

VITAMIN A CONTENT OF FOODS AND FEEDS*

THE importance of small amounts of various ingredients in the rations of man and animal has been recognized only in the last two decades. Before that time dietary standards were based almost entirely upon digestible protein and carbohydrates, even lime and phosphoric acid, though recognized as essential, not being given much attention. Since 1910 it has been recognized that deficiency in growth or production as well as various disorders from which man and animals suffer may be due to deficiencies of various substances. Very small amounts of some of these substances are required, but their presence in adequate amounts is a necessity for health or normal growth and development. These substances include iron, copper, iodine, manganese, and vitamins. Deficiencies of one or more of these substances in the diet may cause diseases such as anaemia, pellagra, scurvy, eczema, rickets, or goiter, as well as susceptibility to other diseases, retardation in growth of young animals, and deficient production of milk or eggs.

CLASSIFICATION, FUNCTIONS, AND SOURCES OF VITAMINS

Vitamin name	Descriptive name	Functions in body	Excellent sources
A	Anti-ophthalmic Anti-infective	Promotes growth, long life, health, vigor, appetite, and digestion. Prevents infections, and essential to reproduction.	Cod liver oil, spinach, mustard greens, turnip greens, tomatoes, butter, milk, cheese, eggs, liver, carrots.
B	Anti-neuritic Anti-beri-beri	Promotes appetite, digestion and growth. Protects from certain nerve diseases, essential to reproduction.	Whole wheat, corn, rice, oats, peas, eggs, yeast, carrots, spinach.
C	Anti-Scorbutic	Required for proper metabolism of bones, formation and maintenance of teeth, and protects from scurvy.	C a b b a g e, lettuce, onion, s p i n a c h, tomatoes, lemons, oranges, celery, pineapple, strawberries.
D	Anti-rachitic	Required for formation and maintenance of bones and teeth and for protection of young a g a i n s t rickets.	Sunlight, cod liver oil, other fish oils, eggs, salmon, milk, and viosterol.
E	Anti-sterility	Essential for reproduction.	Whole wheat, lettuce, vegetable oils, alfalfa, beans, corn, oats, rice, meat.
G	Anti-pellagic	Required for growth and for functions which p r e v e n t pellagra.	Liver, kidney, l e a n meat, spinach, potatoes, turnip greens, eggs, milk, salmon, tomatoes.

* By G. S. Fraps and Ray Treichler in Bulletin No. 477 of the Texas Agricultural Experiment Station.

Vitamins are organic substances which are present in very small amounts in foods and are known to be essential to the health of animals.

VITAMINS AND THEIR IMPORTANCE

The exact number of the vitamins and their nature has not yet been ascertained. Vitamins are studied by means of feeding experiments on animals and the complete or partial lack of them in the food is recognized by the failure of the animal body to grow or perform some of its functions. An outline of the classification, functions, and occurrence of vitamins is given in our table. Following are brief descriptions of the vitamins known at present.

Vitamin A.—This is also called the fat soluble A, anti-ophthalmic, or anti-infective vitamin. Its presence in sufficient amounts promotes appetite, digestion, growth and long life, maintains health and vigour, prevents infections, especially of the eyes and lungs, and is essential for normal reproduction, lactation, and rearing of the young. When deficient or absent from the diet the animal may, if young, have a retardation of growth and development. Animals receiving insufficient vitamin A may suffer a loss of appetite and are susceptible to infections of the glands at the base of the tongue, of the sinuses in the ears, and of the lymph glands, lungs, nose, and skin. The animals may also suffer from night blindness and infections of the eyes, and infections of the kidney, bladder, and alimentary canals. Excellent sources of vitamin A are green feeds such as spinach, mustard, or grass. Carrots, tomatoes, and cod liver oil are also good sources of vitamin A. Vitamin A is closely related to carotene, a yellow colouring matter found in carrots, yellow corn, green vegetables, and other foods. Carotene is converted into vitamin A in the body. Vitamin A survives ordinary processes of cooking but is partly destroyed by long boiling, as in making certain stews.

Vitamin B.—This is also called the anti-neuritic or anti-beri-beri vitamin. Its presence in sufficient amounts promotes appetite, digestion, and growth. It protects the body from such nervous diseases as beri-beri and polyneuritis. It is required by the mother for normal reproduction and lactation. When insufficient amounts are in the food eaten, there occurs a decrease of appetite and impairment of digestive processes, loss of weight and vigor, and impaired growth of the young. Beri-beri or polyneuritis may also occur. Vitamin B is found in whole cereals such as wheat, corn, rice, oats, barley and in peas, wheat bran, egg yolk, yeast, rice polish, and rice bran. Smaller amounts are found in other foods. Vitamin B is partly destroyed by long-continued cooking, especially if the water is alkaline, but only a part is destroyed by ordinary processes of cooking.

Vitamin C.—This is also termed the anti-scorbutic vitamin. When present in sufficient amounts it protects the body from scurvy, and promotes the proper metabolism of the bones and the normal formation and maintenance of the teeth. When present in insufficient amounts in the diet, the disease known as scurvy will occur, which is manifested by spongy and bleeding gums, pains and swelling in the joints and limbs, or haemorrhages of the mucus membranes or skin. The bones may also lose so much lime and phosphoric acid as to become fragile. The teeth may decay or become loose or even be shed. There may be a loss of weight or

appetite and sallow complexion. Vitamin C is found in oranges, lemons, and in vegetables, such as spinach, tomatoes, lettuce, onions, and cabbage. Smaller amounts are found in a number of other vegetables. Vitamin C is partly destroyed by cooking, especially if it is long continued. Ordinary cooking is not highly destructive.

Vitamin D.—This is known as the anti-rachitic vitamin. When present in sufficient amounts it regulates the absorption and metabolism of the lime and phosphoric acid in the bones and teeth. It is, therefore, required for the proper formation and maintenance of bones. When an insufficient amount is in the diet, a bone disease known as rickets may occur, especially with children and young animals. This is manifested in soft and fragile bones, enlargements of the wrist, elbow and junctions of the ribs softening of the bones of the head, or bow-legs or knock-knees. A general muscular weakness and instability of the nervous system may occur together with a low content of lime and phosphoric acid in the blood and bones, and defects in the teeth such as decay or soft teeth. Vitamin D is most abundant in cod liver oil and some other fish oils. It is also supplied by sunlight or ultraviolet light or by food irradiated by ultraviolet light. Vitamin D prepared by irradiating ergosterol is effective for rats but not for chickens. It occurs in eggs and salmon in good amounts, while small amounts are found in butter and milk. A few minutes of bright Texas sunshine is sufficient to supply a rat with all the vitamin D it needs for 24 hours, and is probably sufficient for other animals also. Vitamin D is quite stable and not destroyed by ordinary processes of cooking.

Vitamin E.—This is known as the anti-sterility vitamin. Although other vitamins are also required for reproduction, it is necessary for the normal reproductive functions of both males and females. If a sufficient amount is not present in the food, the animals become sterile. It is found in good quantities in lettuce, wheat, wheat germ, and in a number of ordinary feeds, such as alfalfa, barley, beans, corn, peas, rice, and oats. Vitamin E is not destroyed by ordinary processes of cooking. It is remarkably stable.

Vitamin G.—This is also known as the anti-pellagric vitamin. When present in sufficient amounts it aids in preventing pellagra, although other factors are probably concerned in the prevention or cure of pellagra. When an insufficient amount is present in the food the animal may suffer from pellagra, which manifests itself in disturbances of the digestive tract, darkening and thickening of the spleen, soreness and inflammation of the tongue and mouth, and nervousness and mental disorders. It is found in good quantities in yeast, liver, kidneys, spleen, and lean meat, as well as beet leaves, potatoes, spinach, turnip greens, eggs, milk, and salmon. Vitamin G is not destroyed by ordinary processes of cooking, but is relatively stable to heat.

Other Vitamins.—It appears that vitamin D in cod liver oil is different from that in irradiated ergosterol, since the former will prevent bone-weakness in chickens but the latter will not. Evans applies the term vitamin F to unsaturated fatty acids which appear to act as vitamins. It also seems possible that the vitamin B complex may be split into three other vitamins in addition to vitamin B and vitamin G already accepted.

METHOD OF ESTIMATING VITAMIN A ACTIVITY

There is no chemical method for estimating the vitamin A content of the various foods and feeding stuffs; so the estimation must be made by a biological method. The method consists in measuring the growth of rats fed upon a ration complete except for vitamin A, and to which a weighed amount of the material to be tested is added. The estimation measures the vitamin A activity, since the results may be due to carotene or other precursor of vitamin A, as well as to the vitamin A itself. For the sake of brevity, vitamin A is frequently used in place of vitamin A activity in this Bulletin.

The animals used must have previously been fed upon a ration free of vitamin A until the vitamin A stored up in the body of the animal has been almost removed. This is manifested by the animals beginning to decline in weight.

The determinations made by the method given above are expressed as rat units, a rat unit being a gain of 24 grams in eight weeks. An international unit has recently been adopted which is .001 milligrams of a certain preparation of carotene. Direct comparisons of the international unit and of the rat unit have not been published, but according to a private communication it has been found in one laboratory that the rat unit and international unit are practically the same. It is desirable to standardize the rat units of the various laboratories in terms of international units. They may not be exactly the same in different laboratories on account of differences in procedure.

TABULATION OF VITAMIN A ACTIVITY OF FOODS AND FEEDS

Quantitative estimations of the vitamin A activity in foods and feeds reported in the literature are comparatively small in number. The most extensive report is that of Rice and Munsell, who list 59 foods. Fraps reported on a number of samples of corn. Quantitative measurements have been made by other workers, or their results reported in such a way that an estimate of the quantity could be made.

The vitamin A activity in terms of Sherman-Munsell rat units of a number of foods and animal feeds, as found in the work presented in this Bulletin, and elsewhere in the literature, or calculated from data in the literature is given in the table below. There is considerable variation in the vitamin A content of a particular food or feed, dependent on conditions of growth, storage, or other factors. These are discussed below.

The units of vitamin A are rat units, estimated by the method described, and based upon the edible portion of the feed. Since the vitamin A was not separately estimated, and since vitamin A can be made from carotene in the animal body, the units here used really represent the vitamin A activity of the food, and not the vitamin A alone. The method for estimating vitamin A is not highly accurate. Ordinarily an error of ten per cent. may be expected. For this reason the results in the table are rounded off. In some cases, where the number of units was given by the worker in terms of ounces or pounds, they were calculated by us to units

per gram, and then rounded off to 0.1 unit or whole units. If the units per ounce or pound are then calculated from the units per gram, the results will not check exactly with those given in the table, but they will be within the limit of error.

APPROXIMATE NUMBER OF UNITS OF VITAMIN A IN FOODS AND FEEDS

	Units per gram	Units per ounce	Units per pound
Alfalfa, machine-dried	100	2,835	45,360
Alfalfa, sun-cured	20	567	9,072
Alfalfa, field-cured and exposed to rain	12	340	5,440
Alfalfa, field-cured and exposed to rain	14	396	6,336
Alfalfa leafy hay	3.3	93	1,488
Alfalfa stemmy hay	3	85	1,360
Alfalfa meal	12.5	354	5,664
Alfalfa meal	15	425	6,800
Alfalfa leaf meal	20	567	9,072
Alfalfa leaf meal	10	283	4,528
Alfalfa leaf meal	7	198	3,168
Alfalfa leaf meal	20	567	9,072
Alfalfa leaf meal, machine-dried	66.6	1,888	30,208
Alfalfa leaf meal, machine-dried	50	1,417	22,672
Alfalfa stem meal	2.4	68	1,088
Apples	.5	15	240
Apples	.5	15	240
Apricots, fresh	50	1,417	22,672
Apricots, fresh frozen	7	198	3,168
Apricots, sun-dried, sulphured	12	340	5,440
Apricots sun-dried, unsulphured	8	220	3,620
Artichokes	3	85	1,360
Asparagus	1.2	35	560
Bacon	.2	5	80
Banana	2	56	896
Banana	2	56	896
Banana	3.5	100	1,600
Banana	2	56	896
Barley, less than	1	28	448
Beans	3.6	102	1,632
Beans, canned navy	0.5	15	240
Beans, dried lima	0	0	0
Beans, string	5.2	150	2,400
Beets	0.2	5	80
Bermuda grass, dried in vacuum	120	3,402	54,432
Bread, commercial, less than	1	28	448
Bread, commercial, mixed	0.1	3	50
Broccoli	3.3	95	1,520
Brussels sprouts	3.3	95	1,520
Bur clover, dried in vacuum	200	5,670	90,720
Butter	30	849	13,584
Butter	50	1,415	22,640
Butter	50	1,515	22,640
Butter	49	1,400	22,400
Butter fat, creamery	17	481	7,696

**APPROXIMATE NUMBER OF UNITS OF VITAMIN A
IN FOODS AND FEEDS—(Contd.)**

	Units per gram	Units per ounce	Units per pound
Butter fat, cows on pasture ...	50	1,417	22,400
Butter fat, creamery, average ...	28	792	12,672
Butter fat, cows on pasture ...	40	1,132	18,112
Butter fat, cow on silage (no pasture)	3.6	102	1,632
Butter fat, feed low in vitamin A ...	2.5	71	1,136
Castor Oil ...	0	0	0
Cabbage, new, average of green and white	0.4	10	160
Cabbage, Chinese (estimated) ...	50	1,415	—
Cantaloupe ...	3.3	93	1,488
Cantaloupe ...	3.2	90	1,440
Carrot ...	25	708	11,328
Carrot ...	33	940	15,040
Carrot ...	25	708	11,328
Carrot ...	43	1,219	19,504
Carrot, yellow raw ...	67	1,888	30,208
Carrot, yellow dried ...	25	708	11,328
Carrot, yellow, dried in vacuum ...	77	2,182	35,376
Carrot juice, sterilized ...	0	0	0
Carrot tops, dried (estimated) ...	16	453	7,248
Cauliflower ...	0.5	15	240
Celery, bleached ...	0	0	0
Cereals ...	0	0	0
Cheese, American ...	24.5	700	11,200
Cheese, cottage ...	1.1	30	480
Cheese, cream ...	49	1,400	22,400
Cheese, Farmesan ...	24.5	700	11,200
Cherries, frozen (Montmorency, Royal Ann, Late Duke) ...	0.3	8	128
Cherries, frozen, (Bing, Deacon, Lambert)	0.4	10	160
Clover, bur, dried in vacuum ...	200	5,670	90,720
Cod liver oil ...	250	7,075	113,200
Cod liver oil ...	500	14,150	226,400
Cod liver oil ...	1,000	28,300	452,800
Cod liver oil ...	1,250	35,375	556,000
Collards, green, raw or boiled 45 min.	50	1,417	22,672
Corn, Bloody Butcher ...	2.5	70	1,120
Corn, Bloody Butcher ...	5	141	2,256
Corn, Fentress Strawberry ...	1.1	31	496
Corn, Fentress Strawberry ...	5	141	2,256
Corn, Ferguson yellow dent ...	5	141	2,256
Corn, Ferguson yellow dent ...	6.6	187	2,992
Corn, red ...	0.9	25	400
Corn, red ...	5	141	2,256
Corn, white ...	0	0	0
Corn, white5	14	224
Corn, yellow ...	2.5	70	1,120
Corn, yellow ...	8	226	3,616
Corn, Ferguson yellow dent, Beeville, Texas	6.6	187	2,992
Corn, Ferguson yellow dent, Troup, Texas	6.2	175	2,800
Corn, Ferguson yellow dent, Angleton, Texas	6.6	187	2,992

APPROXIMATE NUMBER OF UNITS OF VITAMIN A
IN FOODS AND FEEDS—(Contd.)

	Units per gram	Units per ounce	Units per pound
Corn, Ferguson, yellow dent, Beaumont, Texas	5.5	155	2,480
Corn, Ferguson yellow dent, Nacogdoches, Texas	5	141	2,256
Corn, Ferguson yellow dent, College Station, Texas	5	141	2,256
Corn, Ferguson yellow dent, Nacogdoches, Texas	5	141	2,256
Corn, yellow	6.6	187	2,992
Corn, yellow	6.6	187	2,992
Corn, yellow	5	141	2,256
Corn germ meal	0	0	0
Corn meal, white (estimated)	0	0	0
Corn meal, golden	3	85	1,360
Corn meal, yellow granulated	3	85	1,360
Corn meal, feed	3.3	93	1,488
Corn meal, feed	3.3	93	1,488
Corn meal, yellow	5	141	2,256
Corn meal, yellow	5	141	2,256
Cottonseed meal, less than	1.0	28	448
Cottonseed meal, (estimated)	0.1	2.8	45
Cottonseed meal and cake, less than	1	28	448
Cottonseed oil, less than	1	28	448
Cucumber	.4	10	160
Dates	3	85	1,360
Dates, Deglet noor	.8	22	352
Dates, Maktum variety	1	28	448
Dates, Thoory	1.3	36	576
Eggs, June laid, Rhode Island Red	28	792	12,672
Eggs, June laid, White Leghorn	28	792	12,672
Eggs (edible part)	19	550	8,800
Egg yolk	50	—	—
Egg yolk, beginning of laying season	30	850	13,600
Egg yolk, end of laying season	6	170	2,720
Egg plant	.7	20	320
Escarole	210	6,000	96,000
Figs, cooking	.4	10	160
Fish, fat	.4	10	160
Fish, lean	0	0	0
Fish "opihii", Hawaiian	500	14,175	226,800
Flour, wheat (estimated)	0	0	0
Grapes, Concord, Tokay, Malaga	.7	20	320
Grapes, Sultanina and Malaga	.2	5	80
Grapefruit peel and pulp, dried, less than	5	—	—
Grapefruit juice (estimated)	0.1	2.8	45
Grape, juice, commercial	0	0	0
Halibut, liver oil	37,500	1,063,000	—
Halibut, liver oil	62,300	1,779,000	—
Hegari, stover	3.3	93	1,488

**APPROXIMATE NUMBER OF UNITS OF VITAMIN A
IN FOODS AND FEEDS—(Contd.)**

	Units per gram	Units per ounce	Units per pound
Hegari, grain	0·3	8·5	136
Hominy, yellow	8·3	235	3,760
Hominy feed, yellow	1·5	42	672
Hominy, white (estimated)	0	0	0
Kafir, grain, black	0·3	9	144
Kafir, grain, red	0·4	11	176
Kafir, grain, white	0·5	14	224
Kidney	8	230	3,680
Lard (estimated)	0	0	0
Lemons	0	0	0
Lettuce	1·5	42	672
Lettuce, head	1·8	50	800
Lettuce, head	1·7	45	720
Lettuce, head, inside leaves	3·3	93	1,488
Lettuce, Iceberg, from centre of head	1·7	45	720
Lettuce, Iceberg, outside green leaves	67	1,888	30,208
Lettuce, Iceberg, outside green leaves	50	1,417	22,672
Lettuce, Romaine	5·3	150	2,400
Liver	98	2,800	44,800
Liver fat	5,000	141,500	2,264,000
Loco weed, air dried	16	453	7,248
Meal, corn, white (estimated)	0	0	0
Meat, average, muscle	0·2	5	80
Meat, pork (estimated)	0	0	0
Milk, condensed	4·9	140	2,240
Milk, dried, whole	17·5	500	8,000
Milk, dried, whole	6·6	187	2,992
Milk, dried, whole	10	283	4,528
Milk, evaporated	4·9	140	2,240
Milk, whole	2·3	65	1,040
Milk, whole	1·3	36	576
Milk, whole	2	56	896
Milo grain, yellow	0·5	14	224
Milo, white, chop	0	0	0
Milo grain, dwarf yellow	0·5	14	224
Milo grain, yellow	0·4	11	176
Milo, dwarf yellow, less than	0·5	14	224
Milo, dwarf yellow, less than	0·3	8	128
Milo, dwarf yellow, less than	0·5	14	224
Milo, yellow, less than	0·5	14	224
Milo, yellow, less than	0·5	14	224
Mushrooms	0	0	0
Oats, less than	0·2	5	80
Oat meal (estimated)	0	0	0
Oat oil, less than	0·6	17	272
Oil, cottonseed	0	0	0
Oil, raisin	0	0	0
Oil, sesame	0	0	0
Okra, ends, dried, less than	2	56	896

APPROXIMATE NUMBER OF UNITS OF VITAMIN A
IN FOODS AND FEEDS—(Contd.)

	Units per gram	Units per ounce	Units per pound
Okra, ends, dried, less than ...	2	56	896
Okra, pods and seed, dried ...	3	75	1,200
Onions ...	0	0	0
Orange juice (estimated) ...	0·5	141	2,256
Oranges ...	0·7	20	320
Orange peel and pulp, dried ...	3	85	1,360
Orange peel and pulp, dried ...	4	113	1,808
Orange peel and pulp, dried ...	6·6	186	2,976
Orange peel and pulp, dried ...	5	141	2,256
Oysters, raw frozen ...	0·5	14	224
Oysters, raw frozen ...	1	28	448
Peaches ...	0	0	0
Peaches, Elberta, fresh ...	20	566	9,072
Peaches, Muir, fresh ...	12	340	5,443
Peaches, canned ...	2	56	896
Peaches, frozen Elberta ...	0·5	14	224
Peaches, frozen Hiley, less than ...	0·5	14	224
Peanut meal, less than ...	0·5	14	224
Peanut meal, less than ...	0·5	14	224
Pears, Bartlett, less than ...	0·1	4	64
Peas, cooked green ...	2	56	896
Peas, dried green ...	3	85	1,360
Peas, dried green ...	12·5	354	5,664
Peas, raw and canned ...	6·1	175	2,800
Peas, raw and cooked ...	2	56	896
Peas, raw or cooked, 10 min. ...	67	1,888	30,208
Peas, canned ...	67	1,888	30,208
Peas, blackeyed, dried ...	2	56	896
Pecan meats ...	3·6	102	1,632
Pecan meats, Burkett variety ...	1·6	45	720
Pecan meats, Texas Prolific variety ...	2	56	896
Pecan meats, stored 14 months less than ...	1	28	448
Peppers ...	6	175	2,800
Peppers, sweet green, dried ...	40	1,134	18,144
Peppers, sweet green, dried ...	20	567	9,072
Pineapple, canned, including syrup ...	0·3	9	144
Potatoes, sweet ...	3	85	1,360
Potatoes, white, or Irish ...	0·4	10	160
Potatoes, sweet, Nancy Hall ...	30	849	13,584
Potatoes, sweet, Porto Rico ...	50	1,417	22,672
Potatoes, yellow, sweet, raw ...	20	567	9,072
Potatoes, yellow, sweet, dried in air ...	2	56	896
Potatoes, yellow, sweet, dried in air ...	2·5	70	1,120
Potatoes, yellow, sweet, dried in vacuum ...	50	1,417	22,672
Potatoes, yellow, sweet, dried ...	2	56	896
Potatoes, yellow, sweet, dried ...	2	56	896
Prunes ...	10·5	300	4,800
Prunes, French, fresh ...	20	567	9,072
Pumpkin, dehydrated ...	50	1,417	22,672

**APPROXIMATE NUMBER OF UNITS OF VITAMIN A
IN FOODS AND FEEDS—(Contd.)**

	Units per gram	Units per ounce	Units per pound
Raisins	0	0	0
Raisins, Thompson seedless and Malaga	0	0	0
Sorghum silage	5.5	156	2,496
Sorghum silage	10	283	4,528
Sourkraut	0.2	5	80
Spinach, canned, juice poured off	100	2,835	45,360
Spinach, canned, juice poured off	140	3,920	62,720
Spinach, dried in vacuum, canned	333	9,324	149,184
Spinach, New Zealand	11	314	5,024
Spinach, ordinary garden	14	402	6,432
Spinach, raw	63	1,771	28,336
Spinach, raw and canned	49	1,400	22,400
Spinach, raw, Virginia Savoy, Princess Juliana and Viroflay	83	2,361	37,776
Strawberries	0.2	5	80
Strawberries	0.16	45	720
Sudan grass, dried in vacuum (estimated)	150	4,245	67,920
Tomatoes, green, raw or canned	7	187	2,992
Tomatoes, raw and canned	6	170	2,720
Tomatoes, ripe, raw or canned	13	374	5,984
Tomato soup, canned	6	170	2,720
Turnips	0.2	5	80
Turnip greens, raw or boiled	50	1,417	22,672
Turnip greens, dried	33	935	14,960
Watermelon pulp	1	28	448
Wheat, whole, less than	0.3	7.8	125
Wheat (estimated)	0.2	5.6	89
Wheat bran, less than	1	28	448
Wheat gray shorts	0.3	9	144
Wheat gray shorts	0.05	1.4	22

**SOME FACTORS WHICH AFFECT THE VITAMIN A
ACTIVITY OF FOODS**

It is known that a number of factors affect the vitamin activity of foods or feeds. Definite measurements are, however, limited in number. There seems to be a definite relation between greenness and vitamin A content. The green outer leaves of cabbage and lettuce contain much more vitamin A than the white inside leaves. Chlorotic spinach contains less vitamin A than normal green spinach. There are indications that the vitamin A content of carrots and of alfalfa is at its maximum during the early stages of growth.

EFFECT OF TIME OF STORING OF FOODS

We have shown that the vitamin A content of dried foods decreases during storage. Dried whole milk lost 60 per cent. in 9 months, alfalfa leaf meal 50 per cent. in 5 months, yellow corn 30 per cent. in 5 months, and dried green pepper 80 per cent. in 19 months. It follows that the quantity of vitamin A present in the dried food at a given time will depend upon

how old the particular material is at the time of the determination. Thus freshly prepared or freshly harvested foods or feeds will contain more vitamin A than those which have been in storage for several months. This fact may account for some of the differences in vitamin A found between different lots of the same kind of material. It is therefore important to record the period of storage, if possible, in connection with the estimation of vitamin A. In a period of several months there may be a decline in the quantity of vitamin A in the food being used.

EFFECT OF DRYING OR CURING

It is known that there is a loss of vitamin A in the drying or curing of alfalfa and similar feeds. Sun-dried alfalfa contains much less vitamin A than heat-dried alfalfa. The extent of the loss seems to depend upon the procedure adopted in the drying. Hauge and Aitkenhead conclude that much of the loss in the drying of hays and fodder is due to changes caused by enzymes in slow drying in the feed. If the material is dried rapidly the loss on drying is much less than if the drying took place slowly. Poorly cured hays or fodders may be low in vitamin A.

The following results were secured in testing the effect of drying upon carrots, spinach and sweet potatoes.

Raw yellow carrots contained approximately 43 units per gram of fresh material containing 11.4 per cent. dry matter. Dried carrots contained 77 units of vitamin A per gram. The carrots lost approximately 80 per cent. of their vitamin A when dried. Canned spinach contained 140 units of vitamin A in the pressed solids containing 14.7 per cent. dry matter, or 952 units per gram of dry matter. Vacuum dried spinach contained about 333 units vitamin A per gram. The spinach lost 65 per cent. of its vitamin A in drying. Yellow Porto Rico sweet potatoes contained 20 units vitamin A per gram, with 28.7 per cent. dry matter or 69 units per gram of dry matter. The vacuum-dried sweet potatoes contained 50 units per gram. The sweet potatoes lost 29 per cent. of its vitamin A in drying.

EFFECT OF CANNING

Green peas or tomatoes canned by modern processes seem to contain as much vitamin A as similar fresh food purchased on the market, according to Eddy and his co-workers.

No direct estimation of the loss of vitamin A during the process of canning has yet been made, as it is difficult to preserve the fresh food without possible loss of vitamin for the period of eight weeks necessary for the test with the rats to compare it with the canned product. Comparisons have been made between the canned food and the fresh food purchased on the market, but the samples compared were grown in different places and under different conditions. It is certain, however, that canned foods retain high percentages of their original vitamins.

EFFECT OF VITAMIN A IN THE FOOD ON VITAMIN A IN MILK, BUTTER, AND EGGS

The vitamin A activity of milk, butter, and eggs depends upon the vitamin A content of the ration. The animal may contain a store of vitamin A, which at first will be used in the milk or eggs, but if the animal is fed a ration containing an insufficient amount of vitamin A, the vitamin

A in the product will gradually decrease. Thus the eggs of pullets fed on diets containing yellow corn as the only source of vitamin A gradually decreased in content of vitamin A, showing these diets contained an insufficient amount of vitamin A. The butter fat from a cow fed on yellow corn but with no other source of vitamin A, decreased in vitamin A. Sorghum silage did not supply enough vitamin A to a cow to produce butter of high potency.

Relation of units of Vitamin A in yolks of eggs to the feed and to the stage of laying period (no green feed)

Date samples taken	Units of vitamin A per gram of eggs yolk		
	Yellow corn	Mixed corn	White corn
Dec. 3, 1931	20	12	13
Dec. 29, 1931	—	12	12
Jan. 29, 1932	14	10	10
Feb. 29, 1932	10	—	14
Mar. 31, 1932	—	6	5
May 2, 1932	5	8	—

Effect of feed of cows on Vitamin A content of butter fat after a feeding period of 15 to 16 months

	Units per gram	Units per cow per day
Cottonseed meal and hulls, average	2.5	340
Cottonseed meal, hulls and silage, average	3.8	1,960
Cottonseed meal, hulls, silage and pasture, average	33	17,280

VITAMIN A IN SOME HUMAN FOODS

Some of the foods listed in our first table are discussed briefly below.

Eggs.—The eggs examined for their vitamin A content were from White Leghorn pullets. The yolks averaged approximately fifteen grams in weight, while the whole eggs weighed about 50 grams, of which 10.9 per cent. was shell. Thus the yolk was 30 per cent. of the whole egg, or about one-third the edible part of the egg. There were nine eggs to the pound. The cost per pound of edible egg would be, for these White Leghorn eggs, the price per dozen multiplied by 0.84. Thus, with eggs at 30 cents a dozen, the edible part would cost 25.2 cents a pound. Assuming the eggs from pullets receiving green food in addition to a diet complete in minerals and other food elements can be called normal eggs, it was found that the normal vitamin A content of eggs from White Leghorn pullets is approximately 290 to 450 units per egg, which is 20 to 30 units to the gram of yolk, or 7 to 10 units to the gram of egg less the shell. From work previously reported, it was found that ration fed pullets when not supplemented with fresh green feed, which is rich in vitamin A, does not supply sufficient vitamin A to enable the pullet to put enough into the egg to keep the vitamin A content up to the normal. In those cases where the pullets

are deprived of an optimum amount, after two or three months the vitamin A content of the egg may decrease to only 7 units per gram of yolk, 2 units per gram of whole egg (less shell), or 105 units per egg. Egg yolk from pullets fed liberal amounts of yellow corn in the mash and scratch feed contained approximately 20 to 30 units of vitamin A per gram at the beginning of the laying season. When the pullets were kept on a ration where the sole source of vitamin A was yellow corn there was a gradual decrease in the vitamin A content from 20.0 units per gram to 7 units per gram over a period of approximately five months. Egg yolk from pullets fed a ration where the source of vitamin A was a mixture of yellow and white corn contained approximately 12 units of vitamin A per gram at the beginning of the laying season with a gradual decrease in the vitamin A content in the eggs laid, to 6 to 8 units of vitamin A per gram, over a period of about five months. White corn contains a negligible amount of vitamin A; so the sole source of vitamin A could be said to be the yellow corn. Egg yolk from pullets fed white corn as the sole source of vitamin A contained approximately 12 units per gram at the end of the first month of feeding and there was a gradual decrease in vitamin A content to 6 units over a period of five months. The vitamin A in these eggs comes from that stored up in the body of the fowl.

Dried Whole Milk.—Three samples of dried whole milk contained from 6.6 units to 10 units of vitamin A per gram, all samples being relatively fresh when tested. After being stored for eleven months, approximately 66 per cent. of the vitamin A had been lost (one sample).

Sweet Potatoes.—Porto Rico (yellow) sweet potatoes were found to be excellent sources of vitamin A, as two samples examined contained 30 to 40 units per gram on the original wet basis. Since the sweet potatoes contained 70 per cent. water, the dry matter would contain 100 to 133 units per gram. Rice and Munsell reported only 3 units per gram, while McLeod, Talbert, and Toale report Nancy Hall sweet potatoes to contain 30 units per gram. Sweet potatoes contained only two units per gram when dried under ordinary conditions, 50 units per gram when dried in a vacuum. Both the Porto Rico and Nancy Hall are yellow sweet potatoes. The vitamin A has not been established in white sweet potatoes, and it may be low in them. Possibly the sweet potatoes used by Rice and Munsell, which contained only 3 units of vitamin A to the gram, were white sweet potatoes.

Carrots.—Carrots, like sweet potatoes, are excellent sources of vitamin A, as the yellow carrots examined contained 43 to 67 units per gram on the original basis. As the carrots contained 87 per cent water, they would contain 330 to 500 units per gram of dry matter. Rice and Munsell report 33 units to the gram, while Browning reports 25 units. These are somewhat lower values than those secured by us. Carrots when dried contained 25 to 67 units per gram, showing a decided loss in drying.

Butter.—Butter ordinarily contains 78 to 82 per cent. butter fat, the remainder being salt, curd, and water. Average creamery butter seems to contain 30 to 40 units of vitamin A per gram, and must be considered to be a good source of vitamin A. The number of units per gram of butter fat depends upon the feed of the cow, as has already been pointed out,

Pecan Meats and Peanut Meat.—Three samples of pecan meats were examined for their vitamin A content. One sample consisted of low-grade pecan meats. The two remaining samples were the Texas Prolific variety, and the Burkett variety. The Burkett variety contained 1.6 units of vitamin A per gram of meats and the Texas Prolific variety contained 2.0 units of vitamin A per gram of meat.

Peanut meal was found to be a poor source of vitamin A. One sample contained approximately .55 units per gram of material, while another sample examined would not allow growth when fed at a level of 2 grams daily.

Spinach and Other Greens.—Spinach, turnip greens, and mustard greens are excellent sources of vitamin A, as they contain 50 to 100 units per gram of the original material. As is shown elsewhere, vitamin A can be purchased in these materials at very low prices. Canned spinach in many cases cost more than the fresh spinach, but is still an excellent source of vitamin A. The canned spinach we examined was guaranteed to contain 1 pound 3 ounces. In one lot of cans, the juice weighed 316 grams and the pressed spinach 237 grams, and the pressed spinach contained 87.4 per cent. water. In another lot the juice weighed 375 grams, the pressed spinach 189 grams, and the fresh spinach contained 85.3 per cent. water. For the two lots, the cans contained an average of 213 grams, or .47 of a pound of pressed spinach. To get the cost of the spinach per pound, it would be necessary to multiply the price of a can (1 lb. and 3 oz.) by 0.47.

Other Human Foods.—The approximate vitamin A content of other human foods is given in the table.

COST OF VITAMIN A ACTIVITY IN HUMAN FOOD

The costs of vitamin A in a number of foods are compared in the table. The costs here given are the cost per pound of the edible part of the food in question, calculated from the prices prevailing in Bryan, Texas, at the time they were collected, divided by the assumed number of units of vitamin A per pound in the edible part of the food, as given in the table. The cost of food of course varies from month to month and from locality to locality. This method of calculating the cost of the vitamin A is not exactly correct, because it does not allow for the value of the other ingredients in the food besides the vitamin A. As the other ingredients have value and the values vary from one food to another the costs given for vitamin A are both too high, and relatively incorrect. A correct calculation would take all the factors of food value into account. This obviously cannot be done at the present time, on account of the absence of complete quantitative information regarding the food values of most foods. In spite of the defect, the calculations of the cost of vitamin A ought to serve some practical purposes.

The units of vitamin A in the table are assumed to be the average quantities present in the edible part of the food. It has already been pointed out that these quantities are likely to vary. There is usually a loss in preparing food for the table or in consuming it. The shells of eggs, the skins of bananas, the culls from greens, etc., are removed. Hence the food as purchased in many cases will contain somewhat less vitamin A than the quantities given in the table, which refer to the edible portion. The prices

given are also for the edible part of the food, and therefore higher than the market price would be at the same time, as this price per pound applies to the unedible as well as the edible portion of the purchase.

Bananas, carrots, yellow corn, cod liver oil, collard greens, liver, mustard greens, spinach, sweet potatoes, and turnip greens are the cheapest sources of vitamin A shown in the table. In these foods, 1,000 units of vitamin A can be secured for half a cent or less. Sweet potatoes and yellow corn, in addition to supplying vitamin A at a low cost, also furnish energy and protein at a low cost per unit, and for this reason are especially important. The canned vegetables, including carrots, spinach, mustard and turnip greens, are somewhat more expensive than the fresh foods listed above but are still relatively low-priced sources of vitamin A.

Butter, cantaloupe, cheese, and dried green peas are other low-priced sources of vitamin A, but the cost of vitamin A ranges from 1 to 2 cents per thousand units, which is much higher than in the mustard greens, etc., listed in the first group. Eggs are a somewhat higher priced source of vitamin A but they also furnish protein, energy, minerals, and other vitamins and so must be considered as a good source of vitamin A. The same applies to milk. It is interesting to note that tomatoes, while a good source of vitamin A, cost more per unit of vitamin A than any of the foods mentioned above. Asparagus, cabbage, head lettuce, and canned peaches are classed as expensive sources of vitamin A.

Cost of 1,000 units of Vitamin A in food of the composition and at the prices given for the edible part

	Approximate units vitamin A per pound of edible part	Assumed cost per pound of edible part in cents	Cost of 1000 units in cents
Apples	240	2	8.0
Asparagus, canned	560	14	25.2
Banana	896	4	0.4
Beans, navy	240	5	20.0
Beans, string, green	2,400	10	4.2
Beets	80	7.5	93.8
Brussels sprouts	1,520	11	7.0
Butter	22,400	22	1.0
Cabbage	160	5	31.0
Cantaloupe	1,488	2	0.9
Carrot	15,000	7.5	0.5
Carrot, yellow, raw	45,500	7.5	0.2
Cauliflower	240	12.5	52.0
Corn, yellow	3,616	1.5	0.4
Corn meal, yellow	2,480	4	1.6
Cheese, American	11,200	18	1.6
Cucumber	160	3	18.7
Cod liver oil	226,500	200	0.4
Collards (greens)	22,672	5	0.2
Dates	500	26	52.0
Egg plant	320	5	16.0
Eggs (30 cents a dozen)	8,800	25	2.8
Grapes, Concord, Tokay, Malaga	320	8	24.9

Cost of 1,000 units of Vitamin A in food of the composition and at the prices given for the edible part—(Contd.)

	Approximate units vitamin A per pound of edible part	Assumed cost per pound of edible part in cents	Cost of 1000 units in cents
Kidney	3,680	10	2·7
Lettuce, head	800	7·5	9·0
Liver	44,800	10	0·2
Milk, whole	1,040	6	6·0
Milk, evaporated	2,240	10	4·0
Milk, dried whole	4,000	85	21·0
Mustard greens	40,000	5	0·1
Oranges	320	5	15·0
Oysters	400	25	62·5
Peaches, canned	896	25	26·7
Peas, dried green	5,664	12	2·0
Peas, green	2,800	13	4·6
Peas, canned	2,800	20	7·2
Peas, blackeyed, dried	896	5	5·6
Peppers	2,800	13	4·6
Pecan meats	720	50	69·0
Potato, white or Irish	160	2·9	18·0
Potato, yellow, sweet	18,000	1	0·1
Prunes	4,800	5	1·0
Spinach, green	22,400	10	0·4
Spinach, canned (solids only).	45,360	21	0·5
Sourkraut	80	10	125·0
Sweet potatoes, yellow	18,000	1	0·1
Tomatoes, raw	2,720	10	3·7
Tomatoes, canned ripe	5,984	15	2·5
Tomato soup, canned	2,720	12	4·4
Turnip tops	22,672	5	0·2

Additional data are needed both on other foods, and on the foods listed in the table, as there may be considerable variations in additions to those pointed out, and the data here presented are far from complete.

QUANTITIES OF VITAMIN A REQUIRED BY ANIMALS AND MAN

It is known that animals require more vitamin A for growth than for maintenance and more for production than for growth. The amount sufficient for bare maintenance is not sufficient for vigorous health and long life, as has been shown by Sherman. There is evidence that supplementary amounts of vitamins A and D added to the human foods ordinarily eaten may in some cases result in decreased sickness and better health.

Information regarding the quantity of vitamin A required by animals is very meagre. There are indications that 4 units per pound per day are required for maintenance of growing rats, 6 units per pound for proper growth of rats, and that White Leghorn pullets require 32 units per pound per day for maintenance while laying and 6·3 units for each unit of vitamin A in the eggs. Milk cows, like chickens, apparently require large quantities of vitamin A for maintenance, and still more to produce butter of high potency.

Feeds such as sorghum silage, corn silage, and corn stover may not supply sufficient vitamin A to produce butter of high potency, and in fact may supply only enough to just about maintain the animal. The vitamin A requirements for animals producing milk or eggs seem to be very high and the producing animals seems to have a higher requirement for maintenance than an animal not producing. Information regarding the number of units of vitamin A required by man and animals is much needed. As a tentative estimate of the vitamin requirements of humans, we propose 5 units per pound per maintenance and 8 units per pound for growth, or a somewhat more liberal estimate of 1,000 units per day per person—man, woman, or child. This may not be ample for the highest health and vigour, but should be sufficient for growth and maintenance.

This requirement of 1,000 units of vitamin A per person per day can be supplied at a cost of one-half cent or less at the prices given in the table by using bananas, carrots, yellow corn, cod liver oil, collard greens, liver, turnip greens, mustard greens, spinach or sweet potatoes, and perhaps other foods. Other economical sources of vitamin A are butter, cheese, green peas, eggs, and milk; while the cost per unit of vitamin A is much higher in these foods than in those first mentioned, the vitamin A is associated with other food materials of high value, which renders them good sources.

VITAMIN A IN SOME FEEDS FOR ANIMALS

The most important sources of vitamin A for animals are green pasture grasses or legumes. These are high in vitamin A, being similar in that respect to spinach, and mustard greens, and probably contain 100 units or more to the gram of green material, when green and rapidly growing. Animals which have access to good pasture thus receive high amounts of vitamin A, and they can store liberal amounts to use when the supply in the food is more limited.

Next to green pasture comes heat-cured alfalfa or other hays. Heat-cured alfalfa may contain 50 to 66 units of vitamin A to the gram. Ordinary dried hays and fodders contain some vitamin A, but not nearly so much as the fresh green material, as there seems to be considerable loss in curing. Alfalfa leaf meal (sun-cured) we found to contain 7 to 20 units per gram. Alfalfa meal contained 3 to 13 units per gram.

Hays and fodders ordinarily furnish enough vitamin A for maintenance and growth, but hays of poor quality, or even of good quality fed in small amounts, may not furnish enough vitamin A, to maintain the milk cow over a long period of time. Leached or weathered prairie grass is probably low in vitamin A.

Yellow corn is an important source of vitamin A, as it contains when fresh, about 5 units of vitamin A per gram. Cottonseed meal is low in vitamin A. Sorghum silage contains 5.5 to 10 units per gram (2 samples) but both corn silage and sorghum silage may not furnish enough vitamin A to cows to produce milk containing normal quantities of vitamin A.

Orange peel and pulp contained 4 to 6 units of vitamin A per gram.

For beef cattle and sheep, the chief sources of vitamin A are pasturage, hays and fodder, and sometimes yellow corn. Under ordinary conditions, these will supply sufficient quantities of vitamin A. Prairie grasses, however, dried and exposed to the weather are probably low in vitamin A. It

is possible that they do not supply enough vitamin A for maintenance, so that towards the end of the winter with the exhaustion of the reserve stored in the animal, the animal may begin to suffer from a deficiency. The same may happen with an animal sustained for several months on poorly-cured hay or with straw or fodder low in vitamin A. The amounts required for maintenance and growth are comparatively small and the deficiencies referred to here may occur only under exceptional conditions.

The chief sources of vitamin A for milk cows are pasturage, hay or fodder, and yellow corn. Green pasturage furnishes an abundant supply and the animal on good pasture is enabled not only to produce butter fat high in vitamin A but also to store large quantities as a reserve in the body. Well-cured hay contains fair amounts of vitamin A but it seems possible that insufficient amounts of well-cured hay even supplemented with yellow corn, may not furnish enough vitamin A to enable the cow to produce milk of high potency in vitamin A or to prevent the animal from depleting its reserve store. Dairy cows fed long periods of time with silage, straw fodder, or other roughages containing moderate amounts of vitamin A may suffer from a deficiency in this vitamin.

The chief sources of vitamin A for pigs are pasturage, alfalfa meal, and yellow corn. Pigs raised on pasturage may store up sufficient vitamin A to last during the fattening period, even though fed on feeds low in this vitamin. If the pigs are raised on insufficient pasturage, the store of vitamin A may not be sufficient and the pigs would then fail to make the good gains and might suffer in other respects from the deficiency. Yellow corn or alfalfa meal or other dried legume hay of good quality, would probably furnish sufficient vitamin A for the growing and fattening pigs.

The chief sources of vitamin A for chickens are pasturage, yellow corn, and alfalfa meal or alfalfa leaf meal. The yellow corn or alfalfa meal would furnish enough vitamin A for maintenance or growth. If hens do not have access to pasture, it is doubtful if the yellow corn and ordinary alfalfa leaf meal together would furnish enough vitamin A to produce eggs of high potency in this vitamin or to prevent the fowls from depleting their reserve store of this vitamin.

SUMMARY

A brief introductory description of the nature and characteristics of various vitamins is given.

The units of vitamin A activity were estimated (in rat units) in over 107 samples of foods or feeds. These are tabulated together with all other estimations of vitamin A found in the literature or calculated from data given. The estimation of units of vitamin A was not highly accurate but they express the content of the material more accurately than the previous methods usually used for indicating the quantity present.

The quantity of vitamin A decreases during the storage of alfalfa, dried whole milk, yellow corn, and other foods. There is a loss of vitamin A in drying moist foods. The effect of other factors is briefly discussed.

As previously shown there is a direct quantitative relationship between vitamin A in corn and the number of genes for yellow pigmentation.

There was a fairly constant gain of vitamin A in each grain during the period of growth of yellow-corn, with the exception of the period of 21 to 28 days, when the gain was excessively rapid, and the last period, near maturity, when there was little gain.

Although some differences were found in yellow corn grown in different sections of Texas, it cannot be said definitely whether or not the locality in which the corn was grown affected its vitamin A content.

As previously shown, the vitamin A content of butter and eggs depended upon the food eaten by the animal. The vitamin A content of butter and of eggs decreased during the period of feeding, when insufficient quantities of vitamin A were fed.

The vitamin A content of eggs, dried whole milk, sweet potatoes, carrots, butter, pecan meats, spinach, and other foods and feeds are briefly discussed.

Bananas, carrots, yellow corn, cod liver oil, collard greens, liver, mustard greens, spinach, yellow sweet potatoes, and turnip greens were the cheapest sources of vitamin A for human food at the prices used. In all of them 1,000 units could be secured from one-half cent or less and in some of them 1,000 units cost only one-tenth of a cent. Canned spinach, canned carrots, and canned mustard cost a little more than those mentioned above but are low-priced sources of vitamin A. Butter, eggs, cheese, dried green peas, and milk must be considered to be relatively economical sources of vitamin A. Asparagus, cabbage, head lettuce, and canned peaches are classed as expensive sources of vitamin A.

As previously pointed out, growing rats required per pound per day for maintenance only and 6 units per pound per day for both growth and maintenance. White Leghorn pullets required 32 units per pound per day for maintenance and 6.3 units of vitamin A for each unit in the eggs. Milk cows have high requirements of vitamin A for maintenance and for production of butter of high potency.

We estimated that a man, woman, or child requires 1,000 units of vitamin A per day per person. Larger amounts may be required for higher vigor and better health.

The 1,000 units per person per day can be supplied at a low price by comparatively small quantities of collard greens, turnip greens, mustard greens, spinach, or by somewhat larger amounts of bananas, carrots, yellow corn or sweet potatoes.

Milk cows seem to require green pasture plants to produce milk of high potency and laying hens seem also to require green feed for the continued production of eggs of high potency.

Orange peel and pulp contained 4 to 6 units of vitamin A per gram.

Cottonseed meal is very low in vitamin A.

Hays and fodders may not supply enough vitamin A to maintain milk cows over a long period of time.

Sorghum silage containing 5.5 to 10 units of vitamin A per gram does not furnish enough vitamin A for cows to produce milk containing normal amounts of vitamin A.