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COLLEGE STATION, BRAZOS COUNTY, TEXAS

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DIVISION OF POULTRY HUSBANDRY
and
DIVISION OF CHEMISTRY

The Vitamin A Requirements of Hens for Egg Production

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CONTENTS

White Leghorn hens receiving vitamin A potency from yellow corn and dehydrated alfalfa leaf meal require for maintenance and egg production approximately four units in the feed for one unit in the eggs. Requirements for maintenance seemed to be in proportion to the requirements for the eggs. The apparent percentage of vitamin A recovered in the eggs varied from 8 to 39, with an average of 25, the utilization being greatest just before or during the period of maximum egg production. The requirements for formation of feathers seemed to be as high as the requirements for laying eggs, since molting hens did not store vitamin A although fed liberal amounts. It is tentatively estimated that for eggs of high potency in vitamin A, hens laying 150 eggs a year would require 600 Sherman-Munsell units of vitamin A per day, or 7.5 units per gram of total feed. This can best be furnished by supplementing the feed with green growing plants. If a high vitamin A potency of the eggs is not required, approximately 240 units of vitamin A per day or 3 units per gram of total feed is tentatively estimated to keep the hens in good health and maintain a good production of eggs. Hens which have access to green feed from time to time may do well on feed containing less than 3 units of vitamin A per gram.

BULLETIN NO. 514 SEPTEMBER, 1935

THE VITAMIN A REQUIREMENTS OF HENS FOR EGG PRODUCTION

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The necessity for vitamin A in the feed of animals has been discussed and the approximate vitamin A potency of various feeds has been compiled in a previous bulletin (2). The vitamin A requirements of laying hens are somewhat high, as has been pointed out in previous publications (4, 5). The vitamin A potency required in poultry feeds in excess of maintenance for the production of one unit in the eggs was estimated to be 6.3 units when 270 units were fed daily (4), 5.7 units when 336 units were fed daily, and 4.04 units when 444 units were fed daily (5). This work was continued in order to secure further information regarding the requirements of hens for vitamin A, and the number of units of vitamin A potency in the feed over maintenance required to produce the vitamin A in the eggs. In view of the fact that the estimation of vitamin A potency by biological methods is not very exact, some variation in the results between different experiments is to be expected.

The vitamin A potency of alfalfa appears to be due chiefly to carotene, while that of yellow corn is claimed by Kuhn and Grundmann (3) to be due chiefly to cryptoxanthin. It is generally held that the vitamin A potency of vegetable materials is due chiefly to coloring matters such as carotene, but relations between the vitamin A potency of feeds and the quantity of carotene or cryptoxanthin present have not yet been worked out sufficiently to permit one to estimate from chemical analyses the vitamin A potency of a feed or food. For this reason and for the further reason that other sources of vitamin A potency besides carotene or cryptoxthin may be discovered, we consider it best at present to use biological methods rather than chemical methods for estimating vitamin A potency. In the subsequent discussion, we have, for the sake of brevity, used the term vitamin A to mean vitamin A potency and to include alpha carotene, beta carotene, gamma carotene, cryptoxanthin, and any other chemical substances which may give rise to vitamin A potency either in the feed or in the eggs.

The work here presented deals entirely with the vitamin A fed and that present in the eggs. The vitamin A may be only partly digested by the animal, or there may be actual destruction in the process of digestion.

METHOD OF PROCEDURE

The White Leghorn fowls which were used in this study had been used in the experiment reported in Bulletin 493 (5). The three groups kept in pens have received the rations given in Table No. 1 since November 15, 1932. When this experiment was started on December 1, 1933, there were 18 hens in the pen of the no-alfalfa group, 18 hens in the 4% alfalfa

group, and 17 hens in the 8% alfalfa group. On January 26, 1934, six hens from the pen of the no-alfalfa group and five each from the other two groups were placed in individual compartments in hen batteries. All groups in pens received yellow corn as a grain feed, and a mash containing

Table 1. Ingredients of Mixtures Used for Laying Fowls in Pens

Ingredients of feed	No-alfalfa group	4% alfalfa group	8% alfalfa group
Mash	Per cent	Per cent	Per cent
Ground yellow corn	20	20	20
Wheat gray shorts	29	29	29
Wheat bran	29	25	21
50% protein meat and bone scrap	20	20	20
Alfalfa leaf meal	0	4	8
Chick size oyster shell	1	1	1
Salt	1	1	1
Grain			
Yellow corn ad lib			

20% yellow corn (See Table 1). One group received no alfalfa meal. The second group received 4% of heat-dried alfalfa leaf meal in place of 4% of wheat bran in the mash, and the third group received 8% of heat-dried alfalfa leaf meal in place of 8% of wheat bran. These groups will be referred to as the no-alfalfa group, the 4% alfalfa group, and the 8% alfalfa group.

The experimental period for the hens fed in pens began on December 1, 1933, and ended August 31, 1934, the duration of the experiment being 274 days. The pens in which the fowls were kept have cement floors to prevent access to green feed. The hens had an abundance of sunshine so that the equivalent of vitamin D was well supplied.

The hens fed in batteries received an all-mash ration containing 65% of yellow corn (See Table 2). Those termed the no-alfalfa group received

Table 2. Ingredients of Mixture Used for Laying Fowls in Batteries

Ingredients of feed	No-alfalfa group	2% alfalfa group	4% alfalfa group
All-Mash	Per cent	Per cent	Per cent
Yellow corn meal	65	65	65
Wheat gray shorts	12½	11½	10½
Wheat bran	12½	11½	10½
50% protein meat and bone scrap	10	10	10
Alfalfa leaf meal	0	2	4

no alfalfa leaf meal; those termed the 2% alfalfa group received 2% alfalfa meal in place of part of the wheat gray shorts and wheat bran; those termed the 4% alfalfa group received 4% alfalfa meal in place of part of the wheat gray shorts and wheat bran. Since the birds in batteries received an all-mash ration, the 2% and 4% of alfalfa leaf meal furnished approximately the same amount of vitamin A as did the rations fed the hens in the pens which contained 4% and 8% alfalfa leaf meal in the mash with corn fed in addition. The experiment with the hens in

batteries began January 26, 1934, and ended August 31, 1934, a period of 218 days. The hens in the batteries were exposed to sunlight from thirty minutes to one hour once each week.

Vitamin A in samples of the yellow corn and the alfalfa leaf meal fed and in the yolks from representative samples of the eggs from the hens in batteries was determined by Mr. Ray Triechler of the Division of Chemistry. The eggs were taken so as to represent the middle of each period and were brought promptly to the laboratory. The eggs were fed to rats in rotation. That is, an egg from the first hen was used, then an egg from the second, then an egg from the third, and so on. While the same number of eggs was fed from each hen, the hens did not all lay at the same rate, so that the period of time during which the eggs were laid was different. The modified Sherman-Munsell unit method with rats was used as we have described elsewhere in full (4). The eggs were kept in cold storage. One or more eggs were boiled; the yolk was separated and weighed; and weighed portions of the yolk were fed twice a week to the test rats. Eight to eighteen eggs were used for each test. The rat unit of vitamin A as here used is the amount of feed fed daily in a 6-day week which will produce a gain of approximately 24 grams in eight weeks. In making the tests, the quantity of material which it was thought might make the desired gain was fed to one group of rats, and lower and higher quantities were fed to two or more other groups. The number of rats which survived, their individual weights, and the average weight of each group for the various amounts of the same feed were given consideration in estimating the units of vitamin A, but the most attention was paid to the quantities of feed which gave the nearest to the desired gain of 24 grams in 8 weeks.

Vitamin A in the Feed and in the Eggs

Tables 3, 4, and 5 contain the average gain in weight of all the rats

Table 3. Details of estimation of Vitamin A potency of feeds

Laboratory No.	Description	Grams fed daily	Number of rats begun	Number of rats at end	Average gain per rat in 8 wks. gms.	Units vitamin A to one gm.
39069	Yellow corn	.150	6	0		
		.200	6	1		
		.250	6	4	15	3.5
39233	Yellow corn	.200	6	1	1	
		.300	6	3	6	
		.400	6	2	32	2.5
		.500	6	1	37	
39294	Yellow corn	.150	6	1	—7	
		.200	6	1	—35	
		.300	6	3	24	3
39324	Deyhdrated alfalfa leaf meal	.010	8	1	—13	
		.012	8	2	28	
		.015	6	1	28	
		.020	6	2	58	60
		.025	6	3	43	

which survived, but the weights of the individual rats which survived the entire period and of those which survived six weeks were also considered in deciding on the number of units. The total number of rats used was 634, not including those used to check the vitamin A free ration. These biological methods do not possess a high degree of accuracy, which fact must be taken into consideration in connection with the results.

The heat-dried alfalfa leaf meal was of excellent quality, containing 83 units of vitamin A potency per gram at the beginning of the experiment. This was much richer in vitamin A content than ordinary alfalfa leaf meal. The yellow corn was not of very good quality with respect to vitamin A content, since it contained only 3.6 units per gram at the beginning of this experiment as compared with 7 units in the corn used for the preceding experiment.

Table 4. Details of estimation of vitamin A potency of egg yolk—individual hens

Laboratory number	Date collected	Group	Yolk fed daily, grams	No. of rats at beginning	No. of rats at end	Average gain per rat in 8 weeks, gms	Units of vitamin A to one gram yolk
39399	February	no alfalfa	.067	6	1	13	
			.100	6	2	25	10
			.150	6	3	29	
39400	February	2% alfalfa	.050	6	2	15	
			.067	6	4	1	
			.100	6	4	28	11
39401	February	4% alfalfa	.040	6	0		
			.050	6	4	13	
			.067	6	3	22	16
39531	March	no alfalfa	.067	6	3	20	
			.100	6	1	6	
			.133	6	2	38	7
			.200	6	5	52	
39532	March	2% alfalfa	.067	6	2	—6	
			.083	6	3	20	
			.100	6	1	6	8
			.200	6	5	41	
39533	March	4% alfalfa	.067	6	4	19	15
			.083	6	6	36	
			.100	6	4	41	
			.200	6	6	73	
39755	April	no alfalfa	.100	6	2	16	9
			.133	6	3	29	
			.200	6	3	45	
39756	April	2% alfalfa	.067	6	2	—5	
			.100	6	3	15	
			.133	6	2	28	9
39757	April	4% alfalfa	.067	6	6	27	18
			.100	6	5	42	
			.133	6	6	62	
39858	May	no alfalfa	.100	6	1	33	
			.133	6	1	22	
			.200	6	5	21	5
39859	May	2% alfalfa	.067	6	2	—21	
			.100	6	4	23	10
			.133	6	1	38	
39860	May	4% alfalfa	.050	6	3	18	
			.067	6	1	37	12
			.100	6	3	29	
40603	August	no alfalfa	.133	6	4	28	5
			.200	6	4	15	
40604	August	2% alfalfa	.100	6	3	11	
			.133	6	3	20	6
40605	August	4% alfalfa	.050	6	3	14	
			.066	6	5	15	
			.010	6	6	22	10

It has been shown by Fraps and Treichler (1) that the vitamin A potency of corn, alfalfa, and other feeds decreases slowly while they are stored. In order to allow for this decrease, it was assumed that the rate of decrease at the end of a month is approximately 7% of that at the beginning of the month, which is the rate found in previous work. The figures used in the calculations for the feeds are therefore corrected for the estimated loss of vitamin A. This correction is of course only approximate, a sufficient number of estimations not having been made to show exactly the rate of loss of vitamin A under the different conditions which affect the loss. It is believed, however, that it is more accurate to make the corrections than to ignore the losses during storage.

The average amount of vitamin A fed to the hens in the different pens

Table 5. Details of estimation of vitamin A content of eggs before and after molt

Laboratory number	Hen number and group	Condition of molt	Yolk fed daily, grams	No. of rats at beginning	No. of rats at end	Average gain per rat in 8 weeks, grams	Units vitamin A to one gram yolk
			Samples from individual hens—				
39054	9270—no alfalfa	before molt	.150	6	4	34	8
			.200	6	4	49	
			.250	6	1	37	
39353	9270	after molt	.050	6	0		
			.067	6	0		
			.100	6	0		
			.150	6	0		6(?)
39056	9724—4% alfalfa	before molt	.067	6	0		
			.100	6	3	12	
			.150	6	4	41	8
39256	9724	after molt	.040	6	1	—24	
			.050	6	1	—36	
			.067	6	1	3	
			.100	6	2	14	8
39052	9217—8% alfalfa	before molt	.050	6	1		
			.067	6	0		
			.100	6	4	28	11
39257	9217	after molt	.040	6	0		
			.050	6	0		
			.067	6	2	11	
			.100	6	3	14	8
39053	9259—8% alfalfa	before molt	.050	6	1	31	
			.067	6	2	27	
			.100	6	6	30	12
			Samples from pens—				
38159	no alfalfa	before molt	.100	6	1	0	
			.150	6	4	21	6
			.220	6	6	41	
39367	no alfalfa	after molt	.050	6	1	—12	
			.067	6	0		
			.100	6	0		
			.150	6	1	15	6
38157	4% alfalfa	before molt	.080	6	4	32	
			.100	6	6	26	12
			.150	6	5	28	
39307		after molt	.040	6	0	0	
			.050	6	0	0	
			.067	6	0	0	
			.100	6	1	11	7(?)
38158	8% alfalfa	before molt	.050	6	3	18	
			.067	6	6	25	15
			.100	6	6	49	
39271		after molt	.040	6	1	—29	
			.050	6	0		
			.067	6	1	4	10(?)

during the period of 274 days was 134 units per day for the no-alfalfa group, 209 units per day for the 4% alfalfa group, and 351 units per day for the 8% alfalfa group. This was much less than the amount fed in the work of the preceding year, the difference being due to the lower

Table 6. Grams of grain and mash eaten per month per fowl in pens

Month	No-alfalfa group		4% alfalfa group		8% alfalfa group	
	Grain	Mash	Grain	Mash	Grain	Mash
December	1262	1389	1298	1035	1348	1940
January	1376	1362	1371	1067	1430	1176
February	1516	1979	1062	1362	1103	1330
March	1394	1657	1185	1430	1444	1362
April	935	1444	781	1035	990	1135
May	981	1203	717	1285	926	1457
June	781	1058	590	1221	790	1389
July	931	813	695	1081	826	1462
August	1103	813	767	994	967	1176
Total	10279	11718	8466	10510	9824	12427

quality of the yellow corn. The average amount of vitamin A fed to the hens in the hen batteries during the period of 218 days was 150 units per day for the no-alfalfa group, 254 units per day for the 2% alfalfa group, and 339 units per day for the 4% alfalfa group. The quantity of food eaten and the units of vitamin A fed per month to the fowls in pens are given in Tables 6 and 7.

Table 7. Total units of vitamin A fed per month in both grain and mash in pens

Month	No-alfalfa group	4% alfalfa group	8% alfalfa group
December	5539	8862	12512
January	5602	8730	13003
February	6115	7453	12154
March	5176	8304	12558
April	3432	5167	9216
May	3173	5621	11908
June	2388	4744	8785
July	2515	4390	8767
August	2788	4118	7350
Total	36728	57389	96253
Average per day	134	209	351

EFFECT OF QUANTITY OF VITAMIN A IN THE FEED ON MORTALITY AND WEIGHTS OF THE FOWLS

In the pens, 6 hens died in the no-alfalfa group, 2 died in the 4% alfalfa group, and 4 died in the 8% alfalfa group. The losses in the no-alfalfa group and in the 4% alfalfa group were concentrated at the end of the feeding period while the loss in the 8% alfalfa group was distributed throughout the experiment as shown in Table 8. This suggests that the slightly higher loss in the case of the 8% alfalfa group over the 4% alfalfa

Table 8. Number of deaths of fowls in pens with day of month on which each occurred

Month	No-alfalfa group		4% alfalfa group		8% alfalfa group	
	Number	Day of month	Number	Day of month	Number	Day of month
December	0	---	0	---	0	---
January	2	16, 19	0	---	0	---
February	0	---	0	---	1	26
March	0	---	0	---	0	---
April	0	---	0	---	1	10
May	1	26	1	29	1	26
June	0	---	1	15	0	---
July	2	1, 24	0	---	0	---
August	1	4	0	---	1	22
Total	6		2		4	

group might be due to causes other than the deficiencies in vitamin A. The mortality for the hens in the pens corresponds to the mortality of similar groups as reported in Bulletin 493 (5).

Of the 16 hens put in batteries, only one died, and it was from the no-alfalfa group. This death occurred on July 6, 1934.

Table 9. Average weights in grams of hens in pens

	No-alfalfa group	4% alfalfa group	8% alfalfa group
December 16, 1933	1629	1670	1584
February 2, 1934	1556	1525	1439
March 2	1560	1531	1452
April 2	1600	1499	1415
May 2	1632	1480	1431
June 2	1580	1443	1395
July 2	1496	1451	1354
August 2	1439	1426	1369
September 1	1543	1420	1425
Average	1559	1494	1429

The weights of the hens are given in Tables 9 and 10. There seems to be no relation between the vitamin A in the feed and the weights of the fowls in the work here reported. In fact, the fowls in the no-alfalfa group were heavier than the fowls receiving alfalfa. This differs from the results previously reported (4, 5).

Table 10. Average weights in grams of hens fed individually

	No-alfalfa group	2% alfalfa group	4% alfalfa group
February 1, 1934	1573	1556	1590
March 1	1774	1661	1679
April 1	1763	1672	1699
May 1	1700	1608	1659
June 1	1675	1656	1617
July 1	1600	1634	1653
August 1	1756	1612	1598
September 1	1795	1571	1587
Average	1705	1621	1635

Effect of Quantity of Vitamin A on the Number of Eggs Produced

Tables 11 and 12 give the number of eggs produced by the hens in the pens and in the batteries. It is noted that the hens in the pens receiving 8% alfalfa laid considerably more eggs than did those receiving no alfalfa, but the hens receiving 4% alfalfa laid fewer eggs than did the group which received no alfalfa. The hens in the battery receiving 2% alfalfa laid more eggs than did those receiving 4% alfalfa, and the fowls receiving 4% alfalfa laid more eggs than did those receiving no alfalfa. These data come from very small numbers of hens. If all of the hens were grouped together, the data would show a low egg production for the no-alfalfa group, a larger egg production for the group receiving the larger amount of alfalfa, and the largest egg production for the group receiving the largest amount of alfalfa. This is closely in line with data previously published in Bulletin 493 (5).

Table 11. Average number of eggs per fowl in pens

Month	No-alfalfa group	4% alfalfa group	8% alfalfa group
December	7.4	7.8	9.2
January	13.8	11.8	15.4
February	12.9	10.3	12.5
March	15.5	12.6	16.0
April	10.6	8.9	12.7
May	11.0	10.2	13.1
June	6.0	6.6	16.1
July	1.5	3.7	8.1
August	5.4	3.3	6.4
Total	84.1	75.2	109.5

Table 12. Average feed consumption and egg production by months per hen in batteries

	No alfalfa lot			2% alfalfa			4% alfalfa		
	Grams feed	No. eggs	Grams eggs	Grams feed	No. eggs	Grams eggs	Grams feed	No. eggs	Grams eggs
January 6 days	554.3	3.67	194.2	722.8	3.0	153.0	521.2	3.6	192.0
February	2946.7	13.67	716.8	2922.0	19.4	1034.6	2899.0	17.2	938.6
March	3570.0	15.67	846.7	3128.0	21.0	1113.6	3149.0	16.0	869.2
April	2596.7	7.67	395.2	2866.0	14.6	755.2	2526.0	9.4	494.6
May	2383.0	9.33	466.5	2528.0	10.8	539.6	2406.0	10.2	529.4
June	2268.0	7.80	366.5	2226.0	10.2	493.4	1952.0	5.6	289.8
July	2263.0	7.00	338.0	2264.0	10.2	491.0	2032.0	8.4	429.6
August	1904.0	2.80	130.4	1658.0	5.8	290.0	1833.0	4.6	225.0
Total	18485.0	67.61	3454.3	18314.8	95.0	4870.4	17318.2	75.0	3968.2

EFFECT OF QUANTITY OF VITAMIN A ON PERCENTAGE OF EGGS THAT HATCHED

In previous experiments it has been shown that there is a rather close relationship between the vitamin A fed to hens and the number of eggs that hatched. The results secured in this present experiment (See Table 13) show that the percentage of eggs that hatched from the hens receiving the smaller amount of vitamin A was 33 to 42 and that from the

Table 13. Relation of percentages of eggs which hatched to vitamin A in feed of hens

Date hatched	No. of eggs	No-alfalfa group, 134 units vitamin A fed per day	No. of eggs	4% alfalfa group, 209 units vitamin A fed per day	No. of eggs	8% alfalfa group, 351 units vitamin A fed per day
		% hatched		% hatched		% hatched
March 2, 1934	48	41.67	49	75.51	52	78.85
April 2, 1934	51	33.33	101	70.30	51	68.63
April 15, 1934	53	33.96	51	68.63	101	69.31
April 25, 1934	51	35.30	----	----	----	----
Total or average	203	35.96	201	71.14	204	71.57

hens receiving the larger amount of vitamin A was from 69 to 79.

It was thought possible that there might be a storage of vitamin A during the molting period, which lasts from 6 weeks to 2 months or longer, especially by hens which were being fed high amounts of vitamin A. Such storage should show the vitamin A content of the eggs higher at the end of the molting period than at the beginning, and the eggs laid at the end of the molting period should contain more vitamin A than those laid before molting. In order to test this possibility, vitamin A potency was estimated in eggs collected just before the molting period from three pens and also from four individual hens, and in eggs from the three pens and from the individual hens which remained at the end of the molting period. The vitamin A potency of these eggs is shown in Table 14. The vitamin A potency of all the eggs is low. The individual hens

Table 14. Effect of molt on vitamin A potency in the egg yolk

Hen number and group	Condition of of molt	Vitamin A units per gram
9270— no alfalfa	before molt	8
	after molt	6
9724—4% alfalfa	before molt	8
	after molt	8
9217—8% alfalfa	before molt	11
	after molt	8
9259—8% alfalfa	before molt	12
	hen died	----
Pen— no alfalfa	before molt	6
	after molt	6
Pen— 4% alfalfa	before molt	12
	after molt	7 (?)
Pen— 8% alfalfa	before molt	15
	after molt	10 (?)

fed the 8% alfalfa and no alfalfa produced eggs containing less vitamin A after molting than before molting. The hen receiving the 4% alfalfa produced eggs containing the same vitamin A content before and after molting. The hens in the pens receiving no alfalfa produced eggs containing the same number of units of vitamin A before and after molting, while the other two lots produced eggs containing less vitamin A after molting. There is thus no evidence of a storage of vitamin A during the molting period. It would appear that the requirements for vitamin A per gram of feed in the formation of feathers may be as great as for the production of eggs. The consumption of feed, and therefore the consumption of vitamin A, is less during the molting period than during the period of egg production.

EFFECT OF QUANTITY OF VITAMIN A IN THE FEED ON THE VITAMIN A CONTENT OF THE EGGS

These calculations are made entirely from the work with the hens fed individually in the batteries.

Table 15. Units of vitamin A per gram of egg yolk and of feed calculated from Tables 3 and 4

Date Collected	Eggs			Alfalfa	Corn
	No-alfalfa group	2% alfalfa group	4% alfalfa group		
December	----	----	----	83	3.6
January	6	7	10	78	3.4
February	10	11	16	73	3.2
March	7	8	15	68	3.0
April	9	9	18	64	2.8
May	5	10	12	60	2.6
June	5	8	11	56	2.4
July (assumed)	5	6½	10½	53	2.3
August	5	6	9½	50	2.2

The units of vitamin A per gram of yolk in the eggs collected at different times are given in Table 15. Since the hens had been fed previously upon rations containing limited amounts of vitamin A and had

Table 16. Comparison of units of vitamin A in eggs of hens fed different quantities of vitamin A

Month	Buletin 468, 1932 work			Bulletin 493, 1933 work			1934 work		
	0 units fed	120 units fed	220 units fed	224 units fed	336 units fed	444 units fed	150 units fed	254 units fed	339 units fed
November	20	12	13	25	----	----	----	----	----
December	----	12	12	22	20	23	----	----	----
January	14	10	10	12	16	20	6	7	10
February	10	----	14	17	16	22	10	11	16
March	----	6	5	12	13	13	7	8	14
April	----	----	----	11	13	14	9	9	18
May	5	8	----	8	15	14	5	10	12
June	----	----	----	7	15	17	5	8	11
July	----	----	----	6½	13½	16	5	6½	10½
August	----	----	----	6	12	15	5	6	9½

not been able to store vitamin A during the molting period, the quantity present in the eggs was low at the beginning of this experiment. There is an increase in the vitamin A content during the first month of feeding followed by a decrease.

Table 16 contains a comparison of the vitamin A content found in the eggs in this experiment with that of the two previous experiments (4, 5). The hens used in the previous experiments (5) had had ample opportunity to store vitamin A from access to green grasses and pasture before being placed on experiment. In the 1933 work, the hens seemed to have more vitamin A stored at the beginning of the work than those in either of the other two years, since the eggs contained more vitamin A at that time. In both 1932 and 1933, there was a gradual decrease of vitamin A in the eggs during the laying period. In the 1934 work, with the vitamin A content at the beginning at a low level, there was some increase in the vitamin A content during the laying period followed by a decrease to approximately the same quantities as at the beginning.

Apparent Percentage of Vitamin A Recovered in the Eggs

The quantities of vitamin A fed to the fowls and the quantities in the eggs were calculated from the data secured, as was done in previous work.

Table 17. Corn and alfalfa leaf meal in grams consumed per hen in batteries

	No alfalfa lot	2% alfalfa lot		4% alfalfa lot	
	Corn	Corn	Alfalfa	Corn	Alfalfa
January, 26-31	360.3	469.8	14.46	338.8	20.85
February	1915.4	1899.3	58.44	1884.4	115.96
March	2320.5	2033.2	62.56	2046.9	125.96
April	1687.9	1862.9	57.32	1641.9	101.04
May	1549.0	1643.2	50.56	1563.9	96.24
June	1474.2	1446.9	44.52	1268.8	78.08
July	1471.0	1471.6	45.28	1320.8	81.28
August	1237.6	1077.7	33.16	1191.5	73.32

Table 12 shows the feed consumption and egg production per hen, while Table 17 shows the grams of corn and alfalfa leaf meal consumed per hen per month. The units of vitamin A in the feed and in the eggs per

Table 18. Units of vitamin A in feeds and eggs per hen in batteries

	No alfalfa lot		2% alfalfa lot			4% alfalfa lot		
	Corn	Eggs	Corn	Alfalfa	Eggs	Corn	Alfalfa	Eggs
January	1225.0	388.4	1597.3	1127.9	357.0	1151.9	1626.3	640.0
February	6129.3	2389.3	6077.8	4266.1	3793.5	6030.1	8465.1	5005.9
March	6961.5	1975.6	6099.6	4254.1	2969.6	6140.7	8565.3	4346.0
April	4726.1	1185.6	5216.1	3668.5	2265.6	4597.3	6466.6	2967.6
May	4027.4	777.5	4272.3	3033.6	1798.7	4066.1	5774.4	2117.6
June	3538.1	610.8	3472.6	2493.1	1315.7	3045.1	4372.5	1062.6
July	3383.3	563.3	3384.7	2399.8	1063.8	3037.8	4307.8	1503.6
August	2722.7	217.3	2370.9	1658.0	580.0	2621.3	3666.0	712.5
Total	32713.4	8107.8	32491.3	22901.1	14143.9	30690.3	43244.0	18355.8
Total fed	32713.4		55,392.4			73,934.3		
Average per day	150		254			339		

month is shown in Table 18. Table 19 shows the apparent percentages recovered in the eggs. As these fowls did not have as much vitamin A stored at the beginning of the experiment as the fowls used in the previous experiments, the vitamin A recovered comes nearer showing the actual utilization of the vitamin than the previous work. However, part of the vitamin A consumed was used for maintenance and part for the production of eggs, while some of it remained undigested or was lost.

The apparent percentage of vitamin A recovered averaged about 25,

Table 19. Apparent percentage of vitamin A recovered in eggs

	No alfalfa	2% alfalfa	4% alfalfa
January	31.7	13.1	23.0
February	39.0	36.7	34.5
March	28.4	28.6	29.6
April	25.1	25.5	26.8
May	19.3	24.6	21.5
June	17.3	22.1	14.3
July	16.7	18.4	20.5
August	8.0	14.4	11.3
Average	24.8	25.5	24.8

but it varied from 8 to 39. It was the highest in the second month of the experiment (February) and lowest in the last month (August). In 1933, the average percentage recovered varied from 8.9 to 59.7, with an average of about 27. The recovery was highest in February or March. The highest apparent recovery of vitamin A in the eggs is near the period of maximum production of eggs.

Units of Vitamin A in Excess of Maintenance Required for Vitamin A in the Eggs

Details of the data necessary to calculate the utilization of vitamin A for the eggs have been given in previous tables. If we assume that the maintenance requirement is the same for each group, it is cancelled when one is subtracted from from the other, and the balances are the requirements for the eggs. The calculations are given in Table 20. The fowls in the 2% alfalfa group produced eggs containing 6036 more units of vitamin A than the fowls in the no alfalfa group. They consumed 22,679 more units of vitamin A in the feed, so that units in the feed required for one unit in the eggs were 3.76. A similar comparison between the fowls of the 4% alfalfa group and those of the 2% alfalfa group gave 4.4 units in the feed required for one unit in the eggs, and a comparison of the fowls in the 4% alfalfa group with those of the no alfalfa group gave 4.02 units required in the feed for one unit in the eggs. These hens went on experiment with low quantities of vitamin A stored in their bodies. In our previous results (4, 5) we estimated that one unit in the eggs required 6.3 units in the feed at 270 units fed daily, 5.7 units when 336 units were fed daily, and 4.01 when 444 units were fed daily to pullets which were put on experiment with good amounts of vitamin A stored. In the experiment at lower level of vitamin A intake, 6.3 units in the feed

were estimated to be required for one unit in the eggs. The results secured in the experiment here reported agree remarkably well with the results previously secured, especially when the difficulties associated

Table 20. Units of vitamin A potency required for the units of vitamin A in the eggs

In eggs, 2% alfalfa group	14,143.9
In eggs, no-alfalfa group	8,107.8
Difference in eggs due to 2% alfalfa	6,036.1
In feed, 2% alfalfa group	55,392.4
In feed, no-alfalfa group	32,713.4
Difference in feed due to 2% alfalfa	22,679.0
Units in feed required for one unit in eggs, no-alfalfa versus 2% alfalfa	3.76
In eggs, 4% alfalfa group	18,355.8
In eggs, 2% alfalfa group	14,143.9
Difference in eggs due to 2% alfalfa	4,211.9
In feed, 4% alfalfa group	73,934.3
In feed, 2% alfalfa group	55,417.1
Difference in feed due to 2% alfalfa	18,517.2
Units in feed required for one unit in eggs, 2% alfalfa versus 4% alfalfa	4.40
In eggs, 4% alfalfa group	18,355.8
In eggs, no-alfalfa group	8,107.8
Difference in eggs due to 4% alfalfa	10,248.0
In feed, 4% alfalfa group	73,934.3
In feed, no-alfalfa group	32,713.4
Difference in feed due to 4% alfalfa	41,220.4
Units in feed required for one unit in eggs, no-alfalfa versus 4% alfalfa	4.02

with the exact estimation of vitamin A potency in feeds and eggs are taken into consideration.

Vitamin A Required for Maintenance of Laying Hens

Since the vitamin A in the eggs was approximately the same at the beginning and at the end of the experiment, it would appear that there was little loss or gain of vitamin A by the body of the hen during the experiment. If this is the case, it should be possible to calculate the amount of vitamin A required for maintenance as well as for the eggs.

Attempts were made to calculate the maintenance requirements of laying hens from the data. These calculations are given in Table 21. If it is assumed that 4 units in the feed are required for one unit in the eggs, and that the balance is left for maintenance, we find that practically

nothing is left for maintenance. If we assume that one unit in the eggs requires three in the feed (Table 21), the amount left for maintenance differs widely for the three tests and increases with the quantity fed. The same applies (Table 21) to the calculations made on the assumption that 2 units in the feed are required for one unit in the egg. By either method of calculation, varying values for maintenance are secured, and these values are obviously incorrect.

The quantities of vitamin A required for maintenance are apparently directly proportional both to the quantities fed and to the quantities in the eggs. It would seem that the maintenance requirements of vitamin A for the laying hens are not a constant value and cannot be separated from the requirements for vitamin A in the eggs.

The maintenance requirement for the period studied in the work here presented appears to be directly proportional to the vitamin A in the eggs.

Table 21. Attempted calculation of maintenance requirement of laying hens for vitamin A

	No-alfalfa group	2% alfalfa group	4% alfalfa group
Units of vitamin A in eggs	8108	14144	18356
Units of vitamin A in feed	32713	55392	73934
Units required in feed for eggs if 4 units in feed is required for 1 unit in eggs	32432	56576	73424
Balance for maintenance (218 days)	281	0	510
Maintenance per day	1.3	0	2.3
Units of vitamin A in feed	32713	55392	73934
Units required in feed for eggs if 3 units in feed is required for 1 unit in eggs	24324	42432	55068
Balance for maintenance (218 days)	8389	12960	18866
Maintenance per day	38.5	59.4	86.5
Units of vitamin A in feed	32713	55392	73934
Units required in feed for eggs if 2 units of feed is required for 1 unit in eggs	16216	28288	36712
Balance for maintenance (218 days)	16497	27104	37222
Maintenance per day	75.7	124.3	170.7

Approximately the four units in the feed required for one unit in the eggs also include maintenance.

Considering again the apparent percentage recovery of vitamin A in the eggs as given in Table 19 of this publication, and in Table 11 of Bulletin 493 (5), we can conclude that hens may utilize more than 25 per cent of the vitamin A potency in their feed at periods of heavy laying, thus leaving part of the average requirement to be used for maintenance during other periods. We conclude that the requirements of laying hens for both maintenance and production are approximately 4 units of vitamin A in the feed for one unit in the egg.

Units of Vitamin A Required for Maintenance and Production Of Eggs High in Vitamin A

The vitamin A content of the eggs at the beginning of the laying period will depend upon the vitamin A stored by the fowl. If the hen has access to green feed so that she can store a good amount of vitamin A, the eggs will contain (Table 16) about 20 to 25 units vitamin A per gram of yolk. If the feed contains insufficient supplies of vitamin A, the eggs may contain as little as 6 units per gram (see Table 16).

The effect of the vitamin A in the feed upon the vitamin A in the eggs will thus depend upon the previous feed of the bird. If the vitamin A content of the eggs is high at the beginning of the laying period, the eggs will decrease gradually in vitamin A potency, unless the hens are fed large quantities of vitamin A such as are contained in green growing plants.

It is possible from the work here presented to estimate approximately the quantity of vitamin A required by laying hens to produce eggs of high potency. It would seem that adequate amounts can best be furnished by access to green feed.

If we estimate that it requires 4 units of vitamin A potency in the feed to produce one unit in the egg, an egg with a yolk weighing 15 grams and containing 20 units vitamin A to the gram of yolk would require 1200 units of vitamin A. Hens laying 150 eggs in 10 months, or 15 eggs a month, would require 600 units per day. This is appreciably more than the 444 units used in any of our experiments. During the molting season, equally as much would be required, if we judge from the work reported in this Bulletin. If the fowls eat 80 grams of mash and grain, they should require 7.5 units of vitamin A per gram of feed to supply the 600 units of vitamin A needed. This might be met by an all-mash feed containing 10% of alfalfa leaf meal having an average vitamin A potency of 75 units per gram. Such alfalfa leaf meal would be of very high quality and 10 per cent is too large to include in an all-mash feed.

As stated in the previous bulletins (4, 5), this high quantity of vitamin A can be supplied best by supplementing the feed with fresh green growing plants such as alfalfa, clovxer, mustard, spinach, turnip greens, oats, wheat, or grasses. Sprouted oats, cabbage, lettuce, or similar light colored green feeds are not sufficiently rich in vitamin A for the purpose.

Units of Vitamin A Required for Laying Hens Without Regard to the Vitamin A Potency of the Eggs

If the vitamin A content of the eggs is disregarded, it is possible to maintain egg production and avoid extensive losses of fowls with amounts of vitamin A less than that required for the production of eggs of high potency. While much more work is necessary to decide exactly on the quantities so needed, it is possible to form a tentative estimate from the work we have presented.

Yellow corn in large amounts furnishing from 150 to 224 units a day does not seem to contain enough vitamin A to keep the hens in good health and maintain production of eggs. There was greater mortality with these hens than with the others, the hatchability of the eggs was less, and ther is the possibility that the fowls would be susceptible to other diseases.

The rations containing 4% of alfalfa leaf meal, averaging from 251 to 336 units per day (See Table 16), seem to provide sufficient vitamin A for health and to maintain good egg production. The vitamin A requirement may be a little less than this.

We make the tentative estimate of about 240 units of vitamin A per day as the requirement for White Leghorn hens laying about 150 eggs a year when the vitamin A content of the eggs is not considered of importance. Additional work is required to make this estimate more exact, but in the meantime it should be useful.

The hens in the experiment consumed on an average 80 grams of feed per day. The feed should therefore contain 3.0 biological units of vitamin A per gram. This amount would be distributed between the mash and the scratch feed or come from green feed. If the scratch feed is low in vitamin A, the mash must be high, unless the hens have access to green feed. Hens which have access to green feed from time to time may store up considerable amounts of vitamin A and get along on less than the amount stated above.

SUMMARY

Three groups of White Leghorn hens were fed different amounts of vitamin A potency from yellow corn and dehydrated alfalfa leaf meal. Some of the hens were fed individually in batteries and the others in pens. The vitamin A potency of the feeds and in the eggs of the hens fed individually was estimated by the Sherman-Munsell biological method.

The mortality was greatest with the hens which received the least vitamin A. No significant differences were observed in the weights of the birds in the three groups. On an average, the lowest egg production was from the birds receiving the least vitamin A and the highest production from those receiving the most vitamin A. The percentage of eggs that hatched was low, 33 to 42% for the hens receiving the smallest amount of vitamin A and 69% to 79% for those receiving the other amounts.

The eggs produced after molting were either lower in vitamin A content than before molting or the same. The units per gram of feed for the formation of feathers seem to be as high as the requirements for egg production.

There apparently was no storage of vitamin A during the molting period by hens receiving as much as 8% alfalfa leaf meal in the mash.

The hens entered the experimental period with eggs low in vitamin A. There was an increase in vitamin A in the eggs during the first month of the feeding period followed by a decrease. The increase was greatest with the hens receiving the most vitamin A.

The apparent percentage of vitamin A recovered in the eggs averaged

about 25% of that in the feed, but the percentage recovered during different months varied from 8 to 39. The highest apparent recovery is just before or during the period of maximum egg production.

On an average, four units in the feed were required for one unit of vitamin A potency in the egg. This may be compared with 6.3 units required at low levels in the 1932 work, or with 5.7 and 4.4 at higher levels in the 1933 work.

Since the hens at the beginning and at the end of the experiment laid eggs containing approximately the same quantity of vitamin A, there was probably little loss or gain of vitamin A by the hens. The requirements for maintenance could not be separated from the requirements for the eggs.

The four units in the feed required for one unit in the egg were apparently sufficient both for the eggs and for maintenance.

Hens during period of heavy laying apparently may utilize more than the 25% of the vitamin A potency in the feed needed for the eggs, leaving some for maintenance.

It is estimated that hens laying per year 150 eggs high in vitamin A would require approximately 600 Sherman-Munsell biological units of vitamin A per day, or 7.5 units per gram of feed. This high requirement can best be met by allowing the fowls access to dark-green growing plants.

It is estimated that if the vitamin A content of the eggs is disregarded, laying hens may be kept in good health and produce eggs in good quantities on approximately 240 units of vitamin A per day, or 3 units per gram of total feed. This estimate is tentative but should serve a useful purpose until more accurate estimates can be made. Hens which have access to green feed from time to time may do well on feed containing less vitamin A than here estimated.

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