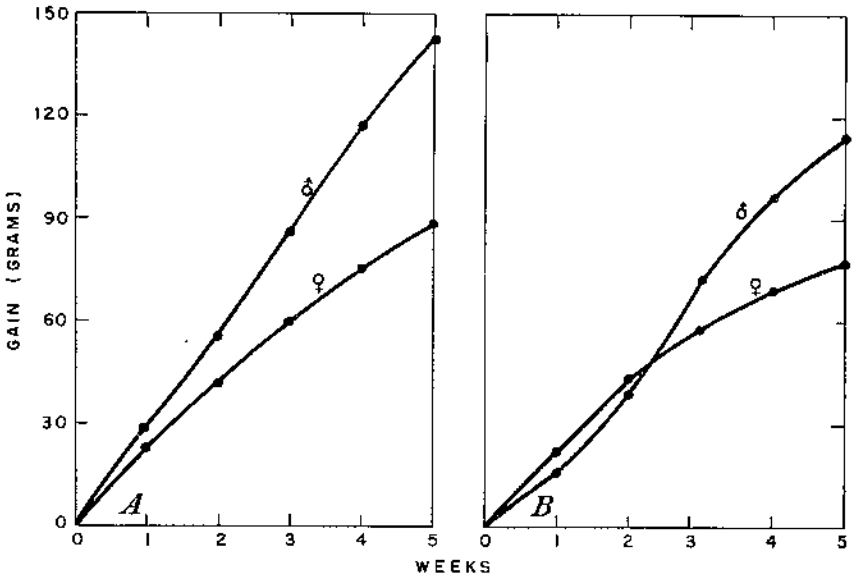


FIGURE 1.—Weekly weight increments of vitamin-A-assay rats: *A*, Rats receiving the vitamin-A-deficient ration plus liberal quantities of crystalline carotene; *B*, rats transferred from vitamin-A-deficient diet to a ration of dry whole milk, ground whole wheat, and daily supplements of fresh lean beef.

The comparative weight increments of these two groups of rats are given in figure 1 which shows that the animals in the group receiving the vitamin-A-deficient ration supplemented with crystalline carotene equivalent to 25 International Units of vitamin A daily increased in body weight at rates at least as great as those of the animals receiving the milk-wheat ration supplemented with lean beef.

The first limiting factor for growth of the assay rats, previously depleted of their vitamin A reserves by subsistence on the vitamin-A-deficient ration, is almost certainly vitamin-A-active compounds. When crystalline carotene was administered in liberal quantities as a supplement for young rats subsisting on this diet, growth rates substantially greater than the restricted growth rates induced in the assay animals were observed. These facts would seem to indicate

that the method used for vitamin assay yielded results which, in the main, were fairly good measures of vitamin A value. This does not mean that the vitamin-A-deficient diet was a perfect diet for the purpose or that the growth rates of animals receiving food supplements in addition to this diet could not have been augmented in some cases by other nutrients in these supplements than those which are vitamin-A-active. For the present, however, these potential imperfections in the rat-growth method, although recognized, are generally accepted and the method is considered reliable so far as practical considerations are concerned.

Since animals in the stock colony of this laboratory have been reared on the same ration of milk, wheat, and lean beef as was provided for the animals of this second experimental group and have successfully reproduced themselves for many generations, it may be concluded that the vitamin-A-deficient ration was of good nutritive value except for the absence of vitamin A. No breeding records were studied for animals reared on the vitamin-A-deficient ration supplemented with crystalline carotene.

METHOD OF CALCULATING VITAMIN A VALUES

U. S. P. reference cod-liver oil was used as the standard of reference for the vitamin A values reported in this bulletin. The accepted potency of the reference oil used for all but 14 of the values recorded in table 2 was 3,000 U. S. P. units (=3,000 International Units) per gram.

For 14 vitamin A values recorded in table 2, the new U. S. P. reference cod-liver oil with an assigned value of 1,700 U. S. P. units per gram of oil was used as the standard of reference. Since the U. S. P. unit is a generally accepted secondary standard for an International Unit of vitamin A, the latter designation only is used in subsequent discourse.

The biologic potency of the U. S. P. reference cod-liver oil with respect to vitamin A value was repeatedly checked against pure crystalline beta carotene during the course of this study. The six assay values obtained for the reference cod-liver oil in terms of beta carotene all fell within the limits of the assay values included in the average originally used to establish the vitamin A potency of the reference cod-liver oil.

One biologic assay value was determined for pure vitamin A alcohol using pure crystalline beta carotene as the standard of reference. In terms of the carotene, 1 gm. of vitamin A alcohol was observed to carry a potency of 2,700,000 International Units of vitamin A value.

The vitamin A potencies of the food items listed in table 2 were calculated from the data obtained as described in the preceding section of this bulletin. The average weekly weight increases were calculated for each group of rats that had received a given daily supplement of test food and for each group of the litter-mate control rats that had received 1, 1.5, or 2 International Units daily in the form of the reference standard of cod-liver oil. If both male and female rats were used in unequal numbers of matched sets, each sex was given equal weight. The average weekly weight increments for the rats on each level of test food were then plotted against the

corresponding daily supplement of test food administered as a vitamin A supplement. A straight-line relationship was assumed for the average weekly weight increments intermediate between those induced in the paired litter mates that had received the two different levels of supplement of test food. The daily supplement of test food, which presumably would have resulted in an average weekly increase in weight equal to that induced in the litter-mate controls that had received 1 or 2 International Units of the reference cod-liver oil daily was then determined by inspection. The complete data for any rat were discarded when the average weekly weight increment differed from the average of all the rats of the same sex on a given supplement by so large an amount that its inclusion would obviously disturb the accuracy of the results. In like manner, when an assay rat died before the test period was completed, its record was excluded from the calculations.

A critical discussion of the factors that are presumably responsible for the lack of consistency in response of vitamin-A-assay rats to vitamin A supplements to the extent of interfering seriously with the precision of the tests has already been presented by Swanson, Stevenson, and Nelson (*9*). Experiences gained during the course of conduct of the assays recorded in table 2 are in accord with the experience of these authors in showing that failure to eliminate vitamin-A-assay rats with definitely erratic response to vitamin A administration will most certainly decrease the precision and reliability of the assay.

In most cases the average weekly weight increment of the rats that received one of the two supplements of the reference cod-liver oil was intermediate between those of their litter-mate pairs, which had received two different levels of the food item under test. In a few cases the quantity of test food equivalent to 1 or 2 International Units of the reference cod-liver oil necessitated some measure of extrapolation. It is not feasible to present the experimental data for each set of paired litter mates together with the litter-mate controls, but the average weight increments for the group of rats on each supplement of the food items and of reference cod-liver oil are shown in table 2.

The evaluation of the vitamin A per 100 gm. of each food was made according to the equation $X = \frac{1, 1.5 \text{ or } 2 \text{ International Units}}{A} .100$ wherein X=units of vitamin A per 100 gm. of food under test, and A=grams of test food that presumably would induce an average gain in weight equivalent to that induced by the 1, 1.5 or 2 International Units of vitamin A in the form of reference cod-liver oil. These values are given in column 2 of table 2.

DESCRIPTION AND PREPARATION OF FOOD SAMPLES

The assays included in table 2 are experimental values determined in the nutrition laboratories of the Bureau of Home Economics. Most of the assays were made during the period July 1938 to December 1940.

The specimens of foods selected for assay were obtained from various sources. When possible, they were secured direct from the producer so that reliable data regarding their variety, habitat, and method of handling would be known. If necessity required that the

product be bought on the local markets of Washington, D. C., this same information was solicited. The foods were in excellent condition and were selected under the personal supervision of one of the laboratory staff. The assay of each one of the foods was made, insofar as possible, during its season of greatest abundance. Perishable foodstuffs were purchased on the average of twice a week during the course of the respective assays. Therefore, in most cases the vitamin A values for fresh meats and dairy products are equivalent to assay values of composited samples comprised of 10 or more different specimens.

Only the edible portions of the foods, prepared as for table use, were subjected to analysis for vitamin A values. All cooking procedures except those used for beef heart and carrots were carried out in a saucepan type of pressure cooker at 15 pounds pressure in a minimum amount of water and in quantities that would be appropriate for a family of three or four persons. The period of time used for the cooking was the minimum required to give a satisfactory table product. Overcooking was prevented by immersing the cooker, immediately after the cooking was completed, in cold water. All cooking liquors were included in the assays with the cooked product. When assays were made on both raw and cooked foods, paired samples of the same products were used. Any storage of perishable foods that was required was done at a temperature of $-17.8°$ C. (0° F.). The beef heart was cooked by boiling in a covered saucepan. The carrots were cooked in a moderate-sized pressure cooker.

Although it was not thoroughly appreciated at the beginning of this study the details of sampling and handling the specimens of raw green leaves had a significant effect upon the vitamin values obtained. In order to ensure satisfactory sampling, leaves, because of their inhomogeneity, require fine chopping or maceration. When this was done for any appreciable time before the supplements of raw green leaves were weighed and consumed by the animals, the vitamin A values were always lower than those obtained for the same product cooked. This difficulty could be greatly reduced by weighing the supplements immediately after preparation for sampling and by purchasing fresh samples for each day that supplements were fed. Further investigation of this matter indicated that the lower values for the raw green leaves as compared with paired samples that were cooked are due to the presence of an oxidative enzyme in the raw product rather than to an increased utilization of the carotene in the cooked product.

Raw frozen foods were sampled immediately after thawing. Cooking of frozen foods was started with the foods still in a frozen condition. The juices of the citrus fruits were extracted with a glass reamer and then strained through a 16-mesh wire sieve. All liquid supplements, as indicated in table 2, were measured in milliliters and the vitamin A values reported as International Units in 100 ml.

The detailed descriptions of the specimens of food assayed and the methods of preparing the samples of these to be fed as vitamin A supplements are as follows:

Almond.—Unblanched nut meats, bought on local market during June. A 3-pound sample was purchased and kept under refrigeration during the period of assay. The nut meats were finely chopped before sampling.

Apple.—Delicious variety, grown in the vicinity of Washington, D. C., purchased during October and November. The fruit was thinly pared, cored, and finely chopped before sampling.

Apricot.—Dried California, sulfured, stored approximately 3 years at −18° C., finely chopped before sampling.

Asparagus.—Palmetto variety, grown in South Carolina and purchased during May. The butt ends of medium green stalks were removed before cooking. The 10 lots used for the assay were finely chopped and mixed before sampling.

Avocado.—Grown in Florida, purchased during June and July. Twelve samples were used. After paring and removing the stone, the fruit was mashed preparatory to sampling.

Banana.—Fully ripened fruit grown in Jamaica, purchased during May and June. Ten fruits were included in the assay. The fruit was peeled and finely chopped for sampling.

Bean.—Golden Wax variety, grown in Maryland, purchased in August. The succulent pods were medium yellow in color. One 3-pound lot was purchased and kept under refrigeration during the period of assay. These were prepared for analysis in the same manner as the snap beans.

Fresh and dry lima beans of Henderson Bush variety, grown in Maryland. The fresh limas were light green in color, purchased in August; the dry limas were practically white, purchased in June. A single 6-pound lot of the fresh limas was cooked, mashed, and kept under refrigeration; portions of a single 5-pound lot of the dried limas were cooked twice each week and sampled as needed.

Snap beans, Early Bountiful variety, green fleshy pods, grown in Florida, purchased during December and January. Twenty-one paired samples were used for assay of raw and cooked products. The ends and strings were removed, and the beans finely chopped before sampling.

Navy beans, Michelite variety, dry mature seeds obtained from the Michigan Agricultural Experiment Station. A single 5-pound lot was used for the assay; prepared and sampled in the same manner as the dry lima beans.

Beef.—Round steak, bought during February and March, 16 samples represented. All visible fat was removed before cutting into small pieces for sampling.

Beet.—Detroit Dark Red variety, grown in Maryland, purchased during August and September, 16 samples represented. Roots 2 to 3 inches in diameter, were thinly pared and finely chopped before sampling.

Beet greens.—Wonderful Early Spring variety, leaves were dark green, grown in Maryland, purchased during July, 10 samples represented. After cooking the leaves were finely chopped and mixed before sampling.

Blackberry.—Large juicy berries, grown in South Carolina, bought during June and July, 15 lots represented.

Blueberry.—A commercially frozen, unsweetened product, packed in New York, purchased in June, stored at −18° C. until October. Four separate 1-pound packages were represented in the assay.

Broccoli.—A single lot of 12 large bunches was bought on the local market in June. After cooking the vegetable the blue-green flower

portions and the tender leaflets adjacent to the stocks were separately chopped, stored at −18° C., and used as needed for the assays.

Brussels sprouts.—A commercially frozen product bought in June. The sprouts were medium green in color. Cooked product only was assayed. Two separate 2-pound packages were represented. Portions of the frozen product were cooked twice each week, finely chopped, and mixed before sampling.

Butter.—Summer-produced butter was obtained in three packs, two from large local dairies and one from the Bureau of Dairy Industry during June. Successive samples were used from these sources each week. Winter-produced butter was secured during January from the same sources as summer-produced butter. Winter-market butter was bought in three lots from three large local grocery stores during winter season; sampling was conducted in same manner as in the case of summer butter.

Cabbage.—Red Dutch variety, grown in California and bought on local market during May. Eleven heads were represented in the assay, and the samples were prepared as described in the case of summer cabbage below.

Summer cabbage, probably Copenhagen Market variety, grown in Florida, bought on local market during April and May. The entire heads, except for the core, were finely chopped before sampling. Ten separate heads were represented, each having green outer leaves and bleached inner leaves.

Carrot.—Bought from local grower in September and October. Eleven samples were represented in the assay. Each carrot was thinly scraped and cut in half. One piece was used as raw while the other was cooked in a large pressure cooker. The samples were finely chopped before feeding.

Cauliflower.—Probably Snowball variety, grown in California and purchased on local market during April. The leaves were discarded and the flowers finely chopped and mixed before sampling. Ten heads were represented.

Celery.—Probably "Golden Self Blanching" variety, grown in Florida, purchased on local markets during March and April. The 18 lots used for the assay were finely chopped, crisp, bleached stalks, all leaves excluded.

Chard, Swiss.—Large Ribbed White variety, grown in Maryland, bought on local market during July. Leaves were medium green. After discarding the stems the tops were cooked, chopped, and kept under refrigeration during the period of assay. Samples for the assay were taken from three 2-pound lots.

Cheese.—American Cheddar, made by Bureau of Dairy Industry in April. Three 1-pound cakes were used alternately during the assay period.

Swiss cheese, unprocessed, light yellow in color, bought on local market during February. Five samples were used for the assay.

Cherry.—Windsor variety, grown in Maryland, purchased on local market in August. The fruits were deep red in color, one-half inch in diameter, smooth, and juicy. The stones were discarded before sampling. One 5-pound lot was used. The fruit was kept at −18° C. from date of purchase and during the assay period which occurred 3 months later.

Chicken.—Raised locally, bought on local market in March. The light and dark meats were fed alternately in carrying out the assay. All visible fat was discarded and the meat cut into small pieces for sampling. Twelve specimens were used for the assay.

Chocolate.—Unsweetened, baker's, bought on local market. One cake was used for the assay.

Clam.—Cherrystone, shipped from Boston in August. The specimens were cut into fine pieces for sampling. Samples from nine lots were used for the assay.

Collard.—Probably Georgia variety, grown in Florida, purchased on local market during December and January. The leaves were medium green in color. Large ribs of the leaves were discarded and the remainder of the vegetable finely chopped and mixed for sampling. Seventeen separate lots were used in the assay.

Corn.—Lancaster variety, dried field corn, grown in Maryland, deep yellow grains; whole grains were finely ground for sampling.

Cowpea.—Whippoorwill variety, packaged dry mature seeds bought on local market in June. Product was cooked once or twice each week and mashed before sampling. Portions of three 1-pound lots were included in the assay.

Cranberry.—Large, firm, red berries grown in New Jersey, purchased on local market during October, November, and December. The fruits were finely chopped for sampling. Twelve lots were included in the assay.

Cream.—Local product, grade A, pasteurized, homogenized, commonly sold as coffee cream, purchased successively from three large local dairies during September and October. Fresh samples used for each feeding.

Cucumber.—Davis Perfect variety, grown in Florida, bought on local market during June and July. The specimens were pared and finely chopped for sampling. Eleven samples were included.

Currant.—Fresh, juicy, bright red fruits, grown locally in June, and bought on local market. The currants were kept frozen during the assay period, which started immediately following their purchase. One 3-pound lot was used during the assay.

Dandelion greens.—Medium green leaves, cultivated in Florida, purchased on local market. After cooking the leaves were finely chopped, mixed, and kept frozen. One 2-pound lot represented.

Date.—Deglet Noor variety, tree-ripened, unprocessed fruit stored for 7 months at 280° F. This variety is white fleshed near the seed.

Saidy variety, processed 2 to 3 days at 130° F., held 3 weeks in common storage, 5 to 6 months at 28°–34°., and then held 3 weeks in common storage. This variety is yellow fleshed near the seed.

Both varieties of dates were supplied by the United States Date Station at Indio, Calif. The entire edible portions (skin and pulp) were included in the material assayed. One 5-pound lot of each kind of date was used.

Eggplant.—Fort Myer Market variety, obtained on the local market in June. The specimens were pared and finely chopped before sampling. Ten samples were included.

Egg yolk.—From summer-produced eggs purchased in late June from 18 different sources, including nearby farms and local markets. The winter-produced eggs were purchased in March from 21 different sources, including nearby farms and local markets. In each case the

yolks were separated from the whites with special care to make the separation as complete as possible. The average weight of the yolks of both summer and winter eggs was 19 gm. The average weight of the whites of winter-produced eggs was 39 gm., and that of the summer-produced eggs 32 gm. The average edible portion of the whole winter eggs weighed 52.8 gm., while that of the summer eggs weighed 50.8 gm. A different egg yolk was used on each feeding day during the assay period. After removal of the chalaza the yolk was thoroughly mixed, the requisite amount weighed on a watch glass and mixed with small portions of the vitamin-A-deficient diet for feeding.

Endive.—Curled, grown locally, obtained on the local markets in July and August. The bleaching of the leaves in the different lots was not uniform. Some were a deep green, while others were almost colorless. The vegetable was chopped finely before sampling. Twelve separate heads were used.

Fig.—Lob Ingir variety, grown in California, packaged, purchased on the local market during December. The fruits had been pulled and then dried unsulfured. The whole fruits were finely chopped for sampling. Three 1-pound packages were used.

Fish.—Fresh haddock and mackerel fillets, shipped from Boston, bought once a week during June. The flesh was macerated for sampling.

Canned United States brands of sardine and yellow fin tuna obtained through the Bureau of Fisheries on local markets in April, and believed to be packs from the previous year. Both kinds of fish were canned in cottonseed oil. The oil was poured off and discarded. Three 3.25-ounce cans of sardines and three 13-ounce cans of tuna fish were represented.

Gooseberry.—Grown in Maryland in July, bought on local market. After removing the calyx and stems, the fruit was placed under refrigeration during the period of assay. The berries originally had a trace of reddish color which deepened during the storage. One 2-pound lot of berries was used.

Grape.—Tokay variety, grown in California, purchased on the local markets during December and January. The seeds were removed and the fruit carefully cut into pieces. Sixteen lots of grapes were included.

Grapefruit juice.—Florida grown fruit, purchased during December on local markets. The fruit was fully ripened and heavy juiced. Strained juice was analyzed. Juices of seven fruits were included.

Heart.—Beef, bought on local market during September. The visible fat was removed and the heart cooked. After cutting into small pieces the meat was kept under refrigeration during the period of assay. Samples from three hearts were included.

Honey.—Produced from sweet clover grown in Michigan the preceding year, obtained through the Bureau of Entomology in May. The honey included the comb. Honey from three 12-ounce frames was represented.

Kale.—Blue Scotch variety, grown in Florida, purchased on the local market during March and April. The leaves were deep green in color. Large ribs of the leaves were discarded and the remainder of the leaves finely chopped for sampling. Thirteen separate lots were included in the assay.

Kidney.—Beef, bought on local market during February and March; outside visible fat was removed and remainder cooked and finely ground. Six samples were used during the assay period.

Lamb.—Lean portions of loin chops purchased during May and June. Eleven samples were used.

Lemon juice.—From California fruits purchased on the local market during December and January. Juices from 10 fruits were included in the assay.

Lentil.—Packaged, dried, matured seeds, purchased in June. Portions from three 1-pound packages were cooked two to three times each week and mashed before sampling.

Lettuce.—Iceberg variety, grown in Florida and Arizona, purchased on local market during April and May. The cores of the heads were excluded from the assay. The remainder of the green and bleached leaves were then finely chopped for sampling. Twelve separate heads were included.

Liver.—Beef, purchased on local market during April. Each lot was cooked and finely ground. Seven samples were included in the assay.

Chicken, bought on local market during January and February. Prepared in same manner as beef liver. Seven samples were included.

Milk.—Commercially evaporated, sweetened, condensed, dry skim, and dry whole milk were bought on local markets during March, May, and June. The pasteurized fluid skim milk (fat content on the order of 0.02 percent) and grade A, pasteurized, fluid, whole milk were bought from large local dairies, the skim milk in July and the whole milk during March and July, respectively. The fluid skim and whole milks represented lots from three different dairies.

Molasses.—A well-known canned commercial product, purchased locally in March. This specimen was brown and of a type widely used in baking. The supplements of molasses were mixed with the vitamin-A-deficient ration for feeding. Two 1-pound cans of molasses were represented.

Mushroom.—*Agaricus campestris*, grown in the south and bought on the local market in May. The fungi were chopped fine for sampling. Seven lots of mushrooms were used.

Muskmelon.—Rocky Ford variety, grown in Colorado, purchased on local market during August and September. The specimens had a bright orange-colored flesh and a gray and green rind. The edible portion was used to within about one-fourth of an inch of the rind. This was finely chopped for sampling. Eight melons were represented.

Mustard greens.—Specimens of medium-green leaves, purchased three times a week during October, November, and December. Preparation for sampling was the same as for kale.

Oatmeal.—Packaged, commercial "quick-cooking" oatmeal, bought on local market during March and April. Three 1-pound packages were represented.

Okra.—Dwarf Green Prolific variety, grown in the Gulf States, purchased on the local market in April. After removing the stems, the vegetable was cooked, chopped, and mixed for sampling. Ten lots were included.

Olive.—Green, Spanish olives, bottled in New York, bought on local market in April and May. The stones were removed and the

flesh finely chopped for sampling. Three 3-ounce bottles were represented.

Onion.—Bermuda variety, grown locally, purchased during July and August. The thin outer skins of the mature white-fleshed products were discarded and the flesh finely chopped for sampling.

Orange juice.—From fully ripened fruits, Pineapple variety grown in Florida, and Navel variety grown in California, both varieties bought on local market in December and January (1939–40).

Two shipments each of tree-ripened, Parson Brown and Pineapple varieties, supplied October 26 and November 24, 1939, and January 8 and 26, 1940, by the United States Agricultural Experiment Station at Orlando, Fla. Each lot consisted of 50 fruits, except the first which included 81 fruits. After juicing, the samples from each shipment were pooled and kept frozen during the period of assay.

Oyster.—Extra standard, Woodfield, purchased on local market. Samples were finely ground, raw. Seven samples used for the assay.

Parsnip.—Probably Hollow Crown variety, grown in Maryland and bought on local market in March. The roots were scraped, cooked, mashed, and placed under refrigeration for the period of assay, which was made during April. One 5-pound lot was used.

Pea.—Green peas, commercially frozen, purchased on local market during January, and kept frozen during the assay period. Thirteen samples were taken from ten 1-pound packages.

Packaged, dried, green split seeds, bought on local market in June. Before sampling, they were cooked and mashed. Three 1-pound packages were used.

Peach.—Elberta free-stone variety, yellow-fleshed, fully ripe fruits, grown in Maryland, purchased on local market during August and September. The skins and stones were discarded and the fruit chopped and mixed before sampling. Thirteen fruits were included.

Packaged dried peaches, grown in California, purchased in June on local market in three 11-ounce packages. The fruits were yellow, sulfured, tenderized, had had 3-percent moisture added, and had been tree-ripened. They were cut into small pieces for sampling.

Peanut.—Spanish, bought on local market in December. After removal of the thin red skins, the peanut butter was prepared by roasting the peanuts at a temperature of 190° C. for 20 minutes. They were then finely ground and placed under refrigeration. One 3-pound lot was used for the assay.

Pear.—Bartlett variety, grown in California, purchased on local market in October and November. The fruits were pared and cored and finely chopped before sampling. Sixteen fruits were represented.

Pecan.—Unblanched, grown in Texas, bought on local market in June. They were kept under refrigeration during the period of assay. The nut meats were finely chopped for sampling. One lot of 3 pounds was used.

Pepper.—Wonder variety, grown in California, bought on local market in August. After removing the stems and seeds, the peppers were finely chopped and mixed for sampling. Seven samples were used.

Persimmon.—Solid Gold Hachiya variety, grown in southern California and bought on local market in June. The fruits were

orange-colored, juicy, and averaged 1¾ inches in diameter. They were kept frozen up to and during the period of assay, which was made 10 months later. One lot of 18 fruits was used.

Pineapple.—Sugar Loaf variety, grown in Florida, purchased on local market during October and November. The samples represented the chopped flesh without parings or core of fully ripened fruit. Sixteen fruits were represented.

Plum.—President variety, grown in California, purchased on local market during October and assayed in January. The fruits were large, juicy, and slightly over 1 inch in diameter. The flesh was light yellow in color. The skin and stones were discarded before sampling. The fruit was kept frozen up to and during the period of assay, which was made during January. One 5-pound lot of fruit was used.

Popcorn.—Probably Queens Golden variety, grown in Indiana probably 2 years previous. The yellow rounded kernel was medium-sized, with medium hull and texture. One 1-pound lot was used during the assay in October and November.

Pork.—Fresh lean loin chops were purchased during February and March on local market. All visible fat was discarded. Eighteen chops were represented.

One-quarter-pound lots of salt pork were purchased on local market during January and February. The samples were ground for feeding. Fourteen lots were represented.

Potato.—White, Irish Cobbler variety, grown in Maine and obtained through the Bureau of Plant Industry, late in October. The tubers were thinly pared. The cooked ones were mashed for sampling, while the raw were finely chopped. One 10-pound lot, kept at room temperature, was used.

Prune.—Packaged dried fruits, grown in California, purchased in June on local market in three 11-ounce packages. The fruits were of average size, good quality, tenderized. Both skins and pulp were included in the samples assayed.

Pumpkin.—Common field or Big Tom variety, grown in Maryland and purchased in January on local market. The flesh was deep yellow in color. The edible portions of three large pumpkins were thinly pared, cooked, mixed, and held in a frozen condition for the assay period, which was 2 months later.

Radish.—Scarlet Globe variety, grown in Maryland, bought on local market in July. The specimens were small, round, and red in color. Before sampling, they were finely chopped and well mixed. Nine lots of radishes were used.

Raisin.—Sultanina variety, grown in California, purchased in January on local market. The entire fruits were finely cut and mixed before sampling. Three 1-pound packages were represented.

Raspberry.—Fresh, juicy, black and red berries, bought on local market in August and June, respectively. The black fruits were grown in California, while the red ones came from New Jersey. The fruits were kept frozen during the assay period. Six 1-pint boxes of each kind of fruit were represented.

Rhubarb.—Myatt's Victoria variety, grown locally, purchased during April. After discarding the leaves, the stems were finely chopped and mixed before sampling. Eight lots were represented.

Rice.—Packaged, brown, purchased on local market in June. It was finely ground and incorporated into the diet by substituting the

rice for a suitable proportion of the starch used in the basal ration. Three 1-pound packages were represented.

Rutabaga.—American Purple Top variety, grown in Maryland, bought on local market in February. The roots were light yellow in color. They were pared, sliced, cooked, and mashed, and kept frozen until the assay was completed in April. One 5-pound lot was used.

Rye.—One 5-pound lot known as No. 2, according to Federal Inspection, obtained in May from a local dealer. The whole grain was finely ground before sampling.

Sauerkraut.—Commercially canned in New York, bought during May on local market. The total contents of the can were mixed and chopped for sampling. Six 1-pound cans were represented.

Scallop.—Purchased on local market, finely chopped and mixed and kept under refrigeration. Four separate 1-pint lots were used.

Soybean.—Sousei variety, dried, mature seeds, obtained from Arlington Experimental Farm in March. Samples were cooked and mashed twice a week. One 3-pound lot was represented.

Spinach.—The commercially frozen product, purchased in February on local market, kept frozen during the assay period. The leaves were dark green in color and included the more tender portions of the leafstalk. The spinach was chopped and mixed for sampling. Twenty samples were taken from four 2½-pound packages.

One lot of fresh spinach from local market was washed and divided into two matched samples. One sample was dried without cooking and the other, after it had been cooked. The assays were made and recorded on the basis of the dehydrated products which contained from 3 to 4 percent of moisture.

Squash.—Summer Crookneck variety, grown in Maryland and purchased on local market during August and September. The entire squash was cooked and finely chopped for sampling. Fourteen samples were included in the assay.

Hubbard, commercially frozen cooked product, purchased on local market during July in three 2½-pound packages, which were kept frozen during the assay period.

Strawberry.—Klondike variety, grown in Pennsylvania and purchased on local market during June and July. The whole of the fresh berries was finely chopped for sampling. Sixteen lots were used.

Suet.—Samples were locally produced. Assays were made using samples from seven ½-pound lots bought on local market in May.

Sweetpotato.—Nancy Hall variety, produced by the Bureau of Plant Industry at the Beltsville Research Center. The samples were obtained in late October and were medium yellow in color. The cooked ones were mashed for sampling, while the raw were finely chopped. The 10-pound lot, used for sampling, was kept in an attic storeroom during the period of assay.

Tangerine juice.—Juice of medium-sized fruit grown in Florida and purchased on local market in January. Ten samples were used during the assay period.

Tomato.—Marglobe variety, fresh specimens for one assay produced by the Bureau of Plant Industry at the Beltsville Research Center, and for a second assay bought on local market. Assays made during October of 2 succeeding years.

Turnip greens.—Medium dark-green leaves purchased on local market during March and April. The entire leaves and a small part of the stems were finely chopped and well mixed before sampling. Nineteen samples were represented.

Walnut.—Persian (English), large firm meats bought without shells on local market. The nut meats were kept under refrigeration and finely chopped for sampling. One 2-pound lot was represented.

Watermelon.—Bought by the slice on local market during August. The fruit was fresh and ripe. Small pieces were carefully cut free in order to save the juice. Twelve samples were represented.

Wheat.—Prolific variety of "feed wheat," grown in Maryland and obtained from a local mill in January. One 3-pound lot was finely ground before sampling.

Wheat germ.—Obtained from a local mill in January. One 2-pound lot, kept under refrigeration during assay period.

EXPERIMENTAL RESULTS

The vitamin A values for the 128 common food items listed in table 2 represent, for the most part, analyses of composited samples of the respective food items. In a few cases, as stated in the description of the samples, the assays were made on a single lot of food.

Vitamin A assays of foods from animal sources are subject to certain difficulties not especially prominent in assays for other vitamins. For example, in the assays of beef kidney a wide range of variation was encountered. In a first trial the supplement levels were obviously too large. On the basis of this information, a second assay was initiated, but the second lot of samples, on the average, was much lower in vitamin A value than that of the first lot, and again the supplement levels were unsuitable. A third lot agreed more nearly in vitamin A value with the first lot and the value given for beef kidney in table 2 represents the assay of this third lot. This same situation could certainly have been true of liver samples, so that the values given for kidney and liver probably reflect only a more or less chance value for this item corresponding to the particular feeding methods used for the beef cattle represented by these samples. It seems reasonable to suppose that foods from animal sources that are important carriers of vitamin A are more subject to wide variations in vitamin A values than are foods from plant sources.

TABLE 2.—*The vitamin-A-assay values of foods* [1]

[Estimated precision, 30 percent]

Food	Vitamin A per 100 gm. (edible portion)	Summary of experimental data					
		Group of rats fed reference cod-liver oil			Group of rats fed designated food supplements		
		Rats	Amount fed per rat per day	Average weight [2] increment per rat	Rats	Amount fed per rat per day	Average weight [2] increment per rat
Almond (*Amygdalus communis*):	*I. U.*	*Number*	*I. U.*	*Grams per week*	*Number*	*Milligrams*	*Grams per week*
Unblanched	0	3	1.0	4.4	5	1,000	(5 D)
Apple (*Malus sylvestris*):							
Fresh, Delicious	ca 50	3	1.0	4.9	5	1,000	2.1
Apricot (*Prunus armeniaca*):							
Dried	5,800	2	1.0	5.6	5	6	2.3
		4	2.0	8.9	5	12	4.6
Asparagus (*Asparagus officinalis*):							
Fresh, Palmetto, cooked	960	6	1.0	7.0	6	120	8.2
		6	2.0	15.9	7	240	18.8
Avocado (*Persea* spp.):							
Fresh	128	3	1.0	8.4	3	600	6.1
		3	2.0	12.9	2	1,200	13.7
Banana (*Musa sapientum*):							
Fresh	ca 400	6	1.0	8.6	7	342	13.4
		9	2.0	[14.8]	6	684	15.9
Bean (*Phaseolus* spp.):							
Fresh:							
Golden Wax, cooked	350	4	1.0	4.4	4	120	1.4
		2	2.0	10.1	3	240	3.5
Lima, Henderson Bush, cooked	270	4	1.0	6.9	5	150	2.2
		4	2.0	13.9	6	300	5.6
Snap, green, Early Bountiful	1,200	8	1.0	9.2	6	120	10.8
		9	2.0	12.9	6	240	15.8
Snap, green, Early Bountiful, cooked	2,000	9	1.0	8.0	6	120	11.7
		9	2.0	11.2	6	240	14.5
Dried:							
Lima, Henderson Bush, cooked	0	1	1.0	9.0	5	1,000	(5 D)
Navy, Michelite, cooked	0	3	1.0	8.4	5	1,000	−5.5(4 D)
Beef:							
Fat (see Suet).							
Muscle, lean	0	4	1.5	9.9	4	1,000	−.6(1 D)
Organs (see Heart, Kidney, etc.).							
Beet (*Beta vulgaris*):							
Fresh, Detroit Dark Red	<100	3	1.0	1.3	4	1,714	1.2(1 D)
Beet greens:							
Fresh, Wonderful Early Spring, cooked	16,100	6	1.0	7.0	5	6	7.4
		7	2.0	13.0	7	12	12.8
Blackberry (*Rubus* spp.):							
Fresh	83	6	1.0	8.4	6	517	2.0
					4	985	6.3
Blueberry (*Vaccinium* spp.):							
Frozen	<50	3	1.0	6.4	7	1,000	−.8(3 D)

See footnotes at end of table.

TABLE 2.—*The vitamin-A-assay values of foods* [1]—Continued

Food	Vitamin A per 100 gm. (edible portion)	Summary of experimental data					
		Group of rats fed reference cod-liver oil			Group of rats fed designated food supplements		
		Rats	Amount fed per rat per day	Average weight [2] increment per rat	Rats	Amount fed per rat per day	Average weight [2] increment per rat
Broccoli (*Brassica oleracea botrytis*):							
Cooked:	*I. U.*	*Number*	*I. U.*	*Grams per week*	*Number*	*Milligrams*	*Grams per week*
Flowers	3,500	5	1.0	5.6	6	30	6.6
		6	2.0	11.9	6	60	12.4
Leaves	7,300	5	1.0	5.9	6	6	4.0
		5	2.0	11.6	6	12	5.2
Brussels sprouts (*Brassica oleracea gemmifera*):							
Frozen cooked	649	5	1.0	4.3	5	240	5.6
		5	2.0	6.7	5	480	9.2
Butter:							
Summer-produced	5,900	9	1.0	5.7	7	25.7	7.2
		11	2.0	8.6	7	51.4	11.8
Winter-produced	3,650	8	1.0	7.4	6	30	7.8
		7	2.0	12.5	6	60	13.5
Winter-market	ca 3,000	9	1.0	5.8	6	167	12.7
			2.7	[11.8]	7	334	14.5
Cabbage (*Brassica* spp.):							
Fresh:							
Red Dutch	ca 40		0.5	3.2	5	1,300	3.4 (1 D)
Summer	<100	5	1.0	4.6	3	240	—1.8(2 D)
		4	2.0	14.0	4	480	—.1
Summer, cooked	170	6	1.0	4.6	5	240	.2(1 D)
		5	2.0	13.4	4	480	3.2
Carrot (*Daucus carota*):							
Fresh	ca 10,000	7	1.0	4.6	3	5	2.4
					5	10	4.7
					7	20	5.7
Fresh, cooked	ca 10,000	5	1.0	4.4	2	5	1.6
					5	10	4.2
					4	20	7.1
Cauliflower (*Brassica oleracea botrytis*):							
Fresh	ca 70	3	1.0	4.6	7	1,000	3.3
Celery (*Apium graveolens*):							
Fresh, blanched stalks	0	4	1.0	7.6	6	1,000	—2.0(5 D)
Chard (*Beta vulgaris*):							
Fresh, large, Ribbed White, cooked	14,500	3	1.0	7.4	4	15	12.9
		3	2.0	12.1	3	30	14.3
Cheese:							
American Cheddar	1,200	3	1.0	7.7	5	100	9.2
					5	200	18.7
Swiss	2,680	3	1.5	10.5	6	60	10.8
					6	120	14.6
Cherry (*Prunus* spp.):							
Fresh, Windsor	<80	9	1.0	3.7	6	300	.5(4 D)
					6	600	—1.6(1 D)
Chicken:							
Muscle, lean	Nil	6	1.0	6.4	6	1,000	2.9(4 D)

See footnotes at end of table.

TABLE 2.—*The vitamin-A-assay values of foods* [1]—Continued

Food	Vitamin A per 100 gm. (edible portion)	Summary of experimental data					
		Group of rats fed reference cod-liver oil			Group of rats fed designated food supplements		
		Rats	Amount fed per rat per day	Average weight [2] increment per rat	Rats	Amount fed per rat per day	Average weight [2] increment per rat
Chocolate:	*I. U.*	*Number*	*I. U.*	*Grams per week*	*Number*	*Milligrams*	*Grams per week*
Unsweetened, baker's	ca 60	4	1.0	8.8	4	1,000	3.0
		2	2.0	14.6			
Clam:							
Fresh, Cherrystone	200	5	1.0	6.3	3	500	6.5
					6	1,000	18.2
Collard (*Brassica oleracea acephala*):							
Fresh	[3] 8,800	9	1.0	4.8	5	6.0	3.2
		10	2.0	5.8	7	12.0	5.6
Fresh, cooked	12,200	6	1.0	4.5	6	6.0	3.5
		6	2.0	6.8	6	12.0	6.2
Corn (*Zea mays*):							
Dried, Lancaster	333	4	1.0	7.6	5	150	1.1
					4	300	7.8
Popped (see Popcorn).							
Cowpea (*Vigna sinensis*):							
Dried, Whippoorwill, cooked	0	5	1.0	4.9	6	500	0(3 D)
					6	1,000	−.6
Cranberry (*Vaccinium* spp.):							
Fresh	ca 70	3	1.0	3.2	4	1,000	2.2
Cream:							
Summer, 20-percent fat	[3] 1,640	3	1.0	3.8	4	[4] .06	3.9
		5	2.0	5.6	5	[4] .13	5.8
Cucumber (*Cucumis sativus*):							
Fresh, Davis Perfect	0	3	1.0	3.7	5	1,000	−1.9(2 D)
Currant (*Ribes* spp.):							
Frozen, red	ca 120	6	1.0	5.5	5	1,000	6.6
Dandelion greens (*Leontodon taraxacum*):							
Cooked	ca 9,000	3	1.0	9.3	5	10	7.3
		3	2.0	13.5	5	20	12.5
Date (*Phoenix dactylifera*):							
Unprocessed, Deglet Noor	Nil	5	1.0	7.6	5	685.0	(5 D)
Processed, Saidy	ca 350	5	1.0	7.6	7	685	19.8
			2.5	[20.5]			
Eggplant (*Solanum melongena*):							
Fresh, Fort Myer Market	0	2	1.0	8.5	5	1,000	.2(1 D)
Egg yolk:							
Fresh:							
Summer-produced	3,760	5	1.0	7.0	5	25.7	6.8
		6	2.0	11.7	6	51.4	13.0
Winter-produced	ca 1,880	6	1.0	5.3	6	133	11.2
			2.5	11.2	6	266	12.2
Endive (*Cichorium endivia*):							
Fresh:							
Curled	[3] 3,850	3	1.0	6.4	5	30	8.5
		6	2.0	13.6	3	60	15.5
Curled, cooked	4,880	6	1.0	6.0	4	30	10.6
		6	2.0	13.0	6	60	16.9
Fig (*Ficus carica*):							
Dried, Lob Ingir	115	6	1.0	9.2	7	1,000	10.0

See footnotes at end of table.

TABLE 2.—*The vitamin-A-assay values of foods* [1]—Continued

Food	Vitamin A per 100 gm. (edible portion)	Summary of experimental data					
		Group of rats fed reference cod-liver oil			Group of rats fed designated food supplements		
		Rats	Amount fed per rat per day	Average weight [2] increment per rat	Rats	Amount fed per rat per day	Average weight [2] increment per rat
Fish:							
Fresh:	*I. U.*	*Number*	*I. U.*	*Grams per week*	*Number*	*Milligrams*	*Grams per week*
Haddock	0	3	1.0	5.0	6	1,000	−5.2(5 D)
		3	2.0	11.2			
Mackerel	175	3	1.0	4.5	4	643	6.2
		6	2.0	11.0	6	1,329	12.8
Canned:							
Sardine	[3] 136	3	1.0	7.2	5	1,000	9.7
		4	2.0	14.1			
Tuna	[3] 200	3	1.0	8.2	5	1,000	14.5
		3	2.0	14.5			
Gooseberry (*Ribes* spp.):							
Fresh, green	380	5	1.0	3.4	4	240	3.0
					4	480	7.5
Grape (*Vitis vinifera* spp.):							
Fresh, Tokay	<100	9	1.0	[4.8]	5	1,000	1.6
Grapefruit (*Citrus grandis*):							
Juice	[4] 0	6	1.0	5.2	5	[4] 3	1.2(4 D)
Heart:							
Beef, cooked	ca 200	3	1.0	8.4	4	1,000	13.2
			2.0	[12.6]			
Honey:							
Unstrained, sweet clover	0	2	1.0	7.8	4	1,000	(4D)
Kale (*Brassica oleracea acephala*):							
Fresh:							
Blue Scotch	[4] 10,500	6	1.0	9.8	3	4.7	5.6
		5	2.0	14.8	6	9.9	10.1
Blue Scotch, cooked	14,490	8	1.0	9.1	7	4.7	6.6
		9	2.0	14.3	7	9.0	12.0
Kidney:							
Beef, cooked	ca 1,150	5	1.5	6.3	6	240	12.9
					6	480	20.4
Lamb:							
Chop, lean portion	0	3	1.0	6.5	5	1,000	1.0
Lemon (*Citrus limonia*):							
Juice	[4] 0	3	1.0	8.3	4	[5] 3	−2.8(3 D)
Lentil (*Lens esculenta*):							
Dried, cooked	<100	3	1.0	6.2	5	1,000	2.7
Lettuce (*Lactuca sativa*):							
Fresh:							
Iceberg	[4] 210	6	1.0	8.4	3	240	3.1
		7	2.0	13.1	6	480	8.8
Iceberg, cooked	300	6	1.0	8.7	5	240	5.6
		7	2.0	11.6	6	480	12.5
Liver:							
Beef	ca 77,000	3	1.0	8.0	3	3	13.3
		3	2.0	11.4	6	6	18.4
Chicken, cooked	ca 24,000	5	1	6.6	7	3.3	1.0(3 D)
		7	2	8.1	7	9.9	11.0

See footnotes at end of table.

TABLE 2.—*The vitamin-A-assay values of foods* [1]—Continued

Food	Vitamin A per 100 gm. (edible portion)	Summary of experimental data: Group of rats fed reference cod-liver oil: Rats	Amount fed per rat per day	Average weight [2] increment per rat	Group of rats fed designated food supplements: Rats	Amount fed per rat per day	Average weight [2] increment per rat
Milk:	*I. U.*	*Number*	*I. U.*	*Grams per week*	*Number*	*Milligrams*	*Grams per week*
Condensed	[3] ca 280	7	1.0	7.0	3	[6] 0.5	13.8
			2.5	[16.2]	5	[6] 1	17.2
Dry, skim	ca 140	2	1.0	4.9	3	600	4.2(2 D)
					5	1,200	4.2
Dry, whole	1,600	6	1.0	7.2	6	150	15.0
		6	2.0	12.8	4	300	18.0
Evaporated	[3] ca 464	2	1.0	5.2	3	[6] 1	10.4
			2.5	[11.2]			
Fluid, skim	[4] ca 17	3	1.0	8.2	5	[6] 6	7.4
		1	2.0	17.0			
Fluid, whole, summer	[4] 230	5	1.0	8.1	6	[6] .64	13.6
		5	2.0	14.0	8	[6] 1.29	14.8
Fluid, whole, winter	[4] 87	6	1.0	11.1	6	[6] 1.03	10.4
					6	[6] 2.06	16.2
Molasses:							
Commercial, canned, brown, baking	[5] 0	4	1.0	6.8	5	1,000	.8(1 D)
Mushroom (*Agaricus campestris*):							
Fresh	0	3	1.0	4.0	8	1,000	−3.8(5 D)
Muskmelon (*Cucumis melo*):							
Fresh, Rocky Ford	2,390	4	1.0	3.8	4	65	6.7
		4	2.0	8.0	5	129	11.0
Mustard greens (*Sinapis*):							
Fresh	[6] ca 10,200	7	1.0	7.2	5	6	3.4
		6	2.0	13.6	6	12	9.5
Fresh, cooked	ca 10,000	5	1.0	8.6	6	6	3.8
		8	2.0	12.3	8	12	10.4
Oatmeal:							
"Quick-cooking"	Nil	4	1.0	9.0	6	1,000	−2.5(4 D)
Okra (*Hibiscus esculentus*):							
Fresh, dwarf Green Prolific, cooked	2,380	3	1.0	6.1	3	120	11.5
		4	2.0	9.4	3	240	18.5
Olive (*Olea europaea*):							
Bottled, Spanish	[7] ca 1,000	2	1.0	6.0	4	300	17.0
		2	2.0	12.4	4	600	19.9
Onion (*Allium cepa*):							
Fresh, Bermuda	0	6	.5	[4.4]	7	1,700	−.8(5 D)
Orange (*Citrus sinensis*):							
Juice:							
Navel	[8] ca 250	4	1.0	4.4	3	[8] .86	7.3
			2.0	[7.0]	4	[8] 1.7	10.2
Parson Brown	[8] 42	5	1.0	6.6	4	[6] 2	5.9
					5	[6] 4	9.9
Parson Brown	[8] 80	7	1.0	7.6	7	[6] 1.5	8.0
					8	[8] 3	10.4
					8	[6] 4.5	14.0
Pineapple	[8] 48	7	1.0	5.0	7	[6] 1.7	4.0
					8	[6] 3	7.4

See footnotes at end of table.

TABLE 2.—*The vitamin-A-assay values of foods* [1]—Continued

Food	Vitamin A per 100 gm. (edible portion)	Summary of experimental data					
		Group of rats fed reference cod-liver oil			Group of rats fed designated food supplements		
		Rats	Amount fed per rat per day	Average weight [2] increment per rat	Rats	Amount fed per rat per day	Average weight [2] increment per rat
Orange—Continued.							
Juice—Continued.	*I. U.*	*Number*	*I. U.*	*Grams per week*	*Number*	*Milligrams*	*Grams per week*
Pineapple	[3] 75	4	1.5	8.8	5	[4] 1	5.0
					5	[4] 2	8.8
					5	[4] 3	11.1
Pineapple	[5] ca 170	3	1.5	10.4	4	[4] 1.5	12.2
					4	[4] 3	14.4
Oyster:							
Fresh	210	6	1.5	7.2	5	300	4.1
					6	600	6.4
Parsnip (*Pastinaca sativa*):							
Cooked	0	5	1.0	8.4	5	600	−3.8(4 D)
					5	1,200	.6(3 D)
Pea (*Pisum* spp.):							
Frozen:							
Green	745	7	1.5	17.5	7	100	11.0
					7	200	17.6
Green, cooked	847	7	1.5	18.8	7	100	11.0
					7	200	16.8
Dried:							
Green, cooked	530	4	1.0	7.6	4	120	5.7
		4	2.0	10.0	5	240	9.0
Peach (*Amygdalus persica*):							
Fresh, Elberta	1,670	5	1.0	2.2	6	141	4.4
		5	2.0	4.1	6	287	6.7
Dried, yellow	3,400	1	1.0	10.5	3	30	10.8
					3	60	21.8
Peanut (*Arachis hypogaea*):							
Roasted, Spanish	[7] 0	9	1.0	[4.8]	5	1,000	−.6
Pear (*Pyrus* spp.):							
Fresh, Bartlett	<50	1	1.0	5.0	6	1,000	−2.0(4 D)
Pecan (*Carya pecan*):							
Unblanched	ca 200	5	1.0	8.0	4	1,000	14.2
			2.0	[13.5]			
Pepper (*Capsicum annuum*):							
Fresh:							
Green, Wonder	[6] 875	8	1.0	5.4	5	150	6.9
		10	2.0	10.5	6	300	13.8
Green, Wonder, cooked	1,100	7	1.0	5.5	6	150	9.2
		9	2.0	10.6	6	300	16.0
Persimmon (*Diospyros* spp.):							
Fresh, Solid Gold Hachiya	2,650	6	1.0	3.5	6	52	6.2
		6	2.0	8.6	6	98.5	10.4
Pineapple (*Ananas sativus*):							
Fresh, Sugar Loaf	ca 200	5	1.0	3.7	7	1,000	5.6
			2.0	[5.6]			
Plum (*Prunus domestica*):							
Fresh, President	300	6	1.0	4.8	6	300	4.9
					6	600	6.1
Popcorn (*Zea mays everta*):							
Freshly popped	[7] ca 600	51	2.0	[8.1]	3	428	9.2
		35	2.0	[12.5]	3	428	14.1

See footnotes at end of table.

TABLE 2.—*The vitamin A–assay values of foods* [1]—Continued

Food	Vitamin A per 100 gm. (edible portion)	Summary of experimental data: Group of rats fed reference cod-liver oil: Rats	Amount fed per rat per day	Average weight [7] increment per rat	Group of rats fed designated food supplements: Rats	Amount fed per rat per day	Average weight [7] increment per rat
Pork:	*I. U.*	*Number*	*I. U.*	*Grams per week*	*Number*	*Milligrams*	*Grams per week*
Fresh, chop, lean portion	Nil	3	1.5	9.0	5	1,000	−1.5 (2 D)
Salt	Nil	4	1.0	5.2	6	1,000	−.9 (2 D)
Potato (*Solanum tuberosum*):							
Irish Cobbler	ca 40	6	1.0	4.3	7	1,000	1.2
Irish Cobbler, cooked	ca 40	7	1.0	3.5	8	1,000	1.4
Prune (*Prunus domestica*):							
Dried	1,560	5	1.0	4.7	6	120	11.6
		7	2.0	12.0	5	240	17.6
Pumpkin (*Cucurbita pepo*):							
Common field, cooked	1,200	6	1.0	8.1	5	60	4.8
					6	120	12.9
Radish (*Raphanus sativus*):							
Fresh, Scarlet Globe	<30	6	.5	4.4	6	1,700	1.4 (2 D)
Raisin (*Vitis vinifera*):							
Dried, Sultanina	Nil	5	1.0	8.6	7	1,000	−8.9 (3 D)
Raspberry (*Rubus* spp.):							
Fresh:							
Black	Nil	48	1.0	[7.1]	4	1,000	.4
Red	133	20	2.0	[6.5]	4	1,700	8.0
			2.5	[9.5]			
Rhubarb (*Rheum rhaponticum*):							
Fresh, Myatt's Victoria	ca 100	20	2.0	[6.5]	4	2,000	6.2
Rice (*Oryza sativa*):							
Brown	Nil	2	1.0	5.0	6	1,000	−4.2 (3 D)
Rutabaga (*Brassica campestris*):							
American Purple Top, cooked	Nil	3	1.0	8.7	5	1,000	2.0 (4 D)
Rye (*Secale cereale*):							
Whole grain	Nil	2	1.0	5.6	5	1,000	2.2 (4 D)
		2	2.0	11.0			
Sauerkraut (fermented cabbage):							
Canned, commercial	[7] 0	4	1.0	7.4	7	1,000	(7 D)
Scallop:							
Fresh	0	4	1.5	10.0	6	1,500	−2.6 (1 D)
Soybean (*Soja max*):							
Dried, Sousei, cooked	0	1	1.0	5.8	6	1,000	(6 D)
Spinach (*Spinacia oleracea*):							
Frozen	[4] 4,166	9	1.0	8.4	7	13.3	4.8
					7	26.6	9.1
Frozen, cooked	ca 10,000	11	1.0	7.4	8	13.3	11.2
			2.0	[13.2]	8	26.6	15.2
Dried without cooking	[4] 100,000	10	1.0	6.8	4	1.37	5.4
		9	2.0	8.1	7	2.74	11.3
Dried after cooking	[4] 203,000	10	1.0	5.4	4	1.41	9.8
		9	2.0	8.5	6	2.83	14.1
Squash (*Cucurbita maxima*):							
Fresh, Summer Crookneck, cooked	700	5	1.0	4.2	5	140	2.9
		4	2.0	6.7	6	280	6.8
Frozen, Hubbard, cooked	[7] ca 6,000	3	1.0	6.2	5	30	11.9
			2.0	[13.0]	5	60	19.5

See footnotes at end of table.

TABLE 2.—*The vitamin-A-assay values of foods* [1]—Continued

Food	Vitamin A per 100 gm. (edible portion)	Summary of experimental data					
		Group of rats fed reference cod-liver oil			Group of rats fed designated food supplements		
		Rats	Amount fed per rat per day	Average weight [2] increment per rat	Rats	Amount fed per rat per day	Average weight [2] increment per rat
	I. U.	*Number*	*I. U.*	*Grams per week*	*Number*	*Milligrams*	*Grams per week*
Strawberry (*Fragaria* spp.):							
Fresh, Klondike	ca 50	9	1.0	[4.8]	4	2,000	5.4
Suet:							
Beef	ca 600	5	1.0	5.1	5	514	8.1
			2.0	[7.6]	5	985	9.3
Sweetpotato (*Ipomoea batatas*):							
Fresh:							
Nancy Hall	3,800	8	1.0	10.7	8	30	8.0
		10	2.0	12.0	7	60	13.3
Nancy Hall, cooked	3,460	5	1.0	11.0	6	30	8.8
		6	2.0	12.7	7	60	13.0
Tangerine (*Citrus nobilis*):							
Juice	[3] ca 348	6	1.0	4.7	6	[4] .86	7.8
			2.0	[7.2]	7	[3] 1.7	9.6
Tomato (*Lycopersicon esculentum*):							
Fresh, Marglobe	1,150	3	1.0	3.6	3	100	5.1
		3	2.0	6.2	4	200	6.6
Fresh, Marglobe	1,455	5	1.5	16.9	3	60	11.2
					4	120	19.1
Turnip greens (*Brassica rapa*):							
Fresh	[4] 15,700	6	1.0	7.0	6	10	10.7
		5	2.0	12.5	6	20	17.8
Fresh, cooked	19,900	4	1.0	5.2	6	10	11.9
		5	2.0	11.9	6	20	15.6
Walnut (*Juglans* spp.):							
Unblanched, Persian (English)	ca 40	4	1.0	7.4	5	1,000	3.2
Watermelon (*Citrullus vulgaris*):							
Fresh, center portion	ca 500				4	300	11.8
		33	2.0	[13.7]	5	600	16.4
Wheat (*Triticum aestivum*):							
Whole grain, Prolific	0	2	1.5	10.8	7	1,000	−4.0(4 D)
Wheat germ (*Triticum aestivum*):							
Commercial sample	ca 100	5	1.0	6.8	8	300	.1(2 D)
					10	600	3.4(4 D)

[1] Figures refer to uncooked product or to cooked product calculated on raw weight basis unless otherwise indicated.

[2] Figures in brackets are data on the same strain of rats but not strictly matched litter mates.

[3] D following numerals indicates that animals died before completion of experimental period.

[4] Figures significantly affected by method of sampling (see text).

[5] Figures refer to values per 100 ml.

[6] Milliliters.

[7] Values on cooked or canned weight basis, whichever is indicated in description.

[8] Value is based on dehydrated, cooked weight.

Weight Increments of Vitamin-A-Assay Rats

Two different strains of albino rats, referred to as stock A and stock B, were used for the measurement of vitamin A values reported in table 2. The average weekly weight increments of the rats receiving standard reference cod-liver oil were as follows:

	Grams
Stock A:	
135 males receiving 1.0 I. U. daily	5.2±2.9
44 males receiving 2.0 I. U. daily	6.8±3.0
126 females receiving 1.0 I. U. daily	3.9±2.2
49 females receiving 2.0 I. U. daily	6.1±2.5
Stock B:	
223 males receiving 1.0 I. U. daily	6.8±3.7
119 males receiving 2.0 I. U. daily	12.6±3.9
208 females receiving 1.0 I. U. daily	6.8±2.9
111 females receiving 2.0 I. U. daily	11.4±2.9

The wide differences in average responses between assay rats of the two strains receiving identical supplements of vitamin A indicate clearly the unreliability of absolute weight increments of single groups of rats as criteria of the vitamin A values of the food items fed as sources of vitamin A.

One rat from each litter was continued on the vitamin-A-deficient diet without a supplement of any kind. All of these rats lost weight, most of them showed marked xerophthalmia, and practically all of them died before the end of the test period.

Statistical Analysis of Results

The significance of the differences between the average weekly weight increments of the pairs of rats on two levels of various test foods was determined by "Student's" t test.[3]

From data on 30 food items selected at random from table 2, it was found that, at the growth levels observed on the 2 levels of food supplements administered, an alteration of about 30 percent of the supplements given would have induced significant differences in growth rates. It is apparent, therefore, that the vitamin A values listed in table 2 should not be considered as established to within narrower limits than ±30 percent. For purposes of planning dietaries, of evaluating the vitamin A values of existing dietaries, or of arriving at an estimate of the relative richness of the different food items with regard to vitamin A value, the information given in table 2 would seem to be entirely adequate. The vitamin A values of foods listed in table 2 are, for the most part, measures of potencies for composited samples of the food items specified and for this reason should not be applied without reserve to other samples of the same general kinds of food materials.

There are more practical difficulties involved in conducting vitamin A assays than in conducting assays of vitamins more evenly distributed in foods. Many common foods are very rich in vitamin A value while many others carry immeasurably small concentrations of this vitamin. In some cases, daily supplements of 2.0 gm. of food are insufficient to promote a substantial growth rate. This situation

[3] The equation $t=\frac{\bar{X}\sqrt{N}}{S.D.}$ is "Student's" t test of the significance of the mean of a small sample. The symbol $\bar{X}$ represents the mean difference between pairs; N, the number of pairs; and $S.D.$ the standard deviation of a single difference.

frequently results in a considerable and unpredictable number of deaths among the groups of assay rats during the course of the test period.

Calculations of vitamin A values of foods were also made on the basis of 3-, 4-, and 5-week assay periods, respectively. The results indicate that there is little if anything to be gained by a 5-week assay period over a 4-week assay period. However, a 3-week assay period gives irregular results as compared with the values obtained for the 4- or the 5-week assay periods. Perhaps a substantially large number of matched pairs receiving the two levels of test food would overcome this trend and in the end might save some time but very little expense.

LITERATURE CITED

(1) BAUMANN, CARL A., and STEENBOCK, H.
1932. THE VAGINAL SMEAR METHOD OF DETERMINING VITAMIN A. Science 76: 417–420.

(2) BAXTER, J. G., and ROBESON, C. D.
1940. CRYSTALLINE VITAMIN A PALMITATE AND VITAMIN A ALCOHOL. Science (n. s.) 92: 203–204.

(3) GILLAM, ALBERT EDWARD, HEILBORN, ISIDOR MORRIS, JONES, WILLIAM EDWARD, and LEDERER, EDGAR.
1938. ON THE OCCURRENCE AND CONSTITUTION OF THE 693 MU CHROMOGEN (VITAMIN A_2?) OF FISH LIVER OILS. Biochem. Jour. 32: 405–416, illus.

(4) HOLMES, HARRY N., and CORBET, RUTH E.
1937. THE ISOLATION OF CRYSTALLINE VITAMIN A. Amer. Chem. Soc. Jour. 59: 2042–2047, illus.

(5) NELSON, E. M., WALKER, REED, and JONES, D. BREESE.
1931. DETERMINATION OF VITAMIN A BY A PREVENTATIVE METHOD. Amer. Soc. Biol. Chem. Proc. 25, Jour. Biol. Chem. 92: vi.

(6) NORRIS, EARL R., and CHURCH, ANNA E.
1930. A STUDY OF THE ANTIMONY TRICHLORIDE COLOR REACTION FOR VITAMIN A. II. THE DILUTION CURVE OF COD LIVER OIL WITH ANTIMONY TRICHLORIDE REAGENT. Jour. Biol. Chem. 87: 139–146, illus.

(7) ——— and DANIELSON, IRVIN S.
1929. COMPARISON OF BIOLOGICAL AND COLORIMETRIC ASSAYS FOR VITAMIN A AS APPLIED TO FISH OILS. Jour. Biol. Chem. 83: 469–475, illus.

(8) SHERMAN, H. C., and TODHUNTER, E. N.
1934. THE DETERMINATION OF VITAMIN A VALUES BY A METHOD OF SINGLE FEEDINGS. Jour. Nutr. 8: 347–356, illus.

(9) SWANSON, PEARL P., STEVENSON, GLADYS T., and NELSON, P. MABEL.
1938. A METHOD OF INCREASING PRECISION IN VITAMIN A ASSAY. Jour. Nutr. 15: 103–123.

(10) UNDERHILL, SYDNEY WILLIAM FRANK, and COWARD, KATHERINE HOPE.
1939. CRYSTALLINE ESTERS OF VITAMIN A. II. BIOLOGICAL POTENCY. Biochem. Jour. 33: 594–600.

(11) WOKES, F., and WILLIMOTT, S. G.
1927. A STUDY OF ANTIMONY TRICHLORIDE AS A POSSIBLE QUANTITATIVE REAGENT FOR VITAMIN A. Analyst 52: 515–524, illus.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS EITHER FIRST PRINTED OR LAST REVISED

Secretary of Agriculture	CLAUDE R. WICKARD.
Under Secretary	PAUL H. APPLEBY.
Assistant Secretary	GROVER B. HILL.
Land Use Coordinator	M. S. EISENHOWER.
Director of Agricultural Defense Relations	M. CLIFFORD TOWNSEND.
Solicitor	MASTIN G. WHITE.
Director of Personnel	JAMES L. BUCKLEY, *Acting.*
Director of Finance and Budget Officer	W. A. JUMP.
Director of Information	MORSE SALISBURY.
Director of Research and Chief, Office of Experiment Stations.	JAMES T. JARDINE.
Director of Extension Work	M. L. WILSON.
Director of Marketing	ROY F. HENDRICKSON.
Director of Foreign Agricultural Relations	LESLIE A. WHEELER.
Office of C. C. C. Activities (Chief)	FRED W. MORRELL.
Office of Plant and Operations (Chief)	ARTHUR B. THATCHER.
Department Librarian	RALPH R. SHAW.
Agricultural Adjustment Administration	R. M. EVANS, *Administrator.*
Bureau of Agricultural Chemistry and Engineering	HENRY G. KNIGHT, *Chief.*
Bureau of Agricultural Economics	H. R. TOLLEY, *Chief.*
Agricultural Marketing Service	C. W. KITCHEN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Commodity Credit Corporation	J. B. HUTSON, *President.*
Commodity Exchange Administration	JOSEPH M. MEHL, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Entomology and Plant Quarantine	P. N. ANNAND, *Chief.*
Farm Credit Administration	A. G. BLACK, *Governor.*
Farm Security Administration	C. B. BALDWIN, *Administrator.*
Federal Crop Insurance Corporation	LEROY K. SMITH, *Manager.*
Forest Service	EARLE H. CLAPP, *Acting Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Bureau of Plant Industry	E. C. AUCHTER, *Chief.*
Rural Electrification Administration	HARRY SLATTERY, *Administrator.*
Soil Conservation Service	H. H. BENNETT, *Chief.*
Surplus Marketing Administration	ROY F. HENDRICKSON, *Administrator.*

This bulletin is a contribution from

Bureau of Home Economics	LOUISE STANLEY, *Chief.*

U. S. GOVERNMENT PRINTING OFFICE: 1941

For sale by the Superintendent of Documents, Washington, D. C. - - - - Price 10 cents

END