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DIVISION OF POULTRY HUSBANDRY
DIVISION OF CHEMISTRY

Requirements of Chickens for Vitamin A When Fed as Carotene

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
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The vitamin A potency in the form of carotene required by chicks and laying hens was studied in eleven experiments. Pullets require more carotene than chicks and laying hens more than growing pullets. Suitable quantities of vitamin A resulted in larger growth and lower mortality for growing chicks than lower quantities. Suitable quantities for laying hens resulted in larger numbers of eggs, a longer productive period as well as longer life, larger percentages of hatchable eggs and less defective chicks hatched, than when insufficient quantities were fed.

For growing chicks up to the age of 12 weeks, 180 micrograms of carotene per 100 grams of feed (300 U. S. P. units) is recommended. This provides a margin of safety over the minimum of 125 to 150 micrograms of carotene per 100 grams of feed which the experiments indicate would be satisfactory. Carotene dissolved in oil seems to be equally as suitable as carotene in alfalfa leaf meal.

For pullets during the period of from 12 weeks to the beginning of the laying period, not less than 200 micrograms of carotene per 100 grams of feed (333 U. S. P. units) is recommended. This affords a margin of safety over the minimum of 150 to 175 micrograms which appears to furnish sufficient vitamin A potency for growth, but which is too low for satisfactory egg production.

For laying hens not less than 500 micrograms of carotene per 100 grams of feed (833 U. S. P. units) is recommended, thus allowing a margin of safety over the minimum of 450 micrograms indicated as satisfactory. When the eggs are to be used for hatching, not less than 600 micrograms of carotene per 100 grams of feed (1,000 U. S. P. units) is recommended, thus allowing a margin of safety over the minimum of 550 micrograms. If eggs high in vitamin A potency are desired, still larger quantities of carotene must be fed.

In some of the experiments, the chickens did well on smaller amounts of carotene than here recommended but in other experiments, higher quantities were found to be needed, and it was thought best to make recommendations on the safe side.

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REQUIREMENTS OF CHICKENS FOR VITAMIN A WHEN FED AS CAROTENE

By Ross M. Sherwood, Chief, Division of Poultry Husbandry
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The exact vitamin A requirements for chickens have not yet been agreed upon, although considerable work has now been done on this subject by a number of investigators. The requirements are different according to the object of feeding the chickens. If the chickens are grown for broilers, the quantity needed is that which will give the most economical growth with sufficiently good health to avoid financial losses by death or unsatisfactory appearance of the chickens. If the pullets are to be kept for production of eggs or for breeding purposes, additional quantities may be needed for storage or to insure more vigorous health, which may result in longer life.

Vitamin A potency may be supplied by vitamin A as such, which occurs as a colorless compound in fish oils, by carotene, which occurs as a yellow compound in alfalfa and other green feeds, or by cryptoxanthin, which occurs as a yellow compound in yellow corn. In northern states, fish oils are fed to supply vitamin D and they furnish vitamin A incidentally, and are an important source of vitamin A potency. In the south, the abundant sunshine supplies the needed vitamin D potency, except for battery brooder chicks, and the most important sources of vitamin A potency are carotene in green colored feeds or cryptoxanthin in yellow corn. According to Record and associates (10) the same number of international units have the same effect on chickens whether fed as vitamin A or as carotene. One international unit is defined as equal to 0.6 micrograms of carotene, 1.0 U. S. P. unit, and approximately .08 Sherman-Munsell (S. M.) unit. The value of a Sherman-Munsell unit may vary from 0.5 to 1.5 (7a).

This is fifth in a series of publications on the vitamin A requirements of poultry on a joint project of the Division of Poultry Husbandry and the Division of Chemistry of the Texas Agricultural Experiment Station. It has been previously shown (15) that laying pullets raised on the same ration lived from 34 to over 199 days on a ration low in vitamin A, indicating wide variations in the vitamin A stored by the birds or wide differences in resistance to a deficiency. Pullets receiving 270 Sherman-Munsell units were heavier in weight than those receiving 120 units and laid more eggs. The vitamin A potency of the eggs, as measured by biological methods, decreased from 20 S. M. units per gram of yolk at the beginning to 5 to 8 units at the end of the period of 6½ months. In subsequent work (16) fowls receiving 444 S. M. units of vitamin A potency laid about 15% more eggs than those in groups receiving lower quantities. The vitamin A potency of the eggs declined regularly from 20-22 S. M. units per gram at the beginning of the experiment to 6 units for pullets receiving 224

units per day, 12 units for those receiving 336 units per day and 15 units for those receiving 444 units S. M. per day. When allowance was made for the vitamin A stored by the pullets, from 4.0 to 5.7 units of vitamin A in the feed was required for 1 unit in the eggs.

In a third publication (17) the vitamin A content of the yolks (10 to 16 S. M. units at first) decreased to 5, 6, and 9 units with pullets receiving 150, 254, and 330 S. M. units per day, respectively. The apparent percentage of vitamin A potency recovered in the eggs ranged from 8 to 39% and averaged 25%, but the recovery of vitamin A potency fed, when the storage in the body was allowed for, was 3.8 to 4.4 units in the feed for one in the egg yolk, or 25% utilization. The process of molting seemed to require much vitamin A. The quantity of vitamin A required for laying birds would be greater if the eggs are desired to have a high potency of vitamin A.

In a fourth publication (18) it was pointed out that both the vitamin A potency of the feed of the hen laying eggs from which chicks were hatched and also the vitamin A potency fed the chicks must be adequate, if good results are to be obtained. Chicks hatched from eggs laid by hens receiving 265 S. M. units per day had low vitality. The mortality of the chicks in this work ranged from 64% for chicks from hens receiving 265 S. M. units per day or 325 S. M. units per 100 grams of feed to 39% for chickens from hens receiving 539 units per day or 325 S. M. units per 100 grams of feed. The vitamin A potency required by chicks is higher for those hatched from eggs laid by hens receiving low amounts of vitamin A than those fed more liberal amounts. In fact, high quantities of vitamin A potency (300 S. M. units per day) did not overcome the influence of a low vitamin content of the feed of the mother hen.

In previous work on vitamin A, the chief attention has been given to the requirements for growth up to 12 weeks and requirements during the laying period. The requirements of pullets from the period of 12 weeks until the time of laying has been given little or no attention. It is during this period, however, that the prospective layer has opportunity to store vitamin A to prevent losses that might occur from high mortality and to provide for the more heavy requirements for laying.

The work here presented deals with the vitamin A potency requirements for growth and for egg production and the effect of the quantity of vitamin A potency fed from 12 weeks to time of laying upon the health and mortality of the chickens. The vitamin A potency was fed in the form of carotene.

Previous recommendations

Vitamin A requirements for growing chicks have been estimated at 150 U. S. P. units per 100 grams of feed by Ringrose and Norris (12), 1,332 U. S. P. units by Schroeder and co-workers (14), 264 U. S. P. units by Wilson and co-workers (21), 50 to 100 micrograms of carotene or 80 to

160 U. S. P. units of vitamin A by Record and associates (10), 175 Sherman-Munsell units by Bearse and co-workers (2), 93 U. S. P. units by Frohring and Wyeno (6), 520 micrograms of carotene by Hinshaw and Lloyd (7), 100 to 150 Sherman-Munsell units by Sherwood and Fraps (18) for chicks hatched from eggs produced by hens receiving adequate supplies of vitamin A and larger quantities for chicks hatched from eggs of hens receiving a diet low in vitamin A. According to Norris (8), 150 U. S. P. units per 100 grams of feed are sufficient for good growth and freedom from symptoms of deficiency of vitamin A, but in order to allow for storage so that the pullets can enter the productive stage with adequate reserves of vitamin A, 300 to 400 U. S. P. units are recommended. Obviously the higher quantity is not needed if the chickens are eaten and not saved for production of eggs. Titus (19) suggested 320 U. S. P. units per 100 grams of feed for growing chicks.

For laying hens, Record and associates (11) estimate that leghorn pullets require 350 to 400 U. S. P. units of vitamin A per 100 grams of feed, while Russell (13) found 485 U. S. P. units give a satisfactory result. Sherwood and Fraps (17) estimated 300 Sherman-Munsell units per 100 grams of feed were required to maintain hens in good health with heavy egg production and 750 Sherman-Munsell units to produce eggs with satisfactory amounts of vitamin A. Bearse and associates (3) reported 500 S. M. units and Titus and associates (19) reported that 1,000 to 1,110 U. S. P. units were necessary for high producing hens and suggested 720 U. S. P. units for laying hens and 1,040 I. U. units for breeding stock, both allowing margins for safety. Norris (8) states that 400 to 500 U. S. P. units of vitamin A are sufficient to maintain hens in good health and enable them to produce eggs which hatch a normal number of usable chickens. Almquist and Mecchi (1) reported that about 440 U. S. P. units per 100 grams of feed was required for laying hens. Williams and associates (20) found that the equivalent of 240 Sherman-Munsell units or 333 U. S. P. units were required per hen per day.

Vitamin A requirements of growing chicks

With young cockerels there is a distinct increase in the rate of growth at about eight to twelve weeks of age. At this time both the primary sexual organs and the secondary sexual characters develop rapidly. Following this there is a decrease in rate of growth followed again by a slight increase as the cockerels approach twenty-two to twenty-four weeks of age. With pullets there are two distinct periods of more rapid growth, one at the age of twelve to eighteen weeks, and the other just when the birds begin to lay.

A number of experiments are reported in this bulletin. In all the experiments, alfalfa leaf meal was used, the carotene content was determined by analysis by Dr. A. R. Kemmerer or S. M. Greenberg, and the quantity of alfalfa leaf meal included in the rations was calculated from the analyses. In experiments 34, 35 and 39, dehydrated alfalfa leaf meal

Table 1. Percentages of ingredients of mixtures used in various chick experiments

(Sufficient alfalfa leaf meal was used in place of white corn or kafir to give desired carotene content.)

Ingredients of mixture	Percentages of ingredients used		
	Experiments 34, 35, 39	Experiments 68, 77, 80*, 84A*, 84B*	Experiments 59 and 60
Meat and bone scraps, 50% protein	6.0	4.0	6.0
Cottonseed meal, 43% protein	6.0	2.0	6.0
Dried skimmed milk	6.0	6.0	6.0
Soybean oil meal, 41% protein	.....	6.0	.....
Wheat gray shorts	20.0	20.0	20.0
Ground whole oats	.....	5.0	.....
Ground white corn	59.37	.....	59.37
Ground kafir	.....	54.62	.....
Chick size oyster shell	1.5	1.5	1.5
Salt	1.0	0.5	1.0
Vitamin A free fortified cod liver oil	0.13	0.38	0.13

*Chicks on Experiment 80, 84A, and 84B had access to sunlight, and the 38% fortified cod liver oil was not used in place of kafir.

Table 2. Gains in live weight of growing chicks on various levels of carotene

Micrograms of carotene for 100 grams of feed	Weight of cockerels in grams				Weight of pullets in grams		
	Exp. 34	Exp. 35	Exp. 39	Mean of three experiments	Exp. 35	Exp. 39	Mean of two experiments
50	627.4	671.6	656.8	651.9	490.9	495.1	493.0
75	731.8	611.3	633.2	658.8	519.2	519.1	519.2
100	744.4	652.1	665.8	687.4	**614.1**	550.1	582.1
125	721.5	712.3	661.5	698.4	599.4	550.8	575.1
150	771.6	**741.5**	**730.6**	**747.9**	589.4	**576.5**	**583.0**
175	**787.6**	625.1	676.8	696.5	573.5	539.6	556.6

Table 3. Per cent mortality and vitamin A deficiency of growing chicks on various levels of carotene

Micrograms of carotene for 100 grams of feed	Per cent mortality				Per cent of chicks showing vitamin A deficiency at the end of the experiments			
	Exp. 34	Exp. 35	Exp. 39	Mean of three experiments	Exp. 34	Exp. 35	Exp. 39	Mean of three experiments
50	27.1	41.7	33.3	34.0	12.5	16.7	19.1	16.1
75	33.3	27.7	34.0	31.7	8.3	10.6	17.0	12.0
100	**9.8**	16.7	17.8	**14.8**	**3.9**	**4.8**	**8.9**	**5.9**
125	10.6	29.3	28.8	22.9	8.5	7.3	26.9	14.2
150	14.9	16.3	**14.3**	15.2	4.3	10.2	12.2	8.9
175	12.8	**8.1**	25.5	15.5	13.2	10.8	17.0	13.7

was used to supply 50, 75, 100, 125, 150 and 175 micrograms of carotene per 100 grams of feed, respectively. Table 1 shows the feeds used. In experiment 34, the number of cockerels used on each vitamin level was 52, in experiments 35 and 39, the total number of mixed cockerels and pullets was 52 per group. These experiments began with day-old chicks and continued for twelve weeks.

As shown in Table 2, the cockerels required 150 micrograms of carotene per 100 grams of feed for best gains. The pullets required from 100 to 150 micrograms of carotene for 100 grams of feed.

The data for mortality and for indications of vitamin A deficiency at the close of the experiment are given in Table 3. The lowest mortality is at 100, 150, and 175 in the three experiments with the average lowest mortality at 100 micrograms of carotene in 100 grams of feeds. The difference between 14.3 per cent at 150 units and 17.8 per cent at 100 micrograms in experiment 39, is within the limits of error. In this experiment 100 micrograms seem to be sufficient. The percentage of chicks with vitamin deficiency at the end of the experiment is lowest at 100 micrograms per 100 grams of feed. The latter data show more variability than the gains in weight. Some of this variability may be the result of leucosis. Losses known to occur from this disease are not included in this data. However, there may have been mild cases of leucosis that were not identified but which weakened the chicks and caused them to die, apparently from vitamin A deficiency, and these deaths might not have occurred had not leucosis been present. According to this experiment, from 100 to 150 micrograms of carotene seems desirable. Chicks fed 50 to 75 micrograms had higher mortality and more cases of vitamin A deficiency symptoms than those fed higher quantities.

Another series of five experiments was conducted with 75, 100, and 125 micrograms of carotene from alfalfa per 100 grams of feed. The basal ration is given in Table 1. Ground kafir was replaced by the alfalfa leaf meal in sufficient quantities to provide the quantities of carotene desired. The gains in weight are presented in Table 4. The highest gains in weight by both the cockerels and the pullets were made on 125 micrograms of carotene per 100 grams of feed, with the exception of experiment 77, in which the highest gains of both pullets and cockerels were made with 100 micrograms, and experiment 80, in which the highest gain of the pullets was made with 75 micrograms. The average gains for the cockerels are appreciably different, but the differences in average weights of the pullets (616.2, 617.9, and 626.2 grams) were not great, but would be greater if experiment 77 was excluded. In this series of experiments, 125 micrograms per 100 grams was required by both cockerels and pullets. With the exception of experiment 84A, the chicks on these experiments made better gains than those in the preceding section. The chickens in experiment 84B were New Hampshires, while all of the others were single-combed white leghorns. There were 52 chickens on each carotene level in all of the experiments of this series except experiments 84A and 84B in which there were 26 chickens on each level.

Table 4. Gain in live weight of growing chicks on 3 levels of carotene

Micrograms of carotene per 100 grams of feed	Gain in live weight in grams					
	Exp. 68	Exp. 77	Exp. 80	Exp. 84a	Exp. 84b	Mean
Cockerels						
75	878.3	811.8	772.0	535.9	692.9	738.2
100	851.5	**840.4**	711.0	501.7	722.6	725.4
125	**968.7**	820.6	**790.8**	**577.5**	**750.2**	**781.6**
Pullets						
75	679.5	709.7	**657.4**	464.6	569.7	616.2
100	690.8	**720.4**	628.1	473.2	**576.8**	617.9
125	**761.9**	675.1	646.2	**482.5**	565.1	**626.2**

Table 5. Percentage of mortality of growing chicks on 3 levels of carotene

Micrograms of carotene per 100 grams of feed	Per cent mortality					
	Exp. 68	Exp. 77	Exp. 80	Exp. 84a	Exp. 84b	Mean
75	15.4	**13.5**	23.1	**1.9**	**0.0**	**10.8**
100	**11.5**	15.4	**7.7**	11.5	11.5	11.5
125	11.5	15.4	19.2	3.8	11.5	12.3

Table 6. Gains in live weight of growing chicks on 3 levels of carotene

Micrograms of carotene per 100 grams of feed		Gains of cockerels in grams			Gains of pullets in grams		
		Exp. 59	Exp. 60	Mean	Exp. 59	Exp. 60	Mean
Alfalfa leaf meal	75	550.9	532.9	541.9	448.2	489.7	469.0
	125	536.8	499.6	518.2	470.0	414.9	442.5
	150	573.0	535.2	554.1	496.8	425.6	461.2
Carotene in oil	75	504.4	465.8	485.1	509.4	427.0	468.0
	125	501.5	515.1	508.3	465.3	452.4	458.9
	150	493.1	513.4	503.3	500.2	424.8	462.5
Differences in favor of alfalfa leaf meal	75	.....	.....	56.8	.....	.....	1.0
	125	.....	.....	9.9	.....	.....	—16.4
	150	.....	.....	50.8	.....	.....	— 1.3

The mortality is given in Table 5. The lowest mortality was with 100 micrograms in two experiments, and 75 micrograms in three experiments, but the significance of these differences is questionable.

In the first series of three experiments, the cockerels required 150 micrograms of carotene per 100 grams of feed for the best gain in weight, while in the second series of experiments, 125 micrograms of carotene was sufficient, though higher quantities were not tested.

We conclude, from the data just presented, that 125 to 150 micrograms of carotene per 100 grams of feed, gives satisfactory results with growing chickens up to the age of twelve weeks. Since 0.6 microgram of carotene equals either 1 international unit or 1 U. S. P. unit, these chicks would require 210 to 250 U. S. P. units of vitamin A per 100 grams of feed. The faster growing breeds of chickens appear to require more carotene.

Comparison of carotene fed in alfalfa leaf meal with carotene in wesson oil

Since the alfalfa leaf meal might possibly supply some other ingredient besides carotene which would affect the results, two experiments were conducted in which carotene dissolved in wesson oil was compared with carotene in alfalfa leaf meal. Crystallized carotene was dissolved in a small quantity of chloroform and made up to the desired volume with wesson oil (purified cottonseed oil). Fresh solutions were made and mixed with the feed every two weeks. The rations used in these experiments are given in Table 1. The ground white corn was replaced by the alfalfa leaf meal or the carotene dissolved in oil in such quantities as to give 75, 125, and 150 micrograms of carotene per 100 grams.

Table 6 shows that the cockerels on the rations containing alfalfa leaf meal averaged 9.9 to 56.8 grams higher gains than the rations containing carotene in oil. With the pullets there were also slight differences in favor of the carotene in oil over the alfalfa leaf meal.

The mortality (Table 7) was lower in the group receiving the alfalfa leaf meal than in the group receiving carotene in oil. However, the per-

Table 7. Mortality and vitamin A deficiency of growing chicks on 3 levels of carotene

Micrograms of carotene per 100 grams of feed		Per cent mortality			Percentage of chicks showing deficiency at close of experiments		
		Exp. 59	Exp. 60	Mean	Exp. 59	Exp. 60	Mean
Alfalfa leaf meal	75	7.69	7.69	7.69	32.70	15.38	24.04
	125	3.85	3.85	3.85	3.85	19.23	11.54
	150	1.92	3.85	2.89	5.77	3.85	4.81
Carotene in oil	75	9.62	13.33	11.48	17.31	24.44	20.88
	125	3.85	11.36	7.61	9.62	9.09	9.36
	150	5.77	11.36	8.57	7.69	13.64	10.67

Table 8. Developing pullets used to make up groups for the following year for Experiments 35 and 39

	Micrograms of carotene per 100 grams of feed					
	50	75	100	125	150	175
Number of pullets alive at 12 weeks of age	31	38	42	32	39	35
Number placed on experiment following	17	20	20	20	20	20
Per cent placed on experiment following	54.8	52.6	47.6	62.5	51.3	57.1

Table 9. Summary of experiment on laying pullets fed various levels of caroteme

Micrograms of carotene per 100 grams of feed	Number of birds at beginning	Mortality, per cent	Number of eggs laid per bird	Average feed per bird per month, grams	Average weight, grams
50	17	100.0	1.1	1590.3	830.5
75	20	100.0	15.9	1688.4	1034.8
100	20	80.0	59.0	2141.8	1329.7
125	20	85.0	46.6	1973.7	1165.6
150	20	90.0	61.2	2317.7	1347.1
175	20	70.0	80.4	2141.3	1213.9

Table 10. Number of laying pullets which died each month on various levels of carotene

	Micrograms of carotene per 100 grams of feed					
	50	75	100	125	150	175
Number birds at beginning	17	20	20	20	20	20
July 11–31	0	3	1	0	0	0
August	7	4	4	1	1	1
September	6	1	0	0	1	0
October	3	3	1	4	1	1
November	1	0	2	2	0	0
December	All dead	2	0	1	4	3
January	.....	2	2	1	0	2
February	.....	0	1	1	1	1
March	.....	2	2	3	1	0
April	.....	2	0	1	3	4
May	.....	1	0	2	2	2
June	.....	All dead	3	1	4	0
July 1–11	.....	.....	0	0	0	0
Number remaining at close	0	0	4	3	2	6
Per cent mortality	100.0	100.0	80.0	85.0	90.0	70.0

centage of chicks showing vitamin A deficiency at the close of the experiment was as high with those receiving alfalfa leaf meal as those receiving carotene in oil. There appears to be no significant difference in the effectiveness of carotene in alfalfa leaf meal as compared with crystallized carotene dissolved in oil. This is in agreement with Record and associates (10). On the other hand, alfalfa contains xanthophyll, and Peterson and associates (9) report that chicks that had shown vitamin A deficiency as a result of depletion, revived in three to seven days after 20 micrograms per 100 grams of feed of a crystalline xanthophyll mixture had been added.

Requirements of pullets from 12 weeks to 20 months, through the laying periods

The pullets used in experiments 35 and 39 (Tables 1, 2, and 3) were continued on the same feeds (see Table 1) in order to ascertain their requirements at later stages of development.

Forty-nine days after the chicks in experiment 35 had reached twelve weeks of age and nineteen days after the chicks in experiment 39 had reached that age, arrangements were made to continue the work for one year longer. The equipment was of limited size, and it was impossible to carry more than twenty pullets in a pen. For that reason, 20 good pullets were placed in each group with the exception of the group receiving 50 micrograms, for which only seventeen satisfactory pullets were available. The pullets discarded were weaker birds than those that were continued on the experiment.

Table 8 shows the percentage of the pullets remaining at the close of the chick-growing experiment that were used in the work the following year.

According to the data summarized in Table 9, none of the 6 levels of carotene from 50 to 175 micrograms per 100 grams were high enough for good results. Egg production increased with the increased quantities of carotene fed with all groups except for the group receiving 125 micrograms. No reason is known for the poorer performance of this group as compared with the others. The mortality was lower as the carotene increased and the weights of the birds increased in the first 3 groups. The mortality is given in Table 10. The length of life of the pullets is longer when they received larger quantities of carotene than when smaller quantities were fed.

The average monthly feed consumption and the monthly weights were influenced greatly by the individuality of the birds remaining alive in the groups each month.

In another experiment (Experiment 19), hens were fed for a period of twenty months on 200, 300, and 400 micrograms of carotene per 100 grams of feed in the ration shown in Table 11. The data are given in Table 12. The mortality was high in all groups as shown also in Tables 12 and 13; it

Table 11. Percentages of ingredients of mixtures used in experiments with laying hens

(Sufficient alfalfa leaf meal was used in place of corn to give the desired carotene content)

Feeds	Percentage ingredients used		
	Experiment 19	Experiment 62	Experiment 94
Meat and bone scraps, 50% protein	7.0	8.0	10.0
Dried skimmed milk	3.0	.....	.....
Dried whey	.....	2.0	3.0
Salt	1.0	0.5	0.5
Chick size oyster shell	4.0	.....	1.0
Wheat gray shorts	10.0	10.0	10.0
Wheat bran	10.0	10.0	10.0
Ground whole oats	10.0	10.0	10.0
Ground white oats	55.0	59.5	55.5

Table 12. Summary for Experiment 19 on laying hens fed 3 levels of carotene

Micrograms of carotene per 100 grams of feed	Time	Number at beginning	Percent mortality of original number	Number of eggs laid per hen	Average feed eaten per hen per month. grams	Average weight, grams
200	First year	20	80.0	50.0	1864.9	1308.0
	Following 8 months	4	15.0	36.9	1936.5	1350.6
	Mean or total	No. at end 1	95.0	86.9	1900.7	1329.3
300	First year	20	55.0	74.6	2286.3	1497.2
	Following 8 months	9	30.0	45.4	2222.3	1463.2
	Mean or total	No. at end 3	85.0	120.0	2254.3	1480.2
400	First year	20	50.0	107.3	2378.9	1433.9
	Following 8 months	10	25.0	60.4	2260.3	1376.4
	Mean or total	No. at end 5	75.0	167.7	2319.6	1405.2

was 80% for the first year in the group on the low level of 200 micrograms per 100 grams of feed, 55% on 300 micrograms, and 50% for 400 micrograms. During the last eight months of the experiment, the hens on the higher levels of carotene were sufficiently depleted to cause a high mortality in those lots also. At the end of 20 months, the total mortality was 95, 85, and 75% respectively for the 3 groups. Egg production and feed consumption increased as the carotene in the feed increased. The number of eggs produced was 86.8 with the hens on 200 micrograms, 120 with hens on 300 micrograms, and 167.7 for hens on 400 micrograms. The average weight was less for the birds on the low carotene levels than for those on the two higher levels.

Table 13 shows the number by months of birds which died in the different groups. It shows clearly that the mortality was high during the first year with the birds on the low level of carotene and that the birds on the higher levels lived longer but died later as their reserve of vitamin A became depleted. Probably the quantity of eggs produced affected the vitamin A depletion and the resulting mortality. None of these levels of carotene were high enough for good results over a long period of time.

Two additional experiments were made. Table 11 shows the ingredients of the feed for experiment 62. A summary of the data is given in Table 14. The birds on experiment 62 were on experiment for two years. The groups received 150, 225, and 300 micrograms of carotene per 100 grams of feed. The egg production, body weight, and hatchability as shown in Table 14 are closely related to the carotene intake, but the results indicate that the highest amount (300 micrograms) is not sufficient for good results over a long period of time. This is also shown in the mortality (Table 15).

The birds on experiment 94 received 200, 400, and 600 micrograms of carotene per 100 grams of feed. The ingredients of the ration are given in Table 11. Table 16 summarizes the data, while Table 17 shows the relative length of life. The egg production and hatchability was closely related to the carotene intake. When the eggs were incubated, as seen

Table 13. Number of hens which died each month on 3 levels of carotene

	Micrograms of carotene per 100 grams of feed		
	200	300	400
Number at beginning	20	20	20
First Year			
November	0	0	0
December	0	1	2
January	1	2	0
February	0	1	2
March	4	2	0
April	1	0	0
May	1	0	1
June	2	1	1
July	2	1	2
August	1	1	0
September	3	2	1
October	1	0	1
Total—1 year	16	11	10
Following Eight Months			
November	1	1	0
December	1	0	1
January	1	2	0
February	0	0	1
March	0	1	1
April	0	1	0
May	0	0	2
June	0	1	0
Total—8 months	3	6	5
Total—20 months	19	17	15

Table 14. Summary of Experiment 62 on hens fed 3 levels of carotene

Micrograms of carotene per 100 grams of feed	Number at start	Mortality per cent	Feed required per hen per month grams	Average hen weight grams	Average eggs per hen	Hatchability Test					
						Number of eggs	Infertile eggs per cent	Embryonic mortality of fertile eggs per cent	Crippled chicks of fertile eggs per cent	Vigorous chicks of fertile eggs per cent	Vigorous chicks of total eggs per cent
1937—38											
150	34	76.5	2089.5	1304.2	58.9	78	23.1	40.0	5.0	55.0	42.4
225	36	72.2	2245.8	1283.2	79.8	158	17.1	19.9	2.3	77.8	64.6
300	34	61.8	2224.6	1283.6	84.3	175	31.4	10.8	.8	88.3	60.5
1938—39											
150	8	62.5	2245.4	1267.8	56.8	115	28.7	30.5	11.0	58.5	41.8
225	10	40.0	2510.6	1271.8	63.9	158	32.9	23.6	2.8	73.6	49.4
300	13	61.5	2160.2	1348.0	51.3	126	12.7	11.8	6.4	81.8	71.4

in Tables 14 and 16, there were more dead embryos and crippled chicks from the eggs produced on the lower levels than on the higher ones. From 400 to 600 micrograms of carotene per 100 grams of feed seems to be required by hens to be used for chick production.

Table 18 summarizes the egg production of all of the experiments on the different levels of carotene. The different levels do not give the same number of eggs in all of the experiments, but in each experiment the production of eggs is closely related to the carotene intake.

These experiments indicate that 550 micrograms or more of carotene (920 U. S. P. units of vitamin A) per 100 grams of feed is necessary for hens producing eggs high in vitamin A potency or for hatching. In

Table 15. Number of birds which died each month on 3 levels of carotene—Experiment 62

	Micrograms of carotene per 100 grams of feed		
	150	225	300
First Year			
Number birds at beginning	34	36	34
November	1	0	0
December	0	1	0
January	3	6	2
February	0	0	2
March	7	6	4
April	1	0	0
May	3	1	5
June	3	3	1
July	3	5	1
August	3	3	4
September	1	0	2
October	1	1	0
Total mortality	26	26	21
Total deficient from vitamin A	16	16	10
Per cent deficient from vitamin A	47.1	44.4	29.4
Number at close	8	10	13
Second Year			
Number at beginning	8	10	13
November	0	2	0
December	0	0	2
January	0	0	1
February	0	0	2
March	1	0	1
April	0	1	0
May	0	0	0
June	2	0	0
July	1	0	1
August	1	0	1
September	0	1	0
Total mortality	5	4	8
Total deficient from vitamin A	0	2	4
Per cent deficient from vitamin A	0	20.0	30.8
Number birds at close	3	6	5

Table 16. Summary for Experiment 94 on laying hens fed 3 levels of carotene

Micrograms of carotene per 100 grams of feed	Number at start	Mortality per cent	Feed required per hen per month grams	Average hen weight grams	Average eggs per hen	Hatchability Test					
						Number of eggs	Infertile eggs per cent	Embryonic mortality of fertile eggs per cent	Crippled chicks of fertile eggs per cent	Vigorous chicks of fertile eggs per cent	Vigorous chicks of total eggs per cent
200.....	33	27.3	2306.2	1319.9	81.4	670	25.8	20.5	7.4	72.1	53.5
400.....	33	33.3	2481.3	1340.9	94.9	837	21.5	15.2	2.6	82.2	64.5
600.....	33	33.3	2595.3	1333.7	116.4	996	15.4	11.3	3.4	85.3	72.2

order to provide a factor of safety, at least 600 micrograms of carotene (1,000 U. S. P. units) are recommended. If the eggs are not to be hatched and the vitamin A content of the eggs is not important, 450 micrograms of carotene (750 U. S. P. units) per 100 grams of feed or more seems to be required. In order to provide a factor of safety, 500 micrograms (833 U. S. P. units) are recommended. These figures are in agreement with the findings of some of the other workers.

Table 17. Number of hens which died each month on 3 levels of carotene—Experiment 94

	Micrograms of carotene per 100 grams of feed		
	200	400	600
Number at beginning	33	33	33
December	0	0	0
January	1	0	0
February	1	1	1
March	1	1	1
April	1	1	2
May	3	5	1
June	1	1	2*
July	2	3	0
August	1	1	0
September	4	2	1
Total mortality	15	15	8*
Number vitamin A deficient	6	5	0
Per cent vitamin A deficient	18.2	15.2	0
Number of birds at close	18	18	19*

*Six other birds were killed accidentally on June 28th.

Table 18. Summary of relation of amount of carotene fed laying hens to number of eggs laid

Micrograms of carotene per 100 grams of feed	Experiment 19		Experiments 35 and 39	Experiment 62		Experiment 94
	First year	Following eight months		First year	Second year	
50			1			
75			16			
100			59			
125			47			
150			61	59	57	
175			80			
200	50	37				81
225				80	64	
300	75	45		84	51	
400	107	60				95
600						116

SUMMARY

The 8 experiments on growing chicks indicate that 125 to 150 micrograms of carotene (210 to 250 U. S. P. units of vitamin A) per 100 grams of feed gives satisfactory results in health and growth up to twelve weeks of age. In order to provide a factor of safety, 180 micrograms of carotene per 100 grams of feed are recommended for growing chicks up to 12 weeks of age. This is equivalent to 300 U. S. P. units per 100 grams of feed. Fast growing chicks appear to require more carotene than slow growing ones.

When alfalfa leaf meal and crystallized carotene dissolved in oil were compared in 2 experiments as sources of carotene for growing chicks, slight differences in gains in weight and mortality were found in favor of the alfalfa leaf meal although it is doubtful whether these differences are significant.

Four experiments were made on pullets from 12 to 20 weeks old to the end of their profitable existence. The mortality of pullets grown on 50, 75, 100, 125, 150, and 175 micrograms of carotene per 100 grams of feed during the period from July 11 to November 1 was 94, 55, 30, 25, 15, and 10 per cent respectively. From July 11 to the following July 11, the mortality was 100, 100, 80, 85, 90, and 70 per cent respectively. This data would indicate that 150 and 175 micrograms of carotene per 100 grams of feed furnish the requirements for growth but are far too low for satisfactory egg production and long life. Allowing a factor of safety, it is recommended that pullets be fed rations containing not less than 200 micrograms carotene per 100 grams of feed (333 U. S. P. units), from 12 weeks of age until they begin to lay.

Experiments with 200, 400, and 600 micrograms of carotene per gram of feed indicate that not less than 450 micrograms of carotene (750 U. S. P. units of vitamin A) per 100 grams of feed is needed for good egg production. In order to provide a factor of safety, not less than 500 micrograms of carotene per 100 grams of feed is recommended (833 U. S. P. units). When the eggs are to be used for hatching or a market where the vitamin A content of the eggs is important, 550 or more micrograms of carotene (920 U. S. P. units of vitamin A) per 100 grams of feed is required. In order to provide a factor of safety, not less than 600 micrograms of carotene per 100 grams of feed (1,000 U. S. P. units) is recommended for hens producing eggs for hatching.

In some of the experiments, the chickens did well on smaller amounts than here recommended, but it was thought best to be on the safe side.

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