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TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR

COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 477 JULY, 1933

DIVISION OF CHEMISTRY

Vitamin A Content of Foods and Feeds

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Vitamin A is one of the most important of the vitamins which must be present in the food of man and animal in optimum amounts for health or growth or good production. The units of vitamin A activity estimated in 107 samples of foods and feeds are tabulated together with all other determinations found in the literature or calculated from the data given. Vitamin A activity decreases with the time of storage of dried milk, alfalfa hay, yellow corn, and other feeds. The vitamin A in crosses of yellow and white corn was found to be in proportion to the number of genes for yellow present. The storage of vitamin A in the grains of corn during growth was found to be fairly regular excepting during the fourth week, when it was high, and after the eighth week, when there was none because the process had been completed. The effects of other factors are mentioned briefly. The amount of vitamin A in butter and eggs depends upon the quantity in the feed. If an inadequate supply of vitamin A is fed to the hen, the quantity in the eggs laid decreases during the period of production. Human beings are provisionally estimated to require 1000 units of vitamin A per day. Bananas, carrots, yellow corn, cod liver oil, collard greens, liver, mustard greens, spinach, sweet potatoes, and turnip greens are low-priced sources of vitamin A and supply 1000 units for one-half cent or less. Other sources of vitamin A are discussed and a table gives the relative cost of vitamin A in a number of feeds at the specified prices. Green pasture plants are the best sources for enabling animals to produce milk or eggs high in vitamin A, or to store a reserve of vitamin A to tide them over periods of scarcity.

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VITAMIN A CONTENT OF FOODS AND FEEDS

By G. S. FRAPS AND RAY TREICHLER

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

Table 1. Classification, functions, and sources of vitamins

Vitamin	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.	Cabbage, lettuce, onion, spinach, tomatoes, lemons, oranges, celery, pineapple, strawberries.
D	Anti-rachitic	Required for formation and maintenance of bones and teeth and for protection of young against 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-pellagric	Required for growth and for functions which prevent pellagra.	Liver, kidney, lean meat, spinach, potatoes, turnip greens, eggs, milk, salmon, tomatoes.

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 anemia, 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.

Vitamins are organic substances which are present in very small amounts in foods and are known to be essential to the health of animals (55).

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 Table 1. Following are brief descriptions of the vitamins known at present (55, 64):

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 vigor, 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 coloring 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 hemorrhages 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 a 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 foods irradiated by ultraviolet light. Vitamin D prepared by irradiating ergosterol is effective for rats but not for chickens (61). 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 necesary 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 (61). Evans (13) 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 (29) 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 (60). This is manifested by the animals begining 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 (27) which is .001 milligrams of a certain preparation of carotin. Direct comparisons of the international unit and of the rat unit have not yet been published, but according to a private communication (1) 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.

Details of Methods of Estimating Vitamin A Activity

In accordance with the established procedure in this laboratory all quantitative vitamin A determinations were made by using a modified Sherman and Munsell procedure commonly known as the unit method (14).

All experimental animals originated from our own stock colony composed of Albino rats, descendants of breeding rats received from the Wistar Institute and the Albino Supply Company, Philadelphia, Pennsylvania (14). The breeding animals were selected for uniformity of growth.

The breeding stock has access to fresh water and a stock ration consisting of the following:

Corn meal	1200 grams
Cottonseed meal	200 grams
Powdered whole milk	600 grams
Alfalfa meal	40 grams
Sodium chloride	10 grams
Calcium carbonate	10 grams
Ferric citrate	1 gram
Copper sulphate	.5 gram

The ferric citrate and copper sulphate were added after April 15, 1931. Fresh cooked bones are fed once a month and canned spinach is given once a week.

At parturition the females are removed to individual cages provided with suitable material for making a nest and continued on the stock ration, fresh water, and canned spinach once a week. At the end of 21 to 28 days the young weigh between 35 and 45 grams. At this point they are weaned and placed in individual cages with raised wire bottoms so as to prevent their eating the excrement, which may contain vitamin A. The experimental animals are provided with fresh water and an irradiated basal ration deficient in vitamin A. This ration consists of the following:

Corn starch (purified)	130 grams
Casein (purified)	40 grams
Powdered yeast	20 grams
Salt mixture	8 grams
Sodium chloride	2 grams

To purify the casein, it was spread on trays in an electric oven to a depth of one-fourth inch, heated at a temperature of 100° C. for 24 hours, and stirred thoroughly twice at equal intervals of time (14).

The corn starch was treated in the same manner. Destruction of vitamin A was found to be completed in both casein and corn starch after having been treated in the above-mentioned manner. The palatability was not affected by the heat and oxidation treatment.

The salt mixture used was a modification of the salt mixture of Osborne and Mendel and has already been described (14).

A supply of vitamin D was furnished by irradiating the basal ration by means of a quartz mercury vapor arc lamp at a distance of 18 inches for 30 minutes. The basal ration was spread in a thin layer directly under the lamp and stirred thoroughly at the end of 15 minutes.

The rats were weighed when placed upon the basal ration deficient in vitamin A. After 28 days the rats were weighed every other day until their weights remained constant for 6 days or until a loss in weight occurred. Weighed quantities of the feed to be tested were then fed daily for eight weeks. If test feed was rich in vitamin A it was in some cases fed every other day or twice a week. The rats were weighed once a week on the same day. Records were kept of the amounts of the basal ration eaten.

Six rats were usually placed on each quantity of feed being tested. An attempt was made to feed such a quantity of the material that the rats would make an average gain of 3 grams per week for the test period of 8 weeks. Considerable difficulty was encountered in finding the right amount to produce exactly this gain. Usually the estimate is made from the average gain in weight of two lots of rats, the gain of one lot being slightly less than 24 grams gain in 8 weeks, the gain of the other lot being somewhat more than 24 grams in 8 weeks.

With some samples so low in vitamin A that it is impossible for the rat to ingest daily a sufficient quantity of vitamin A to bring about the necessary gain in weight, a mixture was used that contained, in addition

Table 2. Estimation of vitamin A in feeds and foods

Laboratory number	Description	Grams fed daily	No. of rats at beginning	No. of rats at end	Average gain in 8 weeks	Grams feed per unit of vitamin A	Units Vitamin A per gram feed
26282	Alfalfa, leafy hay	.3	4	1	31	.3	3.3
26312	Alfalfa stemmy hay	.3	2	1	18	.35	3
32789	Alfalfa leaf meal, original	.1	12	6	23	.1	10
		.15	6	2	34		
	Stored 11 months	.2	6	1	16	.25	4
		.3	6	4	44		
24427	Alfalfa leaf meal	.1	4	1	13	.15	7
		.2	6	6	39		
33973	Alfalfa leaf meal	.1	6	6	73	.05	20
		.033	6	2	—7		
34860	Alfalfa leaf meal, machine cured	.02	6	5	63		
		.03	6	5	56	.015	66.6
36169	Alfalfa meal	.066	6	2	24	.066	15
35120	Alfalfa meal, machine-cured	.026	6	4	44	.02	50
35121	Alfalfa meal, sun-cured	.053	6	3	5		
		.1	6	4	41	.08	12.5
		.133	6	6	58		
34885	Alfalfa stem meal	.4	6	4	44	.36	2.4
35107	Banana, raw	.33	6	4	14		
		.5	6	4	32	.45	2.0
		.66	6	5	59		
36314	Bermuda grass, dried in vacuum	.01	6	5	35	.008	120
		.016	6	4	51		
36294	Burr clover, dried in vacuum	.003	6	1	23	.005	200
		.01	6	6	88		
34182	Carrots, yellow, dried in air	.02	6	2	—15		
		.1	6	6	91	.04	25.0
36027	Carrots, yellow, dried in vacuum	.006	6	2	—1		
		.03	6	4	62	.013	77.0
35108	Carrots, raw, yellow	.02	6	5	67	.015	66.6
		.08	6	6	68		
35974	Carrots, raw, yellow	.02	8	6	11		
		.026	6	6	49	.023	43.0
35672	Carrot juice, sterilized	.24	6	0		0	0
		1.00	6	0			
34183	Carrot tops, dried in air	.1	6	5	68	.06	16
30275	Corn, Bloody Butcher, Beeville	.3	4	1	19		
		.4	4	4	48	.3	3.3
30311	Corn, Bloody Butcher, Temple, orig.	.15	4	1	11		
		.2	6	3	34	.2	5
	Ditto, stored 11 months	.3	4	1	—20		
	Ditto, stored 18 months	.7	5	4	16	.8	1.2
28635	Corn, Fentress Strawberry, Angleton	.8	2	2	1		
		.9	6	3	26	.9	1.1
		1.0	4	4	50		
28647	Corn, Fentress strawberry, Troup	.9	4	2	28	.9	1.1
		1.0	2	2	48		

Table 2. Estimation of vitamin A in feeds and foods—Continued.

Laboratory number	Description	Grams fed daily	No. of rats at beginning	No. of rats at end	Average gain in 8 weeks	Grams feed per unit of vitamin A	Units Vitamin A per gram feed
28978	Corn, Fentress strawberry Nacogdoches	.7	6	3	16		
		.9	2	2	52		
		1.0	2	2	35	.9	1.1
29033	Corn, Fentress strawberry, Lubbock,	.8	2	2	31	.8	1.2
		.9	4	2	41		
	Ditto, stored 15 months	.9	4	3	—5	1.	1
29037	Corn, Fentress strawberry, Beeville original	.9	2	2	67	.5	2
		1.0	2	2	102		
	Stored 15 months	.7	4	3	24	.7	1.4
29134	Corn, Fentress strawberry, College Station	.4	4	3	25	.4	2.5
30213	Corn, Fentress strawberry, Troup	.5	4	4	34	.4	2.5
		.6	2	1	67		
30384	Corn, Fentress strawberry, Denton	.3	4	2	15		
		.4	6	1	25		
		.5	2	2	39	.4	2.5
30274	Corn, Fentress strawberry, Beeville	.4	4	3	13		
		.6	4	3	37	.5	2
30495	Corn, Fentress strawberry, Weslaco	.2	2	2	24	.2	5
33316	Corn, Ferguson yellow dent, Beaumont	.15	6	4	9		
		.2	6	5	30	.18	5.5
33317	Corn, Ferguson yellow dent, Nacogdoches	.15	6	1	—8		
		.2	6	5	25	.2	5
33318	Corn, Ferguson yellow dent, College Station	.15	6	4	8		
		.2	6	4	22	.2	5
34980	Corn, Ferguson yellow dent, 14 days after pollination	.6	6	6	31*	.5	2
		.8	6	6	46*		
34984	Corn, Ferguson yellow dent, 21 days after pollination	.4	6	6	28	.4	2.5
		.8	6	6	75		
35119	Corn, Ferguson yellow dent, 28 days after pollination	.2	6	6	37	.18	5.5
		.4	6	5	53		
35122	Corn, Ferguson yellow dent, 35 days after pollination	.2	6	5	56	.15	6.6
		.4	6	6	50		
35128	Corn, Ferguson yellow dent, 45 days after pollination	.15	6	6	32	.14	7.1
		.2	6	5	53		
		.3	6	6	51		
35126	Corn, Ferguson yellow dent, 50 days after pollination	.2	6	3	42	.15	6.6
		.2	6	5	54		
35165	Corn, Ferguson yellow dent, 57 days after pollination	.15	6	4	29	.15	6.6
		.2	6	6	36		
33309	Corn, red pericarp, yellow endosperm	.2	6	5	6		
		.3	6	3	16		
		.4	8	7	20	.4	2.5
36375	Corn, yellow	.15	6	2	28	.2	5
		.2	6	2	20		
		.25	6	4	37		
33918	Corn feed meal, original	.15	7	2	12		
		.25	6	4	19	.3	3.3
		.3	6	4	26		
	Ditto, stored 7 months	.3	6	2	—4		
		.4	6	3	25	.4	2.5
34884	Corn feed meal	.4	6	6	33	.3	3.3

*6 Weeks.

Table 2. Estimation of vitamin A in feeds and foods—Continued.

Laboratory number	Description	Grams fed daily	No. of rats at beginning	No. of rats at end	Average gain in 8 weeks	Grams feed per unit of vitamin A	Units Vitamin A per gram feed
30995	Corn meal, yellow original	.3	4	2	62	.2	5
	Ditto, stored 8 months	.3	4	4	33	.3	3.3
36170	Hegari stover	.2	6	3	9		
		.3	6	3	29	.3	3.3
		.4	6	5	85		
32304	Kafir, black	2.0	6	1	—31		
32305	Kafir, red	2.0	6	2	11		
29722	Kafir, white	2.0	4	1	37		
29415	Loco weed, air dried		4	4	55		
		.1	2	2	48	.06	16
33249	Milk, whole dried, original	.08	6	2	—18		
		.1	6	3	22	.1	10.0
		.15	6	4	33		
	Ditto, stored 12 months	.2	6	4	17		
		.3	6	6	22	.3	3.0
		.5	6	6	61		
35030	Milk, whole dried	.1	6	3	—1		
		.15	6	3	23	.15	6.6
35125	Milk, whole dried	.24	6	6	57		
		.3	6	6	52		
		.12	6	4	10	.15	6.6
33258	Okra pods, dried in air	.05	6	1	1		
		.2	6	1	28		
		.4	6	6	39	.3	3
32928	Orange peel and pulp, dried	.2	10	4	32	.2	5.0
		.3	6	4	60		
25058	Orange peel and pulp, dried	.2	2	0			
		.3	8	6	21*	.3	3.0
		.4	10	4	40		
30212	Orange peel and pulp, dried	.25	4	3	24	.25	4
		.3	4	4	36		
30490	Peanut meal	2.0	4	2	46		
32224	Peanut meal	1.5	4	0			
		2.0	4	0			
32041	Peas, blackeyed, green, dried in air	.2	4	1	11		
		.3	6	3	14	.4	2
		.45	5	2	16	.5	2.0
	Ditto, stored 9 months	.7	4	1	38		
30186	Peas, green, dried in air	.08	4	4	30	.08	12.5
		.1	2	2	42		
35746	Pecan meats, Burkett variety, original	.6	6	6	25	.6	1.6
		1.0	6	6	59		
		.8	6	4	53		
	Ditto, stored 8 months	.6	6	3	19		
		1.0	6	1	44		
35747	Pecan meats, Texas prolific	.6	6	4	39	.5	2.0
		.8	6	5	59		
34977	Pepper, green dried in air	.02	6	2	17		
		.05	6	5	26	.05	20.0
32060	Pepper, green dried in air	.02	4	3	21	.025	40.0
		.02	6	0			
	Ditto, stored 18 months	.05	6	2	—1		
25918	Potatoes, yellow sweet, porto Rico variety, dried in air, Nacogdoches	.5	2	1	39	.5	2.0
		1.0	4	3	67		
25958	Potatoes, yellow sweet, Porto Rico variety dried in air, Marion county	.5	3	3	22	.5	2.0
33783	Potatoes, yellow sweet, dried in air, Bryan	.3	6	1	21		
		.4	6	4	14		
		.5	6	5	64	.3	3.0
		.8	6	6	76		

*6 Weeks

Table 2. Estimation of vitamin A in feeds and foods—Continued.

Laboratory number	Description	Grams fed daily	No. of rats at beginning	No. of rats at end	Average gain in 8 weeks	Grams feed per unit of vitamin A	Units Vitamin A per gram feed
37082	Potatoes, yellow sweet, Porto Rico variety, dried in vacuum	.01	6	1	5		
		.02	6	4	27	.02	50
		.03	6	6	44		
36942	Potatoes, yellow sweet, Porto Rico variety	.02	6	0	0		
		.04	6	3	8		
		.06	6	5	45	.05	20
33784	Potatoes, yellow sweet, peelings, dried in air	.8	6	4	41	.5	2
		1.0	6	5	43		
35742	Potatoes, yellow sweet, Porto Rico variety, raw	.033	6	6	56	.02	50
		.066	6	6	75		
		.0066	6	2	—15		
		.016	6	3	19		
35831	Sorghum silage	.1	6	0			
		.2	6	3	40	.18	5.5
		.4	6	5	55		
37106	Sorghum silage	.1	6	3	39	.1	10
		.2	6	5	62		
		.3	6	1	19		
36241	Spinach, canned (moist solids)	.01	6	5	30	.01	100.0
		.02	6	6	79		
37086	Spinach, canned (moist solids)	.008	6	3	57	.007	140
		.01	6	4	39		
		.012	6	5	60		
37110	Spinach, canned, dried in vacuum	.0026	6	2	20	.003	333
		.003	6	4	30		
		.005	6	4	61		
36338	Sudan grass, dried in vacuum	.01	6	6	107		
		.02	6	5	57		
		.03	6	6	64		
		.0016	6	0			
		.003	6	0			
		.006	6	1	1		
29455	Mustard tops, dried in air, original	.02	4	3	7		
		.03	2	2	21	.03	33
		.03	2	0			
	Ditto, stored 11 months	.05	4	0	---		

to the test feed, a known amount of yellow corn of which the vitamin A content was known. Additional gains in weight above that caused by the vitamin A in the yellow corn in the test ration was attributed to the vitamin A in the feed being tested (14).

In some cases it was found necessary to mix the feed being tested with casein or other material used in the basal mixture in order to make it more palatable. Only enough of such mixture to last less than two weeks was prepared; in this way any loss of vitamin A due to oxidation was reduced to a minimum.

Some samples too moist for preservation were dried at about 65° C. Other samples were fed in the fresh moist condition, new supplies being secured from time to time. Still others were dried in a vacuum oven at a temperature of 95 to 100° C. for 5, 7 or 12 hours. Butter was melted at a temperature of 60° C. and the water and curd allowed to settle. The clear butterfat was then decanted off and filtered through ordinary filter paper into brown glass bottles tightly stoppered and kept in an electric refrigerator at a temperature of about 6° C. Whole eggs were weighed, and boiled for 10 minutes; the yolks were then removed and weighed. The yolk was cut up and kept in glass bottles in the refrigerator. Fresh samples of yolk were prepared each week.

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 (52), who list 59 foods. Fraps (14) 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 details of some of our quantitative tests are given in Table 2. Other details have been published elsewhere (5, 14, 16).

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 Table 3. The numbers in the last column of the table refer to the source of the data as given in the references cited at the end of this Bulletin. If these are marked T, the work was done at the Texas Station. 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 Table 3 are rounded off. In some cases, where the number of units

Table 3. Approximate number of units of vitamin A in foods and feeds

	Units per gram	Units per ounce	Units per pound	Literature reference number
Alfalfa, machine-dried	100	2,835	45,360	54
Alfalfa, sun-cured	20	567	9,072	54
Alfalfa, field-cured and exposed to rain	12	340	5,440	54
Alfalfa, field-cured and exposed to rain	14	396	6,336	54
Alfalfa leafy hay	3.3	93	1,488	T 17
Alfalfa stemmy hay	3	85	1,360	T 17
Alfalfa meal	12.5	354	5,664	T 17
Alfalfa meal	15	425	6,800	T 17
Alfalfa leaf meal	20	567	9,072	T 17
Alfalfa leaf meal	10	283	4,528	T 17
Alfalfa leaf meal	7	198	3,168	T 17
Alfalfa leaf meal	20	567	9,072	T 17

Table 3. Approximate number of units of vitamin A in foods and feeds—Continued

	Units per gram	Units per ounce	Units per pound	Literature reference number
Alfalfa leaf meal, machine-dried	66.6	1,888	30,208	T 17
Alfalfa leaf meal, machine-dried	50	1,417	22,672	T 17
Alfalfa stem meal	2.4	68	1,088	T 17
Apples	.5	15	240	52
Apples	.5	15	240	2
Apricots, fresh	50	1,417	22,672	45
Apricots, fresh frozen	7	198	3,168	46
Apricots, sundried, sulphured	12	340	5,440	45
Apricots, sundried, unsulphured	8	220	3,620	45
Artichokes	3	85	1,360	52
Asparagus	1.2	35	560	52
Bacon	.2	5	80	52
Banana	2	56	896	2
Banana	2	56	896	T 17
Banana	3.5	100	1,600	52
Banana	2	56	896	T 17
Barley, less than	1	28	448	55
Beans	3.6	102	1,632	3
Beans, canned navy	0.5	15	240	52
Beans, dried lima	0	0	0	52
Beans, string	5.2	150	2,400	52
Beets	0.2	5	80	52
Bermuda grass, dried in vacuum	120	3,402	54,432	T 17
Bread, commercial, less than	1	28	448	52
Bread, commercial, mixed	0.1	3	50	55
Broccoli	3.3	95	1,520	52
Brussels sprouts	3.3	95	1,520	52
Bur clover, dried in vacuum	200	5,670	90,720	55
Butter	30	849	13,584	55
Butter	50	1,415	22,640	55
Butter	50	1,515	22,640	2
Butter	49	1,400	22,400	52
Butter fat, creamery	17	481	7,696	T 15
Butter fat, cows on pasture	50	1,417	22,400	T 15
Butter fat, creamery, average	28	792	12,672	T 15
Butter fat, cows on pasture	40	1,132	18,112	T 15
Butter fat, cow on silage (no pasture)	3.6	102	1,632	T 15
Butter fat, feed low in vitamin A	2.5	71	1,136	T 15
Castor Oil	0	0	0	7
Cabbage, new, average of green and white	0.4	10	160	52
Cabbage, Chinese (estimated)	50	1,415		42
Cantaloupe	3.3	93	1,488	48
Cantaloupe	3.2	90	1,440	52
Carrot	25	708	11,328	2
Carrot	33	940	15,040	52
Carrot	25	708	11,328	3
Carrot	43	1,219	19,504	T 17
Carrot, yellow raw	67	1,888	30,208	T 17
Carrot, yellow, dried	25	708	11,328	T 17
Carrot, yellow, dried in vacuum	77	2,182	35,376	T 17
Carrot juice, sterilized	0	0	0	T 17
Carrot tops, dried (estimated)	16	453	7,248	T 17
Cauliflower	0.5	15	240	52
Celery, bleached	0	0	0	52
Cereals	0	0	0	52
Cheese, American	24.5	700	11,200	52
Cheese, cottage	1.1	30	480	52
Cheese, cream	49	1,400	22,400	52
Cheese, Parmesan	24.5	700	11,200	52
Cherries, frozen, (Montmorency, Royal Ann, Late Duke)	0.3	8	128	51
Cherries, frozen, (Bing, Deacon, Lambert)	0.4	10	160	51
Clover, bur, dried in vacuum	200	5,670	90,720	T 17
Cod liver oil	250	7,075	113,200	65
Cod liver oil	500	14,150	226,400	65
Cod liver oil	1,000	28,300	452,800	65
Cod liver oil	1,250	35,375	556,000	65

Table 3. Approximate number of units of vitamin A in foods and feeds—Continued

	Units per gram	Units per ounce	Units per pound	Literature reference number
Collards, green, raw or boiled 45 min.	50	1,417	22,672	48
Corn, Bloody Butcher	2.5	70	1,120	T 17
Corn, Bloody Butcher	5	141	2,256	T 17
Corn, Fentress Strawberry	1.1	31	496	T 17
Corn, Fentress Strawberry	5	141	2,256	T 17
Corn, Ferguson yellow dent	5	141	2,256	T 17
Corn, Ferguson yellow dent	6.6	187	2,992	T 17
Corn, red	0.9	25	400	T 14
Corn, red	5	141	2,256	T 14
Corn, white	0	0	0	T 14
Corn, white	.5	14	224	T 14
Corn, yellow	2.5	70	1,120	T 14
Corn, yellow	8	226	3,616	T 14
Corn, Ferguson yellow dent, Beeville, Texas	6.6	187	2,992	T 17
Corn, Ferguson yellow dent, Troup, Texas	6.2	175	2,800	T 17
Corn, Ferguson yellow dent, Angleton, Texas	6.6	187	2,992	T 17
Corn, Ferguson yellow dent, Beaumont, Texas	5.5	155	2,480	T 17
Corn, Ferguson yellow dent, Nacogdoches, Texas	5	141	2,256	T 17
Corn, Ferguson yellow dent, College Station, Texas	5	141	2,256	T 17
Corn, Ferguson yellow dent, Nacogdoches, Texas	5	141	2,256	T 17
Corn, yellow	6.6	187	2,992	T 17
Corn, yellow	6.6	187	2,992	T 17
Corn, yellow	5	141	2,256	T 17
Corn germ meal	0	0	0	40
Corn meal, white (estimated)	0	0	0	T 17
Corn meal, golden	3	85	1,360	T 17
Corn meal, yellow, granulated	3	85	1,360	T 17
Corn meal, feed	3.3	93	1,488	T 17
Corn meal, feed	3.3	93	1,488	T 17
Corn meal, yellow	5	141	2,256	T 17
Corn meal, yellow	5	141	2,256	T 17
Cottonseed meal, less than	1.0	28	448	18-55
Cottonseed meal (estimated)	0.1	2.8	45	T 17
Cottonseed meal and cake, less than	1	28	448	52
Cottonseed oil, less than	1	28	448	55
Cucumber	.4	10	160	52
Dates	3	85	1,360	52
Dates, Deglet noor	.8	22	352	58
Dates, Maktum variety	1	28	448	58
Dates, Thoory	1.3	36	576	58
Eggs, June laid, Rhode Island Red	28	792	12,672	23
Eggs, June laid, White Leghorn	28	792	12,672	23
Eggs (edible part)	19	550	8,800	52
Egg yolk	50			2
Egg yolk, beginning of laying season	30	850	13,600	T 56
Egg yolk, end of laying season	6	170	2,720	T 56
Egg plant	.7	20	320	52
Escarole	210	6,000	96,000	52
Figs, cooking	.4	10	160	52
Fish, fat	.4	10	160	52
Fish, lean	0	0	0	52
Fish "opihi", Hawaiian	500	14,175	226,800	43
Flour, wheat (estimated)	0	0	0	T 17
Grapes, Concord, Tokay, Malaga	.7	20	320	52
Grapes, Sultanina and Malaga	.2	5	80	6
Grapefruit peel and pulp, dried, less than	5	—	—	T 17
Grapefruit juice (estimated)	0.1	2.8	45	44
Grape juice, commercial	0	0	0	6
Halibut liver oil	37500	1063000		12
Halibut liver oil	62300	1779000		12
Hegari stover	3.3	93	1,488	T 17
Hegari, grain	0.3	8.5	136	57
Hominy, yellow	8.3	235	3,760	T 17
Hominy feed, yellow	1.5	42	672	T 17
Hominy, white (estimated)	0	0	0	T 17
Kafir grain, black	0.3	9	144	T 17
Kafir grain, red	0.4	11	176	T 17

Table 3. Approximate number of units of vitamin A in foods and feeds—Continued

	Units per gram	Units per ounce	Units per pound	Literature reference number
Kafir grain, white	0.5	14	224	T 17
Kidney	8	230	3,680	52
Lard (estimated)	0	0	0	
Lemons	0	0	0	52
Lettuce	1.5	42	672	2
Lettuce, head	1.8	50	800	52
Lettuce, head	1.7	45	720	3
Lettuce, head, inside leaves	3.3	93	1,488	9
Lettuce, Iceberg, from center of head	1.7	45	720	33
Lettuce, Iceberg, outside green leaves	67	1,888	30,208	33
Lettuce, Iceberg, outside green leaves	50	1,417	22,672	33
Lettuce, Romaine	5.3	150	2,400	52
Liver	98	2,800	44,800	52
Liver fat	5000	141,500	2,264,000	53
Loco weed, air dried	16	453	7,248	T 17
Meal, corn, white (estimated)	0	0	0	T 17
Meat, average, muscle	0.2	5	80	52
Meat, pork (estimated)	0	0	0	T 17
Milk, condensed	4.9	140	2,240	52
Milk, dried, whole	17.5	500	8,000	52
Milk, dried, whole	6.6	187	2,992	T 17
Milk, dried, whole	10	283	4,528	T 17
Milk, evaporated	4.9	140	2,240	52
Milk, whole	2.3	65	1,040	52
Milk, whole	1.3	36	576	37
Milk, whole	2	56	896	37
Milo grain, yellow	0.5	14	224	57
Milo, white, chop	0	0	0	T 17
Milo grain, dwarf yellow	0.5	14	224	T 17
Milo grain, yellow	0.4	11	176	T 17
Milo, dwarf yellow, less than	0.5	14	224	T 17
Milo, dwarf yellow, less than	0.3	8	128	T 17
Milo, dwarf yellow, less than	0.5	14	224	T 17
Milo, yellow, less than	0.5	14	224	T 17
Milo, yellow, less than	0.5	14	224	T 17
Mushrooms	0	0	0	52
Oats, less than	0.2	5	80	41
Oat meal (estimated)	0	0	0	T 17
Oat oil, less than	0.6	17	272	41
Oil, cottonseed	0	0	0	
Oil, raisin	0	0	0	
Oil, sesame	0	0	0	
Okra, ends, dried, less than	2	56	896	T 17
Okra, ends, dried, less than	2	56	896	T 17
Okra, pods and seed, dried	3	75	1,200	T 17
Onions	0	0	0	52
Orange juice (estimated)	0.5	141	2,256	49
Oranges	0.7	20	320	52
Orange peel and pulp, dried	3	85	1,360	T 17
Orange peel and pulp, dried	4	113	1,808	T 17
Orange peel and pulp, dried	6.6	186	2,976	T 17
Orange peel and pulp, dried	5	141	2,256	T 17
Oysters, raw frozen	0.5	14	224	26
Oysters, raw frozer	1	28	448	26
Peaches	0	0	0	52
Peaches, Elberta, fresh	20	566	9,072	45
Peaches, Muir, fresh	12	340	5,443	45
Peaches, canned	2	56	896	30
Peaches, frozen Elberta	0.5	14	224	48
Peaches, frozen Hiley, less than	0.5	14	224	48
Peanut meal, less than	0.5	14	224	T 17
Peanut meal, less than	0.5	14	224	T 17
Pears, Bartlett, less than	0.1	4	64	34
Peas, cooked green	2	56	896	2
Peas, dried green	3	85	1,360	52
Peas, dried green	12.5	354	5,664	
Peas, raw and canned	6.1	175	2,800	52

Table 3. Approximate number of units of vitamin A in foods and feeds—Continued

	Units per gram	Units per ounce	Units per pound	Literature reference number
Peas, raw and cooked	2	56	896	3
Peas, raw or cooked, 10 min.	67	1,888	30,208	11
Peas, canned	67	1,888	30,208	11
Peas, blackeyed, dried	2	56	896	17
Pecan meats	3.6	102	1,632	35
Pecan meats, Burkett variety	1.6	45	720	T 17
Pecan meats, Texas Prolific variety	2	56	896	T 17
Pecan meats, stored 14 months, less than	1	28	448	T 17
Peppers	6	175	2,800	52
Peppers, sweet green, dried	40	1,134	18,144	T 17
Peppers, sweet green, dried	20	567	9,072	T 17
Pineapple, canned, including syrup	0.3	9	144	50
Potatoes, sweet	3	85	1,360	52
Potatoes, white, or Irish	0.4	10	160	52
Potatoes, sweet, Nancy Hall	30	849	13,584	52
Potatoes, Sweet, Porto Rico	50	1,417	22,672	T 17
Potatoes, yellow, sweet, raw	20	567	9,072	T 17
Potatoes, yellow, sweet, dried in air	2	56	896	T 17
Potatoes, yellow, sweet, dried in air	2.5	70	1,120	T 17
Potatoes, yellow, sweet, dried in vacuum	50	1,417	22,672	T 17
Potatoes, yellow, sweet, dried	2	56	896	T 17
Potatoes, yellow, sweet, dried	2	56	896	T 17
Potatoes, yellow, sweet, dried	3	85	1,360	T 17
Potatoes, yellow, sweet, peeling, dried	2	56	896	T 17
Prunes	10.5	300	4,800	52
Prunes, French, fresh	20	567	9,072	45
Pumpkin, dehydrated	50	1,417	22,672	44
Raisins	0	0	0	52
Raisins, Thompson seedless and Malaga	0	0	0	41
Sorghum silage	5.5	156	2,496	T 17
Sorghum silage	10	283	4,528	T 17
Sourkraut	0.2	5	80	52
Spinach, canned, juice poured off	100	2,835	45,360	T 17
Spinach, canned, juice poured off	140	3,920	62,720	T 17
Spinach, dried in vacuum, canned	333	9,324	149,184	T 17
Spinach, New Zealand	11	314	5,024	39
Spinach, ordinary garden	14	402	6,432	39
Spinach, raw	63	1,771	28,336	3
Spinach, raw and canned	49	1,400	22,400	52
Spinach, raw, Virginia Savoy, Princess Juliana and Viroflay	83	2,361	37,776	28
Strawberries	0.2	5	80	31
Strawberries	0.16	45	720	31
Sudan grass, dried in vacuum (estimated)	150	4,245	67,920	T 17
Tomatoes, green, raw or canned	7	187	2,992	32
Tomatoes, raw and canned	6	170	2,720	52
Tomatoes, ripe, raw or canned	13	374	5,984	32
Tomato soup, canned	6	170	2,720	52
Turnips	0.2	5	80	52
Turnip greens, raw or boiled	50	1,417	22,672	48
Turnip greens, dried	33	935	14,960	T 17
Watermelon pulp	1	28	448	47
Wheat, whole, less than	0.3	7.8	125	T 17
Wheat (estimated)	0.2	5.6	89	T 17
Wheat bran, less than	1	28	448	55
Wheat gray shorts	0.3	9	144	T 17
Wheat gray shorts	0.05	1.4	22	T 17

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.

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 (8). 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 (9). 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

The effect of storage of the vitamin A content is shown in Table 4. We (16) 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

Table 4. Effect of storage on vitamin A in dried feeds

Laboratory number	Description	Units vitamin A in one gram feed	Per cent loss of vitamin A
32789	Alfalfa leaf meal, original	10	----
	Stored 8 months	8	20
	Stored 11 months	5	50
32041	Blackeyed peas, dried, original	3	----
	Stored 7 months	2	30
	Stored 9 months	1.5	50
	Stored 14 months	0.7	75
32060	Green sweet pepper, dried, original	50	----
	Stored 19 months	10	80
33249	Powdered whole milk, original	10	----
	Stored 9 months	3	60
30997	Yellow corn, whole, original	7	----
	Stored, whole, 7 months	5	30
	Stored, unground, 30 months	1—	85
	Stored, ground, 30 months	1—	85
33313	Ferguson yellow dent corn, original	7	----
	Stored, ground, 5 months	3	50
	Stored, unground, 5 months	2.5	65
33314	Ferguson yellow dent corn, original	7	----
	Stored, ground, 6 months	3	50
33315	Ferguson yellow dent corn, original	7	----
	Stored, ground, 6 months	3	50
35746	Pecans meats	1.6	----
	Stored in shell 8 months (estimated)	8	50

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 (54). The extent of the loss seems to depend upon the procedure adopted in the drying. Hauge and Aitkenhead (20) 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 (4, 35).

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, or 337 units per gram of 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 (11, 32).

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.

Relation to Hereditary Factors in Corn

Hauge and Trost (21) state that vitamin A is always transmitted with the yellow endosperm of corn. With twenty per cent of corn in the rations fed the experimental rats, all three classes possessing yellow endosperm—

heterozygous F_2, homozygous F_2, and homozygous parent—were equally effective in preventing ophthalmia. Hauge and Trost (22) also found that the vitamin A content of pure yellow corn of the genotype YYY is approximately 3 times that of the crossed grains of the genotype Yyy. Manglesdorf and Fraps (36) showed that there is a direct quantative relationship between vitamin A in corn and the number of genes for yellow pigmentation. The vitamin A content of mixed white and yellow corn is related to the number of genes for yellow corn carried by the grain (see Table 5). They pointed out that the inheritance of vitamin A

Table 5. Relation of vitamin A content to number of genes for yellow in corn

No. of genes for yellow	Factorial composition of endosperm	Units of vitamin A per gram		
		1928	1929	Average
0	y y y	0.05	0.05	0.05
1	y y Y	2.50	2.00	2.25
2	y Y Y	5.00	5.00	5.00
3	Y Y Y	7.00	8.00	7.50

may be an indirect consequence of the inheritance of pigmentation involving the carotinoid pigments, as has also later been pointed out by Dutcher (8). In addition to the main genetic factors governing the formation of pigment in the endosperm of corn, there are numerous modifying factors which affect the amount of pigment and hence also the amount of vitamin A. Russel (54A), for example, has found that white capping in yellow corn, which also has a hereditary basis, reduces the amount of vitamin A.

Relation to Stage of Growth of Corn Seeds

Samples of Ferguson yellow dent corn were examined fourteen days after pollination and thereafter at intervals of one week for a total period of six weeks, at which time the seeds had reached maturity. This work was done in cooperation with Dr. P. C. Manglesdorf of the Division of Agronomy, who also furnished the samples. Table 6 contains a summary of the results obtained. Examination of Table 6 shows that there was a gradual increase in the vitamin A content of the corn from approximately 2.0 units per gram fourteen days after pollination to a level of approximately 6.7 units per gram 43 days after pollination. It appears from these results that the maximum concentration of vitamin A in the corn kernel occurred roughly between the thirty-fifth and forty-fifth day after pollination, after which time it remained constant until maturity, though the total amount of vitamin continued to increase somewhat with an increase in the weight of the seed.

The total number of units of vitamin A gained by each grain of corn was fairly regular for each period, with the exception of the third period

(21 to 28 days), in which the gain was double that of any of the other periods, and the last period, in which there was no gain of vitamin A.

It was also observed that the intensity of the yellow color in the samples increased in proportion to the length of time after pollination

Table 6. Storage of vitamin A in relation to the stage of growth of the grain of yellow corn

Days after pollination	Weight 100 seeds	Units vitamin A to 1 gram corn	Units vitamin A to 100 seeds	Units gained by 100 seeds in the preceding period
14	5.2	2.0	10	....
21	14.3	2.5	36	26
28	18.6	5.5	103	67
35	25.0	5.5	139	36
43	27.0	6.7	180	41
50	31.2	6.7	208	28
57	30.4	6.7	203	—5

at which they were taken, until about the sixth week, after which time the color tended to remain constant up to the eighth week after pollination.

Effect of Locality on Vitamin A in Corn

Results of the experiments on the vitamin A content of Ferguson yellow dent corn as influenced by the localities are summarized in Table 7. Some of these results have already been presented (14).

It is quite possible that any difference in the vitamin A content of the various samples might be due to factors, such as cross pollination,

Table 7. Relation of season and locality to units of vitamin A in Ferguson Yellow Dent corn

Where grown	1926	1927	1928	1930
Angleton	2.5	2.9	4.0	6.6
Beaumont	3.0	-- --	-- --	5.5
Beeville	3.3	5.0	5.5	6.6
Lubbock	2.5	4.0	-- --	-- --
Troup	-- --	6.0	7.1	6.2
Denton	-- --	5.0	-- --	-- --
Nacogdoches	-- --	2.9	-- --	5.0
College Station	3.6	5.5	6.7	5.0
Temple	-- --	3.6	6.7	-- --
Weslaco	-- --	-- --	6.7	-- --
Iowa Park	-- --	-- --	7.1	-- --

other than those encountered during the growing season of the corn. Six samples grown in 1930 were examined for their vitamin A content. Three samples from Beeville, Troup, and Angleton, Texas, contained 6.6, 6.2, and 6.6 units of vitamin A per gram respectively, while three samples from Beaumont, Nacogdoches, and College Station, Texas, contained 5.5, 5.0, and 5.0 units of vitamin A per gram respectively. This variation is comparatively small and might easily fall within the experimental error. For this reason it is not considered significant. It might be due to cross pollination with white corn. A comparison of these and other results (14) leaves the question whether the locality has any effect somewhat doubtful. Three other samples of yellow corn examined contained approximately the same amount of vitamin A as the Ferguson yellow dent corn.

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 (5). Thus the eggs of pullets (56) fed on diets containing yellow corn as the only source of vitamin A gradually decreased in content of vitamin A (see Table 8), 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 (15) to produce butter of high potency (Table 9).

Table 8. 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 egg 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	----

Table 9. 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	1960
Cottonseed meal, hulls, silage and pasture, average	33	17280

Vitamin A in Some Human Foods

Some of the foods listed in Table 3 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 that 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 (56), it was found that a 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 (Table 8). 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 (38). 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 (52) 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 Meal: 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 pressed 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 Table 3.

COST OF VITAMIN A ACTIVITY IN HUMAN FOOD

The costs of vitamin A in a number of foods are compared in Table 10. 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 Table 10 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, 1000 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.,

Table 10. Cost of 1000 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
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

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.

Additional data are needed both on other foods, and on the foods listed in the table, as there may be considerable variations in addition 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 (24).

Information regarding the quantity of vitamin A required by animals is very meager. 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 (56). Milk cows, like chickens, apparently require large quantities of vitamin A for maintenance, and still more to produce butter of high potency (5). 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 (5, 18). The vitamin A requirements for animals producing milk or eggs seem to be very high and the producing animal 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 for maintenance and 8 units per pound for growth, or a somewhat more liberal estimate of 1000 units per day per person—man, woman, or child. This may not be ample for the highest health and vigor, but should be sufficient for growth and maintenance.

This requirement of 1000 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 Table 10 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 (20). 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 (19). 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 (5, 19, 56). Sorghum silage contains 5.5 to 10 units per gram (2 samples) but both corn silage (19) and sorghum silage (5) 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 (5, 19).

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 (56) 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 1000 units could be secured from one-half cent or less and in some of them 1000 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 4 units 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 1000 units of vitamin A per day per person. Larger amounts may be required for higher vigor and better health.

The 1000 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.

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