TEXAS AGRICULTURAL EXPERIMENT STATION
A. B. CONNER, DIRECTOR
COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 468 DECEMBER, 1932

DIVISION OF POULTRY HUSBANDRY

The Quantities of Vitamin A Required by Pullets for Maintenance and for Egg Production

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*Dean School of Veterinary Medicine. As of October 1, 1932.
**In cooperation with U. S. Department of Agriculture.
†In cooperation with Texas Extension Service.
††On leave.

The estimation of the amount of vitamin A required by laying White Leghorn pullets for egg production and for maintenance was made from an experiment in which laying pullets were fed daily an average of 270, 120, and no units of vitamin A in yellow corn. The pullets receiving no vitamin A from yellow corn lived from 34 to over 199 days showing a wide variation in the quantities of Vitamin A stored up in the bodies of the different pullets. The pullets receiving daily 270 units of vitamin A from yellow corn were the heaviest in weight at the end of the experiment and laid the most eggs. Those receiving 120 units a day from yellow corn averaged a slightly smaller weight than the first group and laid about 17 per cent fewer eggs. The pullets receiving no vitamin A from yellow corn had a decidedly smaller weight than the other groups and laid appreciably fewer eggs.

In all three groups the vitamin A of the eggs decreased from about 20 units per gram of yolk at the beginning of the experiment to 5-8 units toward the end of the period of 6½ months, which shows that none of the pullets received sufficient vitamin A to maintain a high potency of the eggs.

It is estimated from the data here given that 1 unit of vitamin A in the egg requires 6.3 units in the feed in addition to the maintenance requirements. The maintenance requirements of the pullets weighing about 3.2 pounds was estimated at 105 units a day or 33 units per pound per day, which is considerably higher than the 4 units per pound per day estimated to be required for maintaining growing rats.

Mash containing as much as 8 per cent of ordinary alfalfa meal would supply only 30 to 40 units of vitamin A a day or only a fraction of the amount required by the laying pullets. Heat-dried alfalfa containing 100 units to the gram fed with yellow corn would not supply sufficient vitamin A to maintain high production and high vitamin A potency in the eggs. Laying pullets apparently require green feed to provide sufficient vitamin A for maximum egg production and high vitamin A potency of the eggs. Ordinary rations fed laying hens do not supply sufficient vitamin A and may cause decreased production of eggs during the second and third years unless the fowls have access to green feed.

CONTENTS

BULLETIN NO. 468 DECEMBER, 1932

THE QUANTITIES OF VITAMIN A REQUIRED BY PULLETS FOR MAINTENANCE AND FOR EGG PRODUCTION

R. M. SHERWOOD AND G. S. FRAPS

No work so far has been reported on the quantity of vitamin A required by laying hens. Some work has been done on the effect of vitamin A on the health of fowls, on their gain in weight, and on the production of eggs as well as on the vitamin A content of the eggs. Holmes and associates (4) reported that the vitamin A potency of the eggs, egg production, weight of eggs, fertility, hatchability, and viability of the chicks hatched, were improved by the addition of cod liver oil to rations deficient in vitamin A. Edson (2) found that cod liver oil increased egg production and hatching power of the eggs, but ascribed the effect to vitamin D and not vitamin A. Bethke, Kennard and Sassaman (1) state that eggs from hens fed cod liver oil or having access to bluegrass pasture contained approximately 5 times as much vitamin A as eggs from hens fed the basal diet, which contained 30 per cent yellow corn, or the basal diet supplemented with alfalfa hay.

The objects of the present work were to ascertain the effect of the quantity of vitamin A fed to pullets upon the quantity of vitamin A in the eggs as well as upon health and egg production, and to estimate the quantity of vitamin A necessary for the production of eggs high in vitamin A and the quantity required for the maintenance of the pullets.

Method of Procedure

White Leghorn pullets that had been raised upon a standard ration, including free access to green feed, were divided into three groups of 36 pullets each, each group being subdivided into two lots of 18 pullets each. One pullet of poor quality was removed from each group on November 5, leaving 35 pullets on each ration. One cockerel was placed with each lot of pullets. The cockerels were exchanged between the lots each week. The feeding began the morning of October 15, 1931, and ended the night of April 30, 1932. The chickens were kept in pens having cement floors, without access to green feed. The pullets had an abundance of sunshine so that the equivalent of vitamin D was well supplied. Yellow corn and white corn were used in varying the amounts of vitamin A in the rations, as fresh yellow corn is comparatively high in this vitamin (3), while white corn contains practically no vitamin A. The chickens in Group 1, here termed the yellow corn group, were fed a mash containing 20 per cent yellow corn, and scratch grain consisting of yellow corn. The mash fed the chickens in Group 2, termed the mixed corn group, contained 10 per cent yellow corn and 10 per cent white corn, and the scratch feed consisted of equal parts yellow corn and white corn. Group No. 3, termed the white corn group, received white corn entirely instead of yellow corn. The complete rations used are given in Table 1.

Table 1. Ingredients of mixtures used for the laying pullets

Ingredients of feed	Yellow corn group Per cent	Mixed corn group Per cent	White Corn group Per cent
Mash			
Yellow corn meal	20	10	
White corn meal		10	20
Wheat gray shorts	20	20	20
Wheat bran	20	20	20
Ground whole oats	20	20	20
50% protein, meat and bone scraps	20	20	20
Scratch feed			
Yellow corn	100	50	
White corn		50	100

Vitamin A was determined in samples of the two lots of yellow corn used and in the yolks from representative lots of the eggs by Mr. Ray Treichler of the Division of Chemistry. The Sherman-Munsell unit method was used with rats, as we have described elsewhere (3) in full. The eggs were kept in cold storage; an egg was taken each week and boiled; the yolk was separated and weighed, and weighed portions of the yolk were fed twice a week to the test rats. The results are expressed as units of vitamin A, a unit being the amount fed daily which will produce a gain of approximately 24 grams in 8 weeks. Tables 2 and 3 contain the results for the quantity nearest to containing a unit, but several other quantities not given in the tables were usually fed. The estimation of vitamin A is not as accurate as ordinary chemical analysis. Vitamin A was not determined in ingredients of the feed other than the yellow corn. The methods at present available do not permit the estimation with any degree of accuracy of small amounts of vitamin A, such as are found in these feeds. The other constituents of the mash contained almost negligible amounts of vitamin A and the three rations were identical, except for the corn. The vitamin A in other feeds than the corn was not disregarded in the calculations and does not invalidate the conclusions here presented.

The vitamin A content of the yellow corn and of eggs, as determined, is shown in Tables 2 and 3. Two lots of yellow corn were used. The vitamin A content of yellow corn decreases during storage, as can be seen by comparing the results in Table 3 for fresh corn, the test beginning Oct. 30, 1931, with the results with the old corn, the test beginning 8½ months later, July 13, 1932. There is a loss of approximately 33 per cent of vitamin A. In calculating the results, some allowance, though possibly not enough, has been made for this decrease. Details of the experiment are given in Table 10.

The average amounts of vitamin A consumed daily in the yellow corn as calculated from data in Table 10 by dividing the total intake per pullet by the 199 days of the experiment, were approximately 270 units for the yellow corn group, 120 for the mixed corn group, and none for the white corn group.

Table 2. Details of estimation of vitamin A in egg yolk

Number	Date Collected	Group of pullets	Grams fed daily	Number of rats beginning	Number of rats at end	Average gain per rat in 8 weeks grams	Grams feed one unit vitamin A	Units vitamin A to one gram feed
34883	July 1, 1931	Check	.033	6	5	24	.033	30
35078	Aug. 10, 1931	Check	.050	6	5	25	.050	20
35763	Dec. 3, 1931	Yellow corn group	.050	6	2	24	.050	20
35764	Dec. 3, 1931	White corn group	.093	6	4	34	.077	13
35765	Dec. 3, 1931	Mixed corn group	.083	6	2	24	.083	12
35885	Dec. 29, 1931	Mixed corn group	.083	6	5	26	.083	12
35886	Dec. 29, 1931	White corn group	.083	6	5	15	.083	12
36029	Jan. 29, 1932	Yellow corn group	.066	8	3	16	.071	14
36028	Jan. 29, 1932	Mixed corn group	.100	6	5	27	.100	10
36030	Jan. 29, 1932	White corn group	.100	8	6	26	.100	10
36149	Feb. 29, 1932	Yellow corn group	.100	6	2	34	.100	10
36150	Feb. 29, 1932	White corn group	.100	6	3	42	.071	14
36245	March 31, 1932	Mixed corn group	.200	6	5	33	.170	6
36244	March 31, 1932	White corn group	.200	6	3	37	.200(?)	5(?)
36336	May 2, 1932	Yellow corn group	.100	6	1	17	.200(?)	5(?)
36337	May 2, 1932	Mixed corn group	.133	6	4	19	.133	8

Table 3. Details of estimation of vitamin A in yellow corn, as collected and after storage

Number	Date Collected	Date rats put on experiment	Grams fed Daily	Number of rats at beginning	Number of rats at end	Average gain per rat in 8 weeks grams	Grams feed to to one unit vitamin A	Units vitamin A to one gram feed
36012	Jan. 27, 1932	Jan. 29, 1932	.150	6	3	21	.150	7
35660	Oct. 7, 1931	Oct. 30, 1931	.200	6	6	30	.170	6
35660	Oct. 7, 1931	July 13, 1932	.250	6	6	21	.250	4

Effect of Amount of Vitamin A on Mortality and Weights of the Pullets

The mortality of the pullets is shown in Table 4. Some of those fed on white corn died in a little over a month. The first one died on November 17 and others continued to die until only 4 remained at the end of the experiment, on April 30, after a period of 6½ months. If it is assumed that these four would have lived a week longer, which is a reasonable assumption in view of the fact that the pullets were in bad condition, the average length of life would be 135 days; furthermore if it is assumed that 3 hens, the equivalent of the number dying in the yellow corn lot, died from other causes than deficiency of vitamin A, the average length of life would be 137 days.

Individual hens lived from 34 to over 199 days. It appears to be a reasonable assumption that the length of life of the pullets is a fair measure of the quantity of vitamin A stored by the pullets before the experiment was begun, when they had all the green feed they could eat. If such is the case the amount of vitamin A contained in different pullets varied to a considerable extent, and some may have contained 4 or 5 times as much as the others. These pullets fed white corn during the

experiment would no doubt have died sooner had they been raised with a less liberal supply of vitamin A.

Table 4. Number of deaths of pullets with day of month on which each occurred

	Yellow corn group		Mixed corn group		White corn group	
	Number	Day of month	Number	Day of month	Number	Day of month
October 15-31 inclusive	0	----	0	----	0	0
November	0	----	0	----	1	17
December	1	28	0	----	2	11-16
January	0	----	1	26	7	7, 11, 15, 22, 25, 30, 31
February	1	3	1	3	8	5, 9, 11, 15, 16, 17, 23, 23,
March	1	15	0	----	9	1, 5, 5, 5, 5, 6, 13, 28, 29
April	0	----	2	18, 20	4	2, 6, 19, 29
Total	3		4		31	

The pullets fed mixed corn and those fed all yellow corn received enough vitamin A to carry them through the experiment, though to judge from the vitamin A content of the eggs (Table 8), the body store must have been depleted at the end of the experiment.

The average weights of the living pullets, during the progress of the experiments, was directly related to the vitamin A content of the feed, as shown in Table 5. After the first weighing which was at the beginning of the experiment, the pullets receiving the yellow corn were heaviest, those receiving mixed corn came next, and those receiving only white corn were lightest, though the differences between the first two groups were small.

Table 5. Weights of pullets in pounds

	Yellow corn group	Mixed corn group	White corn group
Oct. 15, 1931, initial weight	2.89	2.98	2.88
Dec. 23, 1932	3.39	3.33	3.08
Feb. 25, 1932	3.44	3.26	3.07
May 2, 1932, final weight	3.03	2.83	2.43

Effect of Quantity of Vitamin A on Number of Eggs Produced

The number of eggs laid per pullet after the first two months was closely related to the vitamin A content of the feed, as shown in Table 6. The averages are based on the number of pullets alive at the time and not on the total number with which the experiment began. The number of eggs laid by the pullets that received yellow corn was consistently higher than the number laid by those receiving mixed corn, and both were higher than that laid by the hens receiving only white corn. Whether or not the feeding of larger amounts of vitamin A than

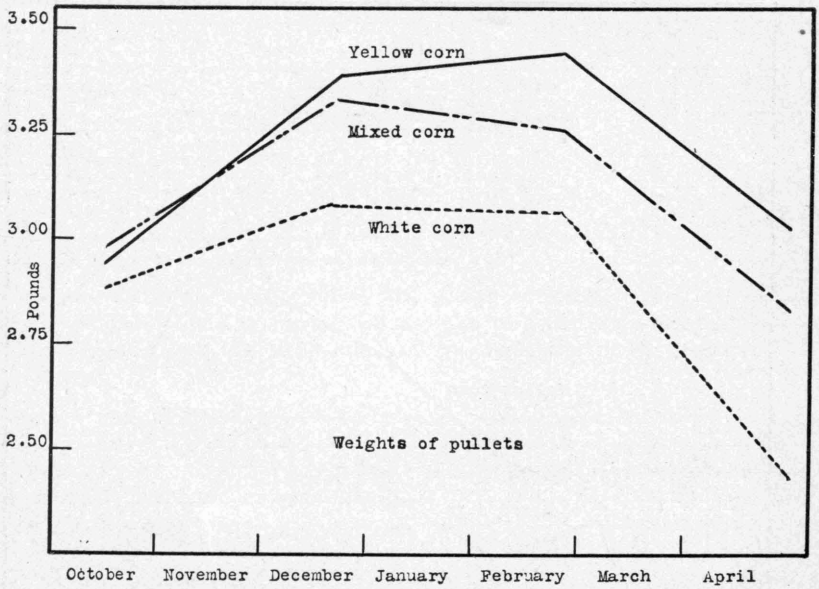

Figure 1. Average weights of pullets fed three different amounts of vitamin A.

those here fed in yellow corn would result in even higher production of eggs, remains to be ascertained.

Table 6. Average number of eggs per pullet

Month	Yellow corn group	Mixed corn group	White corn group
October (½ month)	1.92	1.31	3.64
November	8.45	8.10	9.67
December	9.51	7.14	5.32
January	11.82	8.81	7.95
February	13.17	13.12	9.24
March	18.15	15.18	12.91
April	17.56	13.02	6.76
Total	80.58	66.68	55.49

Effect of Quantity of Vitamin A on Percentage of Eggs that Hatched

Four lots of eggs from the three groups of pullets fed different amounts of vitamin A were incubated, with the results shown in Table 7. With the exception of the second hatching of eggs from pullets on the mixed corn ration, the percentage of eggs hatched increased with the increase in the amounts of vitamin A fed. The relations are regular and positive.

The units of vitamin A to the gram of egg yolk, calculated from the estimations made, are also given in Table 7 and can be compared with the

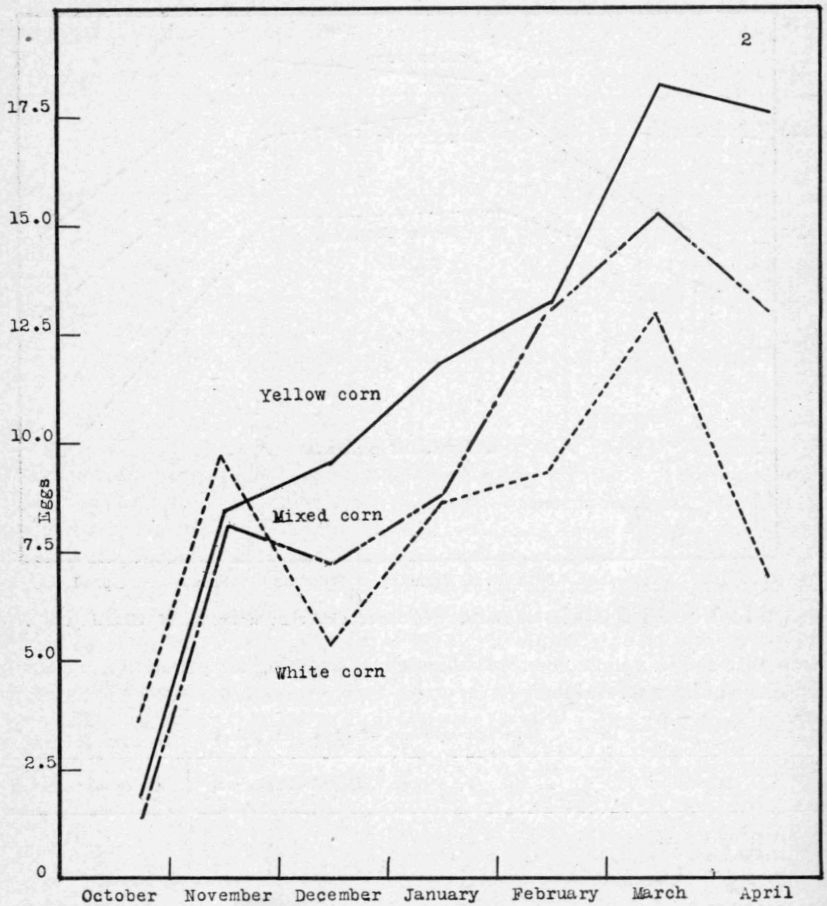

Figure 2. Eggs laid per pullet fed three different amounts of vitamin A

percentage of eggs hatched. The percentage of eggs hatched is not closely related to the units of vitamin A in the eggs, although it is related to the quantity of vitamin A fed. The lower percentage of eggs hatched from mixed corn and the white corn group is probably due to lower vitality of the egg, caused by insufficient supplies of vitamin A.

Effect of Quantity of Vitamin A on the Vitamin A Content of the Eggs

The vitamin A content of the eggs expressed in units per gram of yolk, as rearranged in Table 8 from Table 2, decreased in all three of the groups during the course of the experiment. This might be due to an insufficient intake of vitamin A by the pullets to produce the maximum

Table 7. Relation of percentages of eggs hatched to vitamin A in eggs and in feed of hens

	Percentage hatched			Units per gram of egg yolk Incubated		
	Yellow corn group	Mixed corn group	White corn group	Yellow corn group	Mixed corn group	White corn group
Hatched, Feb. 26, 1932	49.2	44.3	40.0	14	10	10
Hatched, Mar. 9, 1932	55.7	59.3	47.7	12	9	11
Hatched, Apr. 13, 1932	43.8	39.0	25.9	8	6	5
Hatched, May 6, 1932*	72.7	50.0	16.3	5	8	4

*Number of eggs too small for accurate percentage.

amount in the eggs, even on the full ration of yellow corn, or to the inability of the pullets to put high quantities into the eggs during periods of high production. As shown below, the first theory is probably the correct one.

Table 8. Units of vitamin A per gram of yolk of eggs collected at different times

	Yellow corn group	Mixed corn group	White corn group
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	----

The total output of vitamin A per pullet in the eggs, which is the product of the units of vitamin A in the eggs and the number of eggs laid (see Tables 6 and 10), is related to the quantities of Vitamin A fed. The pullets receiving yellow corn have a much greater output of vitamin A in the eggs in almost every month of the experiment than those receiving the mixed corn. On the other hand, the difference between the amounts of vitamin A in the eggs laid by the mixed corn group and in those laid by the white corn group is small. This would indicate that most of the vitamin A received by the mixed corn group was used for maintenance of the body, so that little of it was available for the eggs.

Table 9. Units of vitamin A per pullet in eggs laid during each period

Period	Yellow corn group	Mixed corn group	White corn group
Oct. 15-31	557	385	1,092
November	2,434	1,426	1,876
December	2,539	1,342	984
January	2,636	1,454	1,323
February	2,107	1,679	2,042
March	2,323	1,442	1,033
April	1,422	1,614	433
Total	14,018	9,342	8,843
Average units fed per day in yellow corn	270	120	0

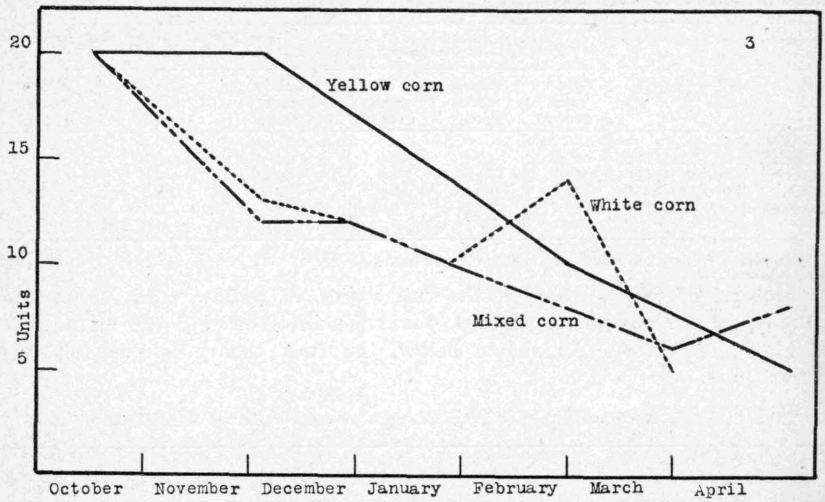

Figure 3. Units of vitamin A per gram of egg yolk from pullets fed three different amounts of vitamin A.

Quantity of Vitamin A Required for the Vitamin A In the Eggs

Details of the experiment, with calculations of the quantities of vitamin A fed and that found in the eggs, are given in Table 10. The number of units of vitamin A in the eggs, divided by the number of units fed in the yellow corn, expressed as percentages, is also given in Table 10. These percentages are remarkably constant for the different months with the pullets fed yellow corn, in all except the first month. The average percentage in the eggs of this group is apparently about 26 per cent. The percentages recovered in the eggs are apparently much higher with the pullets receiving mixed corn than with those fed yellow corn, averaging apparently 39 per cent, but they show a tendency to decrease during the latter part of the experiment. The figures referred to above do not correctly represent the percentage utilization of the vitamin A for the eggs, since some of the vitamin A fed was used for maintenance purposes and large quantities of that in the eggs comes from vitamin A stored in the bodies of the pullets at the beginning of the experiment, as well as from the small amounts fed in the other ingredients of the mash besides the yellow corn.

The amount of vitamin A in the eggs from the pullets fed white corn might be assumed to measure the quantity of vitamin A stored in the pullets at the beginning of the experiment and also that fed in the other ingredients of the feed except the yellow corn. If, therefore, the total units 8,843 of vitamin A per living pullet in the eggs of this group fed white corn are deducted from the total units in the eggs from the group fed the mixed corn (9,342 units), there remains 499 units of vitamin A in the

Table 10. Details of experiment, including the weight of feed, eggs laid, and vitamin A in feed and in eggs by months

	October 15-31	November	December	January	February	March	April	Total
Feed eaten—Yellow corn group								
Yellow corn per pullet, pounds	1.631	3.070	3.117	3.036	2.809	3.094	2.909	
Mash per pullet, pounds	1.447	2.233	2.913	2.958	3.362	3.436	2.221	
Grain per pullet, pounds	1.342	2.623	2.534	2.444	2.137	2.407	2.265	
Yellow corn per egg, pounds	.815	.364	.328	.257	.213	.170	.166	
Feed eaten—Mixed corn group								
Grain per pullet, pounds	.868	2.637	2.432	2.375	1.966	2.157	1.853	
Mash per pullet, pounds	1.447	2.247	2.635	2.036	2.165	3.671	2.656	
Yellow corn per pullet, pounds	.579	1.543	1.480	1.391	1.200	1.446	1.192	
Yellow corn per egg, pounds	.443	.190	.207	.158	.089	.092	.089	
Feed eaten—White corn group								
Grain per pullet, pounds	.750	2.586	2.581	2.457	3.203	3.108	2.253	
Mash per pullet, pounds	1.487	2.042	2.237	2.441	1.861	1.688	1.481	
Weight of yolk in grams								
Yellow corn group	14.5	14.4	15.7	15.9	16.0	16.0	16.2	
Mixed corn group	14.7	14.7	15.7	16.5	16.0	15.8	15.5	
White corn group	15.0	14.9	15.4	17.4	15.8	16.0	16.0	
Units of vitamin A per pound of yellow corn	3,175*	3,000	2,800	2,720*	2,600	2,500	2,400	
Units vitamin A per egg								
Yellow corn group	290	288	267	223	160	128	81	
Mixed corn group	294	176	188	165	128	95	124	
White corn group	300	194	185	174	221	80	64	
Units vitamin A eaten per egg								
Yellow corn group	2,702	1,092	918	699	554	425	389	
Mixed corn group	1,407	570	580	430	231	230	214	
Units vitamin A eaten per pullet								
Yellow corn group	5,178	9,210	8,728	8,258	7,303	7,735	6,982	53,394
Mixed corn group	1,838	4,629	4,144	3,784	3,120	3,615	2,861	23,991
Vitamin A in eggs in percentage of that fed								
Yellow corn group	10.8	26.4	29.1	31.9	28.9	30.0	20.4	26.3
Mixed corn group	21.0	30.8	32.4	38.4	53.8	39.9	56.4	38.9

*Direct estimation, others assumed from the estimations made.

eggs, which might be assumed to come from 23,391 units fed per pullet in the yellow corn for the entire experiment. By a similar calculation the 8,843 units in the eggs of the white corn group are deducted from the 14,018 units in eggs from the yellow corn group. The remaining 5,175 units in the eggs from the pullets on the yellow corn group are assumed to be produced from 53,394 units fed in the yellow corn (see Table 11). Therefore, if correction is made in this way for the amount of vitamin A in the pullets at the beginning of the experiment, the amount of vitamin A recovered in the eggs of the mixed corn group is apparently only 2.1 per cent, and in the eggs of the yellow corn group, 9.7 per cent.

The low percentage of vitamin A given above and calculated to be recovered in the eggs from the pullets fed the mixed corn were no doubt due to the fact that a large proportion of the vitamin A fed was used for maintenance purposes and therefore was not available for storage in the eggs. Therefore, the figures given above are not correct for the utilization of vitamin A in the eggs, but correction must still be made for that portion of vitamin A used for maintenance purposes by the mixed corn group of pullets. This correction can be made if the units of

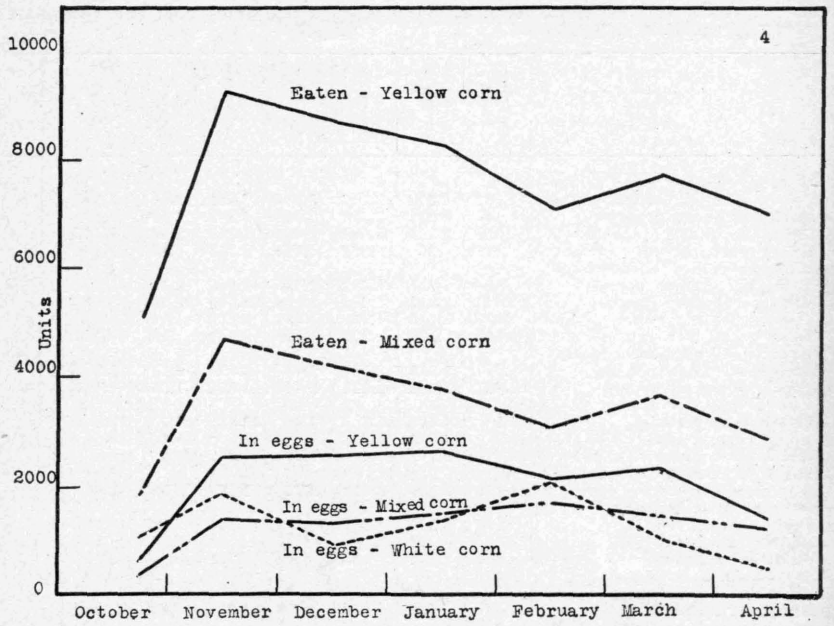

Figure 4. Units of vitamin A eaten monthly and units in eggs laid per pullet.

vitamin A fed and those found in the eggs in the group receiving mixed corn are deducted from the units of vitamin A fed and those found in the eggs of the group receiving yellow corn. The calculation is given in Table 12. Thus 29,403 units of vitamin A fed in excess of the amount fed in the mixed corn, produced 4,676 units more in the eggs than were in the eggs of the pullets fed mixed corn. This is a utilization of 15.9 per cent of the vitamin A for the eggs. To put it another way, one unit of vitamin A in the eggs requires 6.3 units in the feed in excess of maintenance requirements. This method of calculation allows for both the vitamin A used for maintenance and that stored in the bodies of the pullets at the beginning of the experiment as well as for the small amounts in the feed other than the corn. Sufficient allowance may not have been made even here for maintenance requirements. Also the units of vitamin A in the eggs of the white corn group may be too high, since it is based on the living pullets, and excludes those which died from a deficiency of vitamin A. But in any case the figures used are the closest that can at present be secured for the utilization of vitamin A for storing it in eggs, when fed in fair amounts but still too little for maximum storage. It is possible that the percentage utilization would be lower if there were fed amounts very much larger than were here used. With very high quantities of vitamin A more than 6.3 units of vitamin A in the feed would probably be required to produce a unit in an egg of high vitamin A content. This must be ascertained by further experiment.

Table 11. Percentages of vitamin A recovered per pullet after allowing for that stored in the bodies of the pullets.

Units in eggs, entire period, mixed corn group	9,342
Units in eggs, white corn group (chiefly from stored vitamin A)	8,843
Difference due to yellow corn	499
Total units fed to mixed corn group	23,991
Percentage recovered in eggs of mixed group	2.1
Units in eggs, entire period, yellow corn group	14,018
Units in eggs, white corn group	8,843
Difference due to yellow corn	5,175
Total units fed to yellow corn group	53,394
Percentage recovered in eggs of yellow corn group	9.7

Quantity of Vitamin A Required for Maintenance During Egg Production

The estimation of the amount of vitamin A required to meet the maintenance requirements of the pullets is more uncertain than that for the vitamin A in the eggs, on account of the wide variations in the amounts of vitamin A stored in the bodies of different pullets, as shown by the variations in the survival periods of the pullets fed on white corn. An approximate estimate of the average maintenance requirements may be made from the data here given. The maintenance requirements were estimated from the data in Table 10 on the pullets fed the mixed corn ration by aid of the estimate that 6.3 units of vitamin A are required for the production of one unit of vitamin A in the eggs (see Table 12). The pullets of the mixed corn group laid eggs during the experiment containing 9,342 units of vitamin A, of which it is assumed that 8,843 came from the body of the pullet, leaving 499 units to have come from the feed, which would require 3,144 units (499 multiplied by 6.3). When this 3,144 units is deducted from the 23,991 units fed during the period, it leaves 20,847 units for maintenance 199 days; which is, approximately 105 units of vitamin A per day for maintenance.

Table 12. Units of vitamin A per pullet required for eggs and for maintenance of laying pullets (entire period)

In eggs, yellow corn group	14,018
In eggs, mixed corn group	9,342
Difference in eggs between yellow corn and mixed corn group	4,676
Fed, yellow corn group	53,394
Fed, mixed corn group	23,991
Difference in amount fed yellow corn and mixed corn groups	29,403
Percentage recovered in eggs	15.9
Units required for one unit in the egg	6.3
Units required for 499 units in eggs, mixed corn group, (Table 11)	3,144
Units available for maintenance, 199 days, mixed corn group (23,991 less 3,144)	20,847
Units used for maintenance per day and pullet	105

The pullets of the mixed corn group averaged about 3.2 pounds in weight; if the vitamin A requirements of a laying pullet are in proportion to weight, the maintenance requirements of laying pullets would be

about 33 units per pound per day. The maintenance requirements of rats is a little less than one unit a day for rats weighing 80 to 130 grams, since the definition of a unit is the amount required to produce 3 grams of grain a week on rats previously depleted of vitamin A. Rats would require therefore approximately 4 units of vitamin A per day per pound. The laying pullets require approximately 8 times as much, which would indicate that for laying eggs or perhaps for similar productive purposes, such as giving milk, animals require much more vitamin A than for maintenance alone.

Quantities of Vitamin A Required for Both Maintenance And Egg Production

The vitamin A required for the production of eggs would depend upon the number and size of the eggs, and the quantity of vitamin A in the yolk. These must be based upon average requirements. For White Leghorn eggs with a yolk weighing 15 grams, having a high content of 20 units of vitamin A to the gram, and with the assumption that 6.3 units of vitamin A in the feed will produce one unit in the egg, 1,890 units (300x6.3) would be required for each egg, which is 63 units per day for each egg laid during a 30-day month. With a production of 10 eggs in a 30-day month, 630 units of vitamin A a day would be needed for egg production, plus 105 units for maintenance of a 3.2 pound pullet; with 20 eggs a month, 1,260 units of vitamin A a day would be required, plus 105 units for maintenance. This may be assumed to represent approximately the maximum requirement for production of eggs. Eggs of lower vitamin A content would be produced with less vitamin A in the food. For 10 units to the gram of egg, and 10 eggs a month, 315 units of vitamin A would be required daily for the eggs; for 20 eggs a month, 630 units. Thus a total of 420 and 735 units respectively would be required for both maintenance and egg production. The requirements for eggs are decidedly higher than the requirements for maintenance.

The above estimates of vitamin A requirements for eggs and maintenance of laying pullets are based upon the experiment, described here, and of course require further confirmation. They are, however, in line with the work of Bethke, Kennard and Sassaman previously cited (1), who stated that hens fed on a basal diet containing 30 per cent yellow corn supplemented with alfalfa meal fed ad libitum, produced eggs containing only one-fifth as much vitamin A as when they received cod liver oil or blue grass pasture.

Supplying Vitamin A to Laying Hens

Alfalfa meal, alfalfa leaf meal, and yellow corn are the feeds ordinarily used for supplying vitamin A to poultry. The yellow corn used in the experiments here described contained 5 to 7 units to the gram, which is the quantity we ordinarily find in sound fresh yellow corn. Although all the scratch feed was yellow corn and in addition yellow corn consti-

tuted 20 per cent of the mash, still it did not furnish enough vitamin A to produce eggs high in vitamin A. The units of vitamin A consumed in the yellow corn varied from 307 per day in November to 249 per day in March (see Table 10), and averaged about 270 units a day. To produce eggs with the maximum vitamin A content of 20 units to the gram or 300 to the egg would require 1,890 units per egg, which is 63 units per day for each egg laid during the month. The pullets would be assumed to need 637 units per day to produce 8.45 eggs in November and 1,249 units in March to produce 18.16 eggs, including both eggs and maintenance.

In the laboratory of the Division of Chemistry, three samples of ordinary alfalfa leaf meal have been found to contain 8, 6, and 10 units of vitamin A to the gram respectively. Samples of alfalfa meal were found to contain 3, 10, and 12 units to the gram respectively. If the mash is eaten in the amounts given in Table 9 for the yellow corn group, with 8 per cent of alfalfa meal in the mash, the pullets would eat only 2.7 to 4.0 grams of alfalfa meal a day, and with 10 units to the gram this would supply only 27 units a day in November and 40 units a day in March. It is evident that ordinary alfalfa meal or hay alone supplies comparatively small amounts of vitamin A to laying hens. The experiment indicates that alfalfa meal and yellow corn meal together would not supply anywhere near enough vitamin A to produce eggs containing 20 units of vitamin A to the gram of yolk during periods of high production.

One sample of heat-dried alfalfa meal we examined contained 100 units of vitamin A to the gram. Fed in the proportion of 8 per cent of the mash and eaten in the quantity given in Table 10, this alfalfa would supply approximately 270 units per day per pullet in November, and 400 units per day in March. This quantity, even added to the quantities consumed in the unusually high amounts of yellow corn fed in the experiment (307 units per day in November, 249 in March) would still lack 76 units in November and 635 in March of the estimated amount (653 units in November, 1,284 in March) required by the pullets for high potency of the eggs laid in this experiment. According to the work here presented, it seems imposible to supply laying hens with a sufficient amount of vitamin A to produce eggs of the maximum vitamin A content by feeding them upon grains and dry mash without green feed, even if high-potency heat-dried alfalfa meal is used. On such a feed, we would expect the eggs to fall off in content of vitamin A during the heavy laying season, and the body of the animal to lose vitamin A. The fowl must then be allowed to recuperate, and replenish its bodily stores of vitamin A, either by a period of rest, or a period of green feed. Whether the fowl would suffer injury or not would depend upon the extent to which she would compensate for insufficient vitamin A by reducing the number and vitamin A content of her eggs. This requires further experiment.

Green grasses and other green growing plants are high in vitamin A. A sample of green spinach the Division of Chemistry found to con-

tain 100 units of vitamin A to the gram, which would be about 500 units to the gram of dry matter. Of this, 2.8 grams a day of dry matter would supply the 1,365 units of vitamin A required for 20 eggs a month of high vitamin A content. Access to green grass or similar green feed seems to be the best way of furnishing hens the high amounts of vitamin A needed for the purpose of producing eggs high in vitamin A, or of replenishing bodily stores and thus avoiding a break-down.

It appears that laying hens require comparatively large amounts of vitamin A. Examination of the rations usually recommended and used shows that hens are frequently not supplied with sufficient amounts of vitamin A when fed without access to green feed. This probably results in many cases in low egg production, low vitamin content of the eggs, undernourishment of the body of the hen, and eventual break-down and death of the fowl.

This work is being continued.

SUMMARY

Three groups of White Leghorn pullets were fed different amounts of vitamin A by varying the relative proportions of yellow and of white corn fed in the grain and in the mash. While the quantities eaten varied, the yellow corn group consumed on an average approximately 270 units of vitamin A a day, the mixed corn group 120 units, and the white corn group, although it got no vitamin A from yellow corn, yet like the other groups, got relatively insignificant amounts from the other constituents of the feed.

The pullets of the white corn group lived from 34 to over 199 days, showing that the amounts of vitamin A stored in their bodies probably varied widely.

The pullets receiving on an average 270 units of vitamin A daily averaged the heaviest in weight, those receiving the 120 units averaged slightly lower, while those of the white corn group, low in vitamin A, had a decidedly lower weight.

The pullets of the yellow corn group receiving 270 units of vitamin A daily averaged 80.58 eggs each during the experiment, those of the mixed corn group receiving 120 units daily averaged 66.60 eggs, and those of the white corn group receiving practically none, 55.49 eggs each. In the latter case the averages are for those living during the month.

In four hatching tests the percentages of eggs hatched increased with the increase in the amounts of vitamin A in the feed, but they were not related to the amounts in the eggs themselves.

The vitamin A content of the eggs decreased with all three of the groups from about 20 units per gram of yolk at the beginning of the experiment to 5-8 units towards the end of the period of six and one-half months.

It is calculated from the results of the experiment that 6.3 units of vitamin A over maintenance are required for one unit of vitamin A in the egg yolk, or 1,890 units for an egg with a yolk weighing 15 grams and containing 20 units of vitamin A to the gram.

The maintenance requirements of White Leghorn pullets weighing about 3.2 pounds is estimated from the experiment at 105 units of vitamin A a day or about 33 units a pound. This is eight times the estimate of 4 units per day per pound for maintenance of growing rats.

It is estimated that White Leghorn pullets averaging 10 eggs in a 30-day month would require 630 units of vitamin A a day for egg production plus 105 units for maintenance, if eggs containing 20 units of vitamin A to the gram are produced. A pullet averaging 20 eggs a month would require 1,365 units of vitamin A a day for maintenance and for produtions of eggs containing 20 units of vitamin A per gram of yolk. Smaller amounts of vitamin A would be required for eggs containing less vitamin A.

Yellow corn fed as the entire scratch feed and as 20 per cent of the mash did not furnish enough vitamin A to produce eggs of high vitamin A content.

Mash containing as much as 8 per cent of alfalfa or alfalfa meal eaten in the quantities found in the experiment, if it contained 10 units to the gram, would supply only about 30 to 40 units of vitamin A a day or about one-third of the requirements of the laying pullets for maintenance, exclusive of that in the eggs.

Heat-dried alfalfa meal containing 100 units to the gram would supply about 300 to 400 units a day, which is still far short of the average requirements of the laying pullets for high egg production with high vitamin A content of the eggs.

Rations usually fed laying hens apparently do not supply enough vitamin A for maintenance and high egg production unless the hens have access to green grass or similar green feed. It seems possible that pullets which do not have access to green feed and are fed many of the ordinary laying feeds are likely to break down from deficiency of vitamin A during the second and third years.

REFERENCES

1. Bethke, R. M., Kennard, D. C., and Sassaman, H. L., 1927. The fat-soluble vitamin content of hen's egg yolk as affected by the ration and management of the layers. Jour. Biol. Chem., 72:695.
2. Edson, A. D., 1932. Cod-liver oil in the winter ration of pullets. Results of a three-year study of the effects on egg production and the hatching power of the eggs laid. Minnesota Agr. Expt. Sta., Bul. 286.
3. Fraps, G. S., 1931. Variations in vitamin A and chemical composition of corn. Texas Agr. Expt. Sta., Bul. 422.
4. Holmes, A. D., Doolittle, A. W., and Moore, W. B., 1927. Studies of the vitamin potency of cod-liver oil. XXI. The stimulation of reproduction by fat-soluble vitamins. J. Am. Pharm. Assoc. 16:518-27. (Chemical Abstracts, 21:3938).