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THE EFFECT OF INADEQUATE RATIONS ON THE PRODUCTION AND HATCHABILITY OF EGGS

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THE EFFECT OF INADEQUATE RATIONS ON THE PRODUCTION AND HATCHABILITY OF EGGS[1]

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INTRODUCTION

During the period from 1912 to 1917 one of the authors *(16)* used chickens along with pigeons and rats as experimental animals in a study of the nutritive value of corn. Difficulties encountered in attempting to raise the chickens in confinement in the nutrition laboratory on experimental feed showed that they were very susceptible to an inadequate diet. Some of the difficulties encountered, such as roup, leg weakness, and production of thin-shelled eggs of low hatchability, were the same as those that were baffling the practical poultrymen. This indicated that the solution of these practical problems might be found in a study of the nutritive requirements of chickens.

In accordance with this idea a project was started in the fall of 1918 to study the influence of an inadequate diet on the production and hatchability of eggs. This experiment was continued each year until the fall of 1929, when the work was temporarily discontinued in order that certain problems relating to young chicks might be studied.

At the time this project was started very little was known about the vitamins. McCollum *(27)* and coworkers had pointed out that there were two essential food factors, one soluble in fats designated as fat-soluble A and another soluble in water which they called water-soluble B. Scurvy *(28)* was thought to be due to bacterial decomposition in the intestinal tract rather than to a food deficiency. Nothing was known about vitamin D or the relation of ultra-violet light to rickets.

Because of the lack of information concerning the factors necessary in an adequate diet, many difficulties were encountered during the first years of the experiment. The failure of the hens to function normally in the lots which were supposedly receiving an adequate diet to function normally made the interpretation of the results uncertain.

With our present knowledge it is easy to see that these lots which

Acknowledgment.—The authors wish to acknowledge the assistance of Mr. F. E. Fox who was actively in charge of Experiments I and II, and also the valuable assistance of Messrs. H. B. Hinds and G. T. Klein who were actively in charge of Phases B and C of Experiment VIII.

1. Contribution No. 65 from the Department of Poultry Husbandry and No. 172 from the Department of Chemistry.

were intended to receive an adequate diet were often lacking in vitamins A and D. The lack of vitamin D resulted from keeping the birds in a house that admitted only a small amount of direct sunshine. (Fig. 1.) Vitamin A was provided in the ration by mixing butter fat in the mash. In some cases sufficient feed was prepared to last for several months. There is no doubt but that much of the vitamin A w as lost through oxidation.

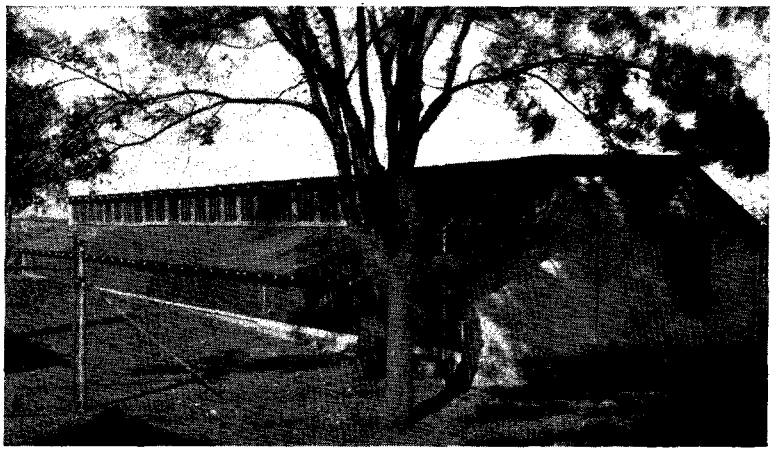

FIG. 1.—A remodeled semimonitor house in which the experiments were conducted. The low-front roof eliminated most of the sun's rays.

These facts explain why satisfactory results were not secured in the control lots during the first years of the experiment. The results which were obtained, however, pointed the way to the discovery *(18)* in 1923 of the importance of direct sunlight to the poultry industry.

GENERAL PLAN OF THE EXPERIMENT

The general plan of the experiment was the same for each of the ten years. Each fall a series of lots of birds was placed on experimental feed November 1, and continued until May 1, June 1, or August 1. Each year, one or more of the lots which served as checks, were given what was supposed to be an adequate feed. The other lots in the series received a feed similar to the adequate feed but lacking in one or more of the known feed essentials. Observations were made to determine what effect these deficiencies would have on the weight and the general condition of the hens, the number of eggs laid, the hatchability of the eggs, and the quality of the eggs as determined by chemical analyses and biological tests of their vitamin content.

A small number of hens was used in each lot the first years of the experiment when the object was to study the effect of omitting cer-

tain food substances from the feed. Five were used in each lot for the first three years (Experiments I, II, and III) and 10 in each lot for the next five years (Experiments IV, V, VI, VII, and VIII). During the last years of the experiment (1926-'29) when the object was to determine the amount of the vitamin A containing feed necessary to supply an adequate amount of this vitamin, the number of hens in each lot was increased to 50 or more for Experiments IX, X, and XI.

Barred Plymouth Rocks were used the first year. Apparently the restricted exercise produced an over-fat condition and egg production was low. Therefore, during each of the following years Single Comb White Leghorns were used unless otherwise stated. It was thought that the greater natural activity of this breed would function more normally in confinement, which was necessary for complete control of the diet. In order to insure uniform lots, the birds, which were hens in experiments I to V and pullets thereafter unless otherwise stated, were selected from the college flock. In this way the exact breeding and the nature of the feed which they had received before being placed on the experiment were known. The hatchability of eggs reported for all experiments is calculated on the number of fertile eggs set. Eggs for hatching were not collected from any of the lots until after April 1 in order to give ample time for the experimental rations to have their effects upon the birds. The number of eggs set from the different lots varies widely as there was a great variation in the number produced by the different groups. During the period eggs were saved for hatching, all sound shelled eggs produced in each lot were set. In practically all calculations where the fraction was .5 or more, one was added. When 0.4 or less, the fraction was dropped.

The II experiments which follow deal with vitamins A, B, C, and D in order to determine if possible their importance in the poultry ration. Their value in the ration of laying hens was measured by (1) number of eggs produced, (2) fertility and hatchability of eggs, (3) mortality and general health of the birds, and (4) gain or loss in body weight during the period of the experiment.

EXPERIMENT I, 1918-'19, LOTS 1-6

The first year the six lots received feeds differing in nutritive value as follows:

Lot No.

1. An adequate ration.
2. Ration deficient in protein.
3. Ration deficient in vitamin A.
4. Ration deficient in vitamin B.
5. Ration deficient in calcium.
6. Ration deficient in sodium chloride.

The feeds used were similar to those which had been used in the study of the nutritive value of corn *(16)*. AH the lots received pearl hominy as a scratch grain. The differences in the feeds were obtained by varying the composition of the mash.

The experimental or so-called adequate ration was composed of the following ingredients:

Pearl hominy	76 per cent
Alcohol extracted casein	12 per cent
Butter fat	6 per cent
Bakers yeast, dried	3 per cent
Bone ash	3 per cent
Sodium chloride	1 per cent

In addition to the above, oyster shell and water were fed *ad libitum* in all lots except number 5 in which the shell was omitted. The low protein diet was secured by replacing the casein with hominy. Lard replaced the butter fat in the vitamin A deficient mash. Yeast was replaced by hominy in the

FIG. 2.—Hen showing nutritional roup resulting from a lack of vitamin A. The swollen eyes resemble certain forms of roup except for the absence of a pronounced and disagreeable odor.

vitamin B deficient mash. Oyster shell was withheld from the low calcium lot. Sodium chloride was omitted from the mash for lot 6 which was to be deficient in this essential food substance.

The mash was kept before the hens at all times. The consumption of scratch grain was regulated so that birds would eat about the same amount of mash and scratch grain. This method of feeding was open to the serious objection that the individual birds in a lot might not consume the same relative amount of mash and scratch grain. As the vitamins, protein, and mineral supplements were all added to the mash, while the pearl hominy used as a scratch grain was very deficient in these food substances, the individuals that consumed relatively more scratch grain and less mash would have a deficient ration. It was found that the cock birds, which usually showed the effect of deficient feed before the hens in the same lots, did so because they consumed very little of the mash.

Three definite conclusions were drawn from the first year's work:

1. The diet which had seemed to be an adequate one for rats was not adequate for chickens. While at the time the difficulty was not understood, it is now evident as explained above, that the feed was probably deficient in vitamins A and D. The deficiency in vitamin A resulted from the oxidation of the butter fat which was mixed with the feed at the beginning of the experiment and the deficiency in D resulted from a lack of a sufficient amount of direct sunshine.

2. Most of the birds in lot 3, which received a ration deficient in vitamin A, developed typical cases of roup *(17)* characterized by eye infection. (Fig. 2.) This was the first clean cut evidence that the lack of vitamin A was the cause of one form of roup which was so prevalent in Kansas at that time. Previous to this, it was thought that this form of roup Fas of bacterial origin as reported by Jackley *(21)*.

3. Biological tests with rats showed the eggs from the vitamin deficient pens to contain very little vitamin as compared to the eggs from the general flock at the college poultry farm.

EXPERIMENT II, 1919-'20, LOTS 7-12

The hens in lot 1 the previous year, which received what at that time was thought to be an adequate diet including the necessary mineral, did not produce eggs with normal hatchability. It was decided, therefore, to discontinue the work on mineral-deficient diets until a diet could be developed which would produce normal results.

In the place of the mineral deficient rations, one lot (No. 11) was included which had protein added to the adequate diet, and another (No. 12) was given 10 per cent dried alfalfa leaves in the mash. Two vitamin A and B deficient lots (Nos. 9 and 10) were continued in order to further study the effect of the vitamin content of the feed on the vitamin content of the eggs produced.

The results were simiiar to those secured in Experiment I during the preceding year. The adequate diet lot did not do nearly so well as the college farm flock which had access to a range. The addition of dried alfalfa leaves materially improved the ration but the hens receiving them were still below the production of the farm flock and the eggs had a lower hatchability than those produced by the farm flock. The benefit derived from the alfalfa leaves was no doubt due to the vitamin A which they added to the diet. The lack of an adequate amount of direct sunshine probably prevented this lot from functioning normally.

The hens in lot 9 receiving the vitamin A deficient feed died of roup, which substantiated the conclusion drawn the previous year that the lack of vitamin A in the feed of hens could result in the type of eye infection commonly called roup.

In the annual report of the California Agricultural Experiment Station for the year 1919-'20, Haring, Beach, and Jaffa *(10)* describe this roup-like disease which they attributed to a lack of green feed in the ration. Beach later *(3) (4)* concluded that the trouble which he had previously designated as a "nutritional disease resembling roup" was caused by a vitamin A deficiency and that "nutritional roup" would be a more suitable name for the condition.

The biological analyses in which rats were used as experimental animals again showed the eggs from the hens on the vitamin deficient feed to be much lower in their vitamin A and B content than the eggs produced by the general flock which received a feed rich in these vitamins. From this it was concluded that the vitamin content of eggs depended on the vitamin content of the feeds which the hens received. It was further concluded that the lack of this vitamin in the eggs was one of the important factors in causing poor hatchability.

EXPERIMENT III, 1920-'21, LOTS 13-19

During the first years, the hens receiving the experimental adequate ration[2] did not give so good production or hatchability as the general farm flock which received the regular K. S. C. ration and had access to the range. It was thought that this difference might be due to one of the following:

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2. The term experimental ration is used to differentiate the ration made up of more or less purified feeds (hominy, casein, butter, lard, etc.) from those made up of commercial feed (cornmeal, bran, ground oats, meatscraps, etc.) designated as K. S. C. (Kansas State College) ration.

1. Difference in the composition of the rations.
2. Difference in the amount of light received by the two lots of hens.
3. Difference in the amount of green feed which the farm flock secured on the range.

In order to devote more attention to the study of the ration, thought to be adequate, the work on protein was discontinued. In the place of the two lots which had been devoted to the study of protein, two lots (Nos. 13 and 18) were substituted. These received the same feed as the general farm flock designated on page 11 as K. S. C. One of these lots (No. 13) was to be confined under the same condition as were the experimental birds during the previous two years and the other (No. 18) was given access to limited range and green feed. Two other lots (Nos. 14 and 19) were handled exactly like the birds in lots 13 and 18, but they received the experimental adequate ration that had been used during the two preceding years. Another lot (No. 15) was given the experimental adequate ration and had access to a cement-covered yard or sun porch. The lots on feed deficient in vitamins A and B were continued.

The sun porch which was about 10 feet square was covered on the top and sides with screen wire to exclude flies and bugs. There was no green feed or dirt in this cemented pen; its only object being to provide the birds with direct sunshine without their coming in contact with the ground.

The rations used are listed below:

Lot No. Rations.

13. K. S. C., no green feed (birds confined).
14. Experimental, adequate, no green feed (confined).
15. Experimental, adequate, no green feed (sun porch).
16. Experimental, deficient, vitamin A (confined).
17. Experimental, deficient vitamin B (confined).
18. K. S. C., green feed (limited range).
19. Experimental, adequate, green feed (limited range).

The effect of the rations on the weight of hens and the hatchability of eggs is given in Table I. The value of limited range and access to green feed and direct sunshine is shown in the results from lots 18 and 19. The lack of apparent benefit from the direct sunshine in lot 15, led to the conclusion that the green feed was responsible for the better results in lots 18 and 19.

TABLE I.—EGG PRODUCTION, AVERAGE GAIN OR LOSS IN WEIGHT, AND HATCHABILITY DATA IN EXPERIMENT III.

November 1 to June 1.

Lot No.	Average gain or loss in grams.	Number of hens from which eggs hatched.	Number of eggs set.	Percentage fertile.	Percentage hatched.
13	82	5	157	95	32
14	9	3	93	85	24
15	0	2	31	89	14
16	0	5	80	92	15
17	82	2	66	91	10
18	45	5	218	99	64
19	—27	5	187	94	64

While the individual variation in egg production and hatchability of the hens in the different pens was so great that no quantitatlve relation between the feeds used and the results obtained could be drawn, the results showed quite clearly that limited range including green feed was beneficlal while no apparent benefit was derived from the limited range without green feed.

It can now be seen that the K. S. C. ration at that time was deficient in vitamin A as it was composed largely of white corn, kafir, and oats. The importance of yellow corn as a source of vitamin A was then not well known *(36)*. This lack of vitamin A no doubt accounts for the poor results secured with lot 13 which received the K. S. C. ration, without green feed.

It has been explained previously that the experimental supposedly adequate diet was somewhat lacking in vitamin A. This was probably a result of the loss of this vitamin after the feed was mixed. This, no doubt, accounts for the poor results of lot 15 which received the experimental adequate diet and limited direct sunshine. It should be explained that the birds spent very little time in the concrete runway. The lack of the vitamin A accentuated by exposure to the cold, damp cement floor of the outside pen caused considerable trouble with eye infection and marked reduction in the number of eggs laid. Had the experimental diet contained an adequate amount of vitamin A, perhaps the importance of direct sunshine for poultry would have been shown by this experiment. As it was, this was not appreciated until two years later *(18) (19)*.

Lot 16 receiving a feed low in vitamin A and lot 17 receiving a feed low in vitamin B again produced eggs deficient in these vitamins.

EXPERIMENT IV, 1921-'22, LOTS 20-26

The work for the year was planned to study the effect of fresh greens and succulent feed as the results of the previous year's work indicated that the green feed the hens received on the range, rather than the direct sunlight was responsible for the benefit derived from the range. None of the hens was allowed an outside range. Sprouted oats and yellow mangels zerved as the supplementary feeds.

The rations used were as follows:

Lot. No.	Rations.
20.	K. S. C. (no green feed).
21.	K. S. C. (sprouted oats).
22.	K. S. C. (mangels).
23.	Experimental, adequate (sprouted oats).
24.	Experimental, inadequate (deficient vitamins A and C).
25.	Experimental, inadequate (deficient vitamins B and C).
26.	Experimental, adequate (no green feed, deficient in vitamin C).

The K. S. C. rations consisted of:

Scratch grain.		*Dry mash.*	
Cracked white corn	400 lbs.	Ground white corn	200 lbs.
Wheat	100 lbs.	Ground oats	200 lbs.
Kafir	100 lbs.	Wheat bran	100 lbs.
		Meatscraps	100 lbs.
		Dried buttermilk	20 lbs.

This ration as now known was very low in vitamin A.

The revised experimental adequate ration consisted of:

Scratch grain.		*Dry mash.*	
White pearl hominy	100 lbs.	Pearl hominy meal	62 lbs.
		Tankage	10 lbs.
		Casein	10 lbs.
		Corn bran	5 lbs.
		Butter	5 lbs.
		Bone ash	6 lbs.
		Yeast	3 lbs.

The vitamin A deficient ration used in lot 24 was secured by replacing the butter in the adequate mash with lard. The vitamin B deficient ration used in lot 25 was obtained by replacing the yeast in the adequate mash by an equal weight of ground pearl hominy. The corn bran was left in the ration to furnish a limited amount of vitamin B. A previous experiment had shown that if vitamin B was entirely eliminated from the ration, sufficient eggs would not be produced to secure a test of their hatchability.

The sprouted oats used in this experiment were produced in a commercial oat sprouter which was provided with very little sunlight. Later experiments showed that oats sprouted under such conditions were not a good source of vitamin A. The results are summarized in Table II.

TABLE II.—EGG PRODUCTION, AVERAGE GAIN OR LOSS IN WEIGHT, AND HATCHABILITY DATA IN EXPERIMENT IV.

November 1 to June 1.

Lot No.	Average gain or loss in grams.	Number of hens from which eggs hatched.	Number of eggs set.	Percentage fertile.	Percentage hatched.
20	229	4	177	85	31
21	63	6	166	82	59
22	95	9	216	90	47
23	5	8	203	92	33
24	—18	3	55	100	45
25	—248	3	57	75	26
26	172	4	128	93	43

The low hatchability of the eggs from the various lots indicates in the light of present knowledge that none of the hens received a wholly adequate ration. There is no doubt but that the rations were somewhat deficient in vitamin A. The K. S. C. ration had as its basis white corn. The sprouted oats used in this experiment did not supply an adequate amount of vitamin A. The butter that was intended as a source of vitamin A was mixed with the rations at the beginning of the experiment and no doubt lost most of its vitamin A potency in a very short time. Mangels as later shown by Davis and Beach *(5)* are not a good source of vitamin A.

The slight superiority in hatchability of the eggs from lot 21, which received K. S. C. ration plus sprouted oats, and lot 22, which received K. S. C. ration plus mansels, as compared with the eggs from lot 20, which received the K. S. C. ration only, would indicate that the addition of the small amount of vitamin A had some beneficial action.

It will be seen that the eggs from lot 23, receiving the sprouted oat supplement, had a lower hatchability than those from lot 26 which received the experimental ration alone. These results indicate that 10 hens are not sufficient to give reliable hatchability results when a test is being made between two inadequate diets differing only slightly in nutritive value.

The record of the individual hens in lot 24 which received the feed deficient in vitamin A shows great variation in the reaction of individual hens to vitamin A deficiencies. For the duration of the experiment, three of the 10 hens in this lot showed no ill effects from the vitamin A deficient ration they received. The 55 eggs which these three hens laid were all fertile and 25, or 45 per cent, hatched. These hens appeared to be in normal condition at the conclusion of the experiment on June 1. The seven-months period on a diet very deficient in vitamin A produced no visible signs of a deficiency disease. This is somewhat typical of the response of hens to a vitamin A deficient diet. There are usually a few individual hens in a group that seem to continue in a normal condition long after the others in the group have died as a result of the vitamin A deficiency as shown clearly in Experiments IX and X. In one case the hens that appeared normal at the conclusion of the experiment were removed to the nutrition building and continued on a vitamin A free diet until they died. One of these hens lived for an additional 12 months.

Birds do not usually show a gradual decline in physical condition after being placed on a diet deficient in vitamin A. Their appetites remain normal and they appear normal in every way for a considerable period. The first symptoms noticed are a slight watering of the eyes and the formation of small white pustules in the mouth and œsophagus.[3] After these conditions develop, the onset of the disease is very rapid. The bird ceases to eat and drink, marked infection usually occurs in the eye, and death soon follows.

The biological test of the eggs from these hens on inadequate diets showed them to be much lower in vitamin A content than the eggs from the farm flock which had access to the range.

The result of the year's work, outstanding at the time, was that sprouted oats fed to hens in confinement did not produce the good results obtained the previous year when the green feed was secured by the use of limited range.

EXPERIMENT V, 1922-'23, LOTS 27-33

It was decided to repeat the work as none of the lots receiving the supposedly adequate feed the previous year gave good results. The lot fed mangels was discontinued and a lot substituted received the K. S. C. diet fortified with a number of supplements which were thought might make up any deficiencies in this diet. The supplements used were cod liver oil, alfalfa hay, buttermilk, and sprouted oats. All lots were confined to the house during the experiment. The rations used were as follows:

Lot No. Rations.

27. K. S. C. (no green feed).
28. K. S. C. (sprouted oats).
29. K. S. C. (1% cod liver oil, alfalfa, and dried buttermilk added to ration used in lot 28).
30. Experimental, adequate (green feed).
31. Experimental, inadequate (deficient in vitamin A).
32. Experimental, inadequate (deficient in vitamin B).
33. Experimental, adequate (no green feed).

The results for Experiment V are presented in Table III.

TABLE III.—EGG PRODUCTION, AVERAGE GAIN IN WEIGHT, AND HATCHABILITY DATA IN EXPERIMENT V.

November 1 to June 1.

Lot No.	Average gain in grams.	Number of hens from which eggs hatched.	Number of eggs set.	Percentage fertile.	Percentage hatched.
27	77	8	269	55	30
28	46	7	247	50	33
29	349	5	277	46	42
30	208	9	201	91	42
31	77	3	89	87	27
32	158	7	122	79	46
33	91	3	99	94	25

The low fertility in lots 27, 28, and 29 may be attributed to the use of one male which was alternated among these pens daily. This was done to avoid the variation that different males might have on the hatchability of eggs.

3. Poultry diseases, their prevention and control. Kan. Agr. Expt. Sta. Bul. 247, pp. 28-29, 1929.

As in the previous experiment, it is evident that none of the lots received an adequate diet. The cod liver oil was mixed with the feed at the beginning of the experiment as it was not known at that time that such a procedure would cause a rapid loss of its vitamin A content. The amount of green feed consumed evidently did not add sufficient vitamin A to the ration.

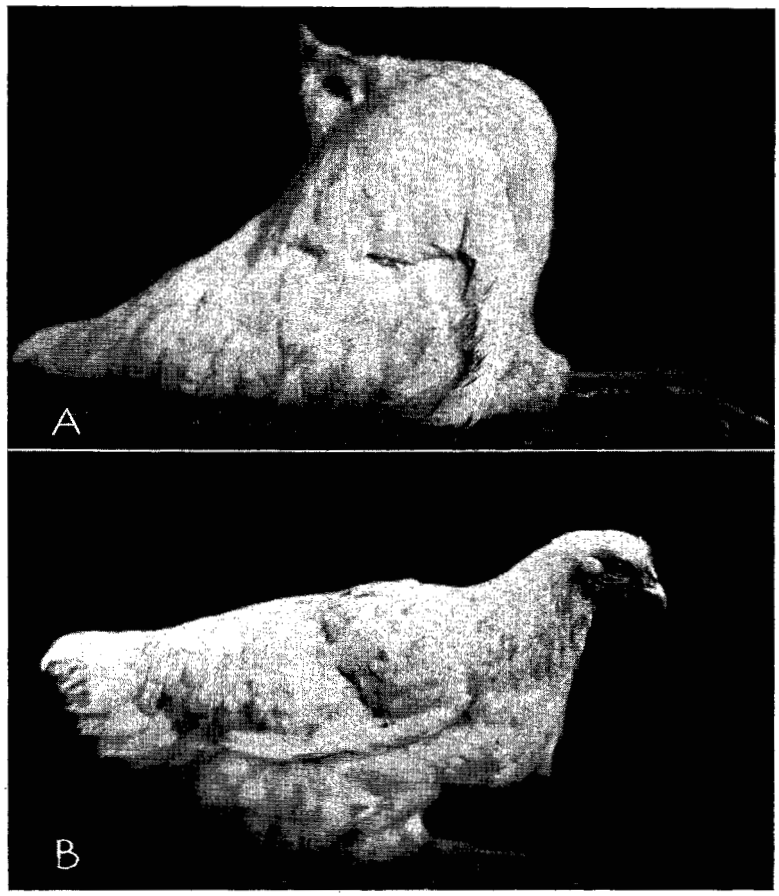

FIG. 3.—(A) Hen suffering from lack of vitamin B in the ration. (B) The same bird 36 hours after receiving three feeds of whole corn which supplied vitamin B.

While the differences are small, the eggs from the lots receiving the vitamin A supplements hatched better than the eggs in the unsupplemented lots. This was true of both the K. S. C. and the experimental rations.

The scratch grain and mash method of feed was still being used. It may be that some of the variation in the results of the individual hens in all lots was due to the consumption of different proportions of mash and scratch grain. In the lot receiving the diet low in vitamin B, five male birds died during the experiment. The previous year three males died in the low vitamin B lot. For some reason the male birds in this lot did not consume much of the mash, so their ration consisted largely of pearl hominy. (Fig. 3.)

Anderson and Kulp *(1)* found that a continued lack of vitamin B in the

diet evidently causes a serious impairment of the digestive functions which, during polyneuritis, results in an almost complete cessation of digestion and assimilation. When animals were forcibly fed, the utilization of food was much delayed. Undigested rice was found in the crop and gizzard more than a week after the last feeding. According to their report, the most striking effect in vitamin B starvation was the inability of the animals to utilize a normal quantity of food and the consequent decided decline in heat production. In some cases the decrease in heat production ranged from 40 to 50 per cent below that of normal basal metabolism.

Atwood *(2)* reports on experiments conducted during the winter of 1913-'14, and repeated in 1921-22, when he tested the effects of green feeds and confinement on the production and hatchability of eggs. Sprouted oats added to the ration during the winter increased the fertility and hatchability of the egg. The rations fed contained a large proportion of corn but the data do not indicate whether white or yellow corn was used. The fact that the birds with the outdoor range gave so much better results than the confined birds might be explained by the probable difference in the amount of vitamin D received.

EXPERIMENT VI, 1923-'24, LOTS 34-40

Increased information concerning the vitamin A content of yellow corn, and a knowledge of the variability of this vitamin in sprouted oats, made it possible to prepare for this experiment a diet containing an adequate amount of vitamin A. Yellow corn replaced white corn in the K. S. C. ration. In the experimental rations, white corn was used as a scratch grain and as a basis of the mash in lot 39 which was intended to be deficient in vitamins A and C. Yellow corn was used as a scratch grain and as a basis of the mash in lots 37 and 38. Pearl hominy was used as the scratch grain and as a basis of the mash in lot 40 which was to be low in vitamin B. As in previous experiments, five per cent of whole corn was included in the mash in lot 40 to provide a limited amount of vitamin B.

During the spring of 1923, experiments with growing chicks showed the importance of direct sunshine for normal development *(18)*. (Fig. 4.) For this season the question of direct sunshine on the production and hatchability of eggs was again considered. Two lots (35 and 36) were given access to the concrete sun porch. All the other lots were confined to the building having a limited amount of open space on the south. (See fig. 1.)

The rations used in Experiment VI were as follows:

Lot No.	Rations.
34.	K.S.C. adequate (green feed).
35.	K.S.C. adequate and access to wire enclosed sun porch.
36.	Experimental adequate and access to wire enclosed sun porch.
37.	Experimental adequate (green feed and yellow corn).
38.	Experimental adequate (no green feed, yellow corn).
39.	Experimental inadequate (no green feed, white corn).
40.	Experimental inadequate (no green feed, pearl hominy).

Green sprouted oats were the source of green feed for lots 34, 35, 36, and 37. All birds had access to tap water, oyster shell, and grit. The results are presented in Table IV.

The results shown in all the lots, except 39 which had a diet deficient in vitamin A, and 40 which had a diet low in vitamin B, gave hatching records slightly superior to the general farm flock. This indicated that the ration was well balanced. The birds that received yellow corn (lot 38) produced eggs which gave a hatchability of 72 per cent and gained 136 grams in weight, while those on the white corn ration (lot 39) produced eggs which showed a 17 per cent hatch and lost an average of 22 grams a bird. Six of the 10 birds in this group died compared with three in the yellow corn group.

Hauge, Carrick, and Prange *(13)* later found that when the basal ration

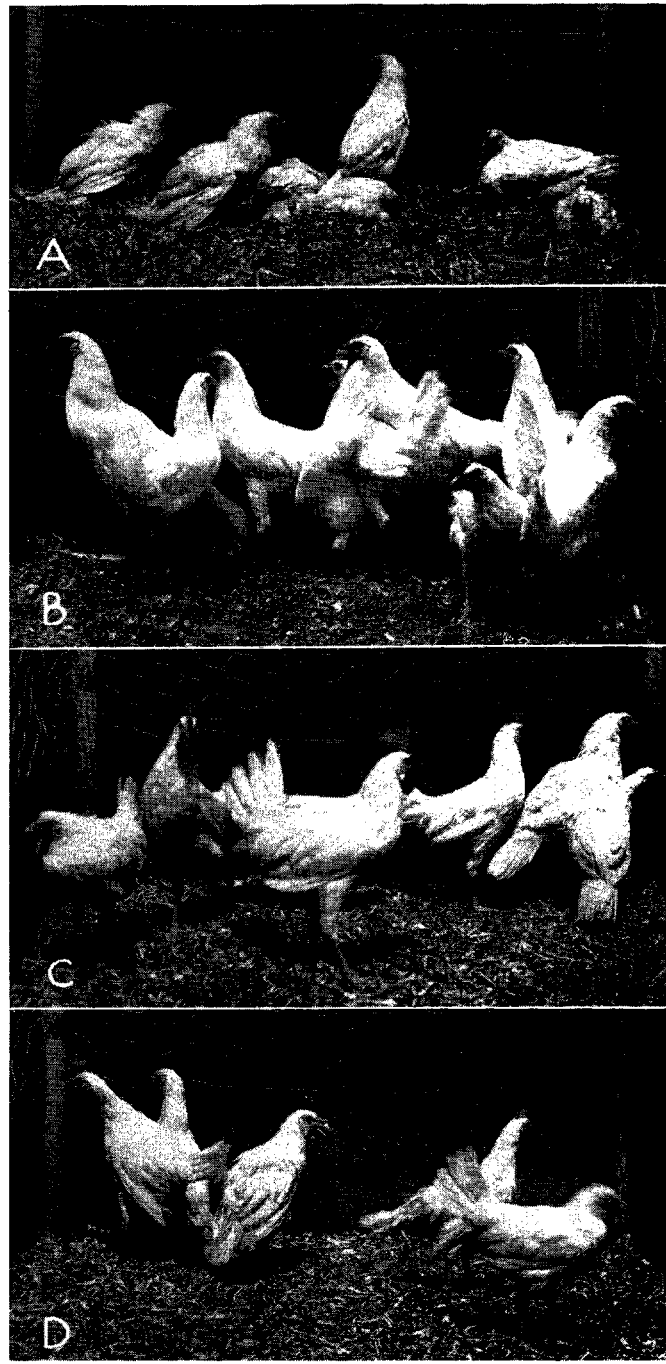

FIG. 4.—See opposite page for legend.

TABLE IV.—EGG PRODUCTION, AVERAGE GAIN OR LOSS IN WEIGHT, AND HATCHABILITY DATA IN EXPERIMENT VI.

November 1 to June 1.

Lot No.	Average gain or loss in grams.	Number of hens from which eggs hatched.	Number of eggs set.	Percentage fertile.	Percentage hatched.
34	4	.....	285	94	74
35	136	Individual	230	97	64
36	213	hatching	327	97	75
37	36	records	327	92	76
38	136	were	212	95	72
39	—22	not	85	95	17
40	—91	kept.	179	82	46

included 50 per cent of yellow corn, the fat soluble A requirements for pullets up to laying age seemed to be met.

The high hatchability in lots 34, 35, 36, 37, and 38 shows a marked improvement in results over those of previous years which indicated that the A, B, and D vitamins were more nearly approaching the optimum amounts. In marked contrast with these results were those from lot 39, on a diet deficient in vitamins A and C, and lot 40 receiving a diet low in vitamins B and C. Since the eggs from hens in lot 38, which had no vitamin C supplement, had a hatchability of 72 per cent, it indicated that this vitamin was not an important factor in egg production and hatchability. This result has been confirmed by Hauge and Carrick *(12)* who found that chickens can synthesize vitamin C.

The ultra-violet rays received through the openings in the fronts of the houses and by direct exposure of birds in lots 35 and 36 undoubtedly provided enough vitamin D to aid the hatchability of eggs from groups that received the better balanced rations.

TABLE V.—INFLUENCE OF ULTRA-VIOLET LIGHT ON HATCHABILITY OF EGGS.

Lot.	LIGHT TREATMENT.	Number of fertile eggs set.	Number of chicks hatched.	Percentage hatched.
a	Ultra-violet light 10 minutes twice a day.....	295	223	76
b	No ultra-violet light.....	46	15	33
c	Direct sunlight.....	207	126	58

The desirable effect of ultra-violet rays on hatchability was strikingly shown in another experiment which ran parallel with Experiment VI. The results, as given in Table V, are condensed from the Director's Biennial Report of the Kansas Agricultural Experiment Station for 1922-'24, page 166.

FIG. 4.—These 14-week-old chicks came from one hatch, receiving the same feed, and were brooded together in the absence of direct sunlight. Group (A) received no special treatment. All chicks in Group (B) were placed in direct sunshine three hours daily from the beginning of the experiment. After the chicks in Group (C) developed rickets, each chick was given one-half c.c. of codliver oil daily. Group (D) represents chicks which were irradiated 30 minutes each day with a mercury quartz lamp after rickets had developed as in Group (C).

These figures show the importance of direct sunlight and ultra-violet light on the breeding stock for the production of eggs with good hatchability. It was in this experiment that the ultra-violet light and sunlight materially affected the composition of the eggs as shown in Table VI.

TABLE VI.—COMPOSITION OF EGGS AFFECTED BY TREATING HENS WITH ULTRA-VIOLET LIGHT.

All weights are for seven eggs.

Lots	a.	b.	c.
Light treatment	Ultra-violet light.	Inside away from light.	Direct sunlight.
UNDRIED WEIGHT IN GRAMS:			
White	218.3000	204.4000	215.2000
Yolk	116.6000	110.5000	125.0000
Shell	34.4000	25.3000	32.3000
DRY WEIGHT IN GRAMS:			
White	36.7000	22.7000	26.1000
Yolk	58.2000	54.3000	63.1000
CALCIUM IN GRAMS:			
Shells	12.8000	9.0700	11.9800
Whites	.0232	.0133	.0214
Yolks	.1410	.1150	.1670
PHOSPHORUS IN GRAMS:			
Whites	.0339	.0220	.0305
Yolks	.6720	.5920	.7310
Yolk residue after extraction	.3470	.3250	.3760
Lipoids in yolks	.3250	.2670	.3550
PER CENT OF CALCIUM IN—			
White	.0870	.0585	.0820
Yolk	.2420	.2120	.2640
PER CENT OF PHOSPHORUS IN—			
White	.1270	.0970	.1170
Yolk	1.1550	1.0900	1.1600
Yolk extracted (alcohol and ether)	.5970	.5970	.5960

The figures in Table VI show that the mineral composition of the egg is altered when the hens develop a rickety condition resulting from the absence of ultra-violet light as pointed out by Hughes, Payne, and Latshaw *(19)*. The most marked characteristics were the thinner shell of the egg although the amount of calcium and phosphorous was decreased in both the white and the yolk. Doyle *(6)* called attention to the fact that hens confined to the house during the winter months will lay thin shelled eggs as a result of a lack of direct sunshine.

In another experiment with growing chicks, a study was made of two different sources of vitamin D. It was demonstrated conclusively as shown in figure 5 that direct sunlight was far superior as a growth promoter to diffused sunlight. The value of ultra-violet light as a substitute for direct sunshine in the development of normal bone growth is illustrated in figure 6.

The foregoing experiments showed a vast difference in the results obtained from rations differing only in the kind of corn used when fed to laying hens. Yellow corn, as used in lot 38, gave far better results than white corn as used in lot 39. These results also indicated that yellow corn alone might be fed in sufficient quantities to supply the vitamin A requirements, since the hatchability was not materially improved in lot 37, which was fed green feed in addition to the yellow corn in the ration. The possibilities of making more use of the direct sun's rays or ultra-violet light, where sunshine is not available, for growing chicks and laying hens were established in these results.

EXPERIMENT VII, 1924-'25, LOTS 41-52

The results of the preceding experiments showed clearly that vitamins A, B, and D were essential and that vitamin C was not required for normal egg production. They also showed that the ordinary grain mixtures used in poultry feeds supplied an abundance of vitamin B. For these reasons, the work on vitamins B and C was discontinued and the studies of vitamins A and D were continued.

Vitamin A was known to be lacking in the majority of Kansas poultry rations, especially during the winter months, since vitamin A deficient white corn, wheat, and grain sorghums were grown extensively and green feed was not always available. The prevailing methods of housing the flocks during the winter were frequently such that the birds did not receive a sufficient amount of direct sunshine and a practical means of supplying vitamin D to the ration had not as yet been adopted. Therefore, the two important poultry nutrition problems were the securing of adequate amounts and practical sources of vitamins A and D.

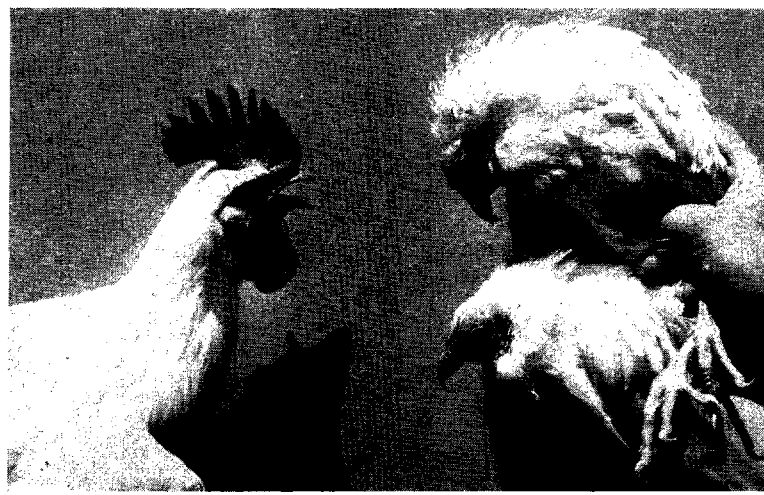

FIG. 5.—A close view of representative chicks from groups (A) and (B), figure 4. The long beaks and toenails of the rickety chicks on the right which received sunlight diffused through window glass were soft, showing a lack of calcification due to the absence of vitamin D. The bird on the left was the same age and received the same ration, but it was exposed to the direct sun's rays a few hours each day.

A study of the sunshine records in the different states showed that the sun was visible 69 per cent of the daylight time in Kansas during the four spring months as shown in figure 7. The fact, however, that many of the poultry houses had closed fronts and thus excluded much of the direct rays of the sun suggested experiments to find, if possible, a suitable substitute for vitamin D as provided in the sun's rays. The work was divided into phases A and B.

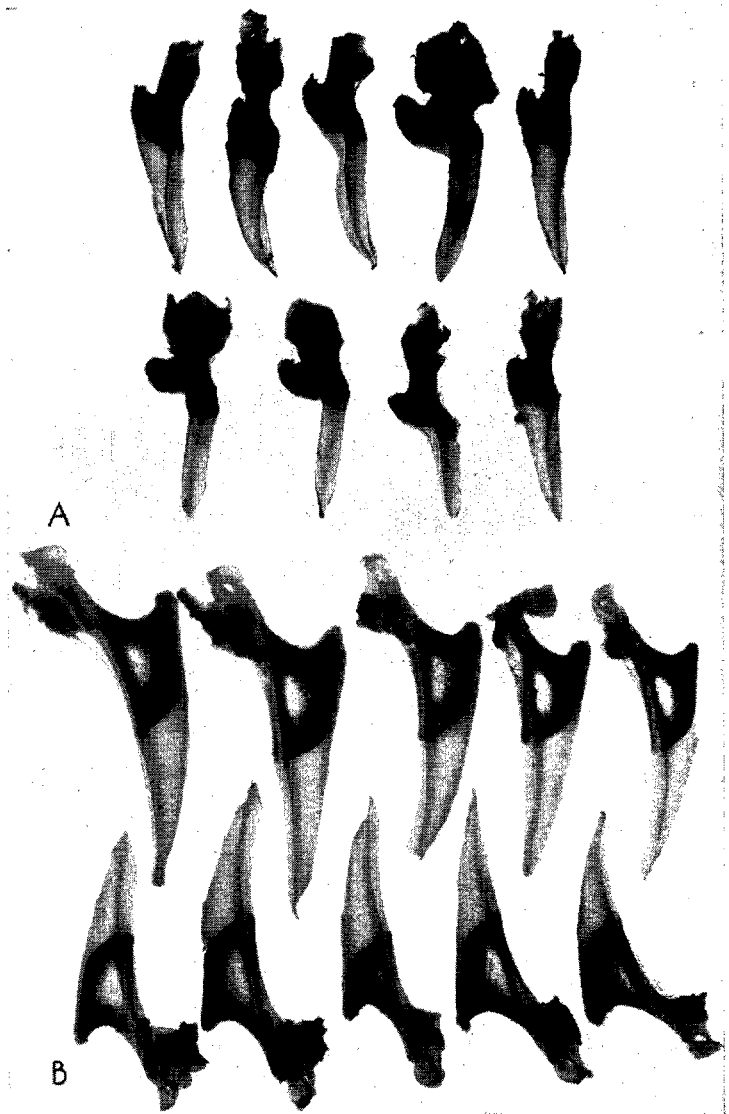

FIG. 6.—The breast bones of 12-week-old chickens which received the same basal ration. Group A was not treated with ultra-violet light while group B received ultra-violet light treatment a few minutes each day. Note how straight and evenly ossified the lower group is compared with the twisted and poorly ossified group above.

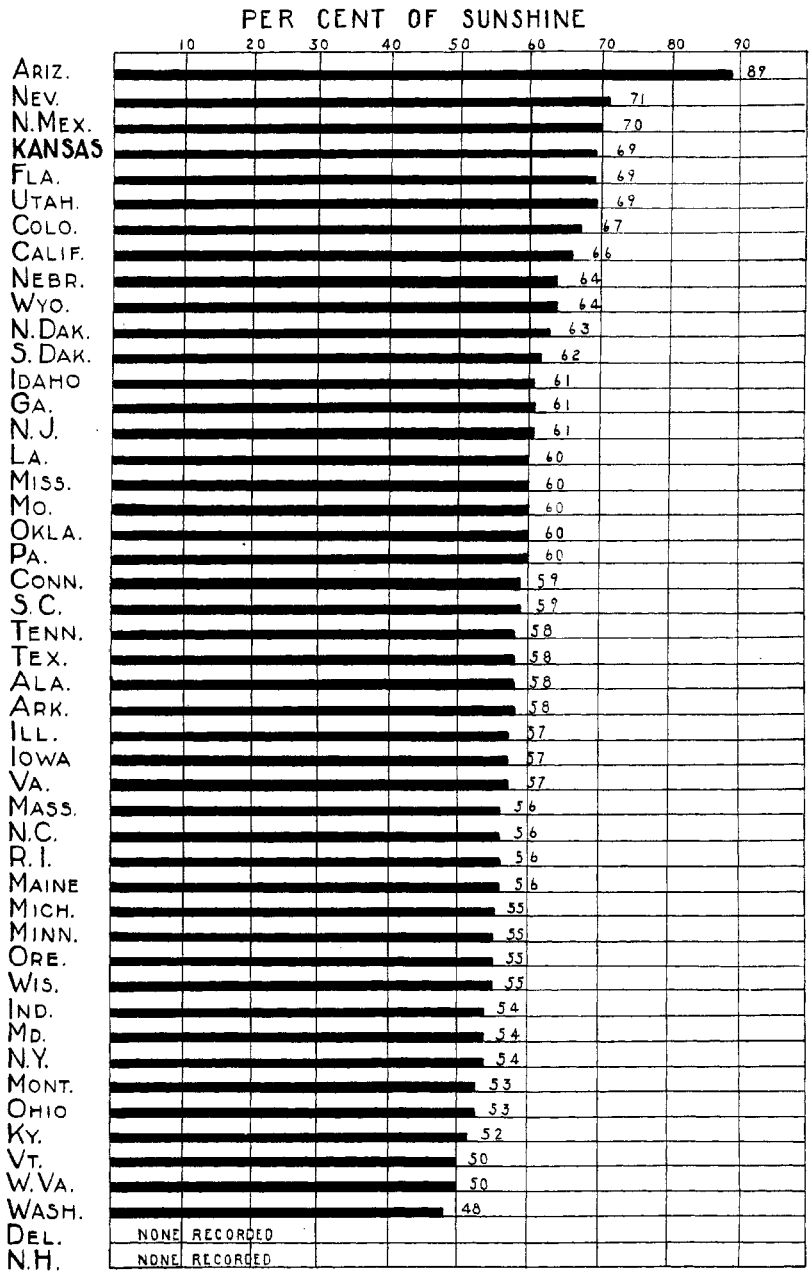

FIG. 7.—Graph showing the percentage of the total sunshine available for the four spring months (February, March, April, and May), 1921-'23, as reported by the United States Weather Bureau.

PHASE A

This phase, which was confined to the study of vitamin A, involved three lots of hens in which white and yellow corn were compared with and without supplementary sprouted oats. The K. S. C. standard ration was revised this year so as to use more of the whole grains and less of the grain by-products. The ration is given below and the results will be found in Table VII.

Scratch grain.		*Dry mash.*	
Cracked yellow corn	50 lbs.	Ground yellow corn	100 lbs.
Wheat	50 lbs.	Ground wheat	100 lbs.
		Ground oats	100 lbs.
		Meatscraps	75 lbs.

Water, milk (when used), oyster shell, grit, and sprouted oats were fed *ad libitum*. The rations for the different lots were:

Lot No. Rations.

41. K. S. C. standard, yellow corn, buttermilk, and no sprouted oats.
42. K. S. C. standard, white corn used as a substitute for yellow corn, sprouted oats.
43. K. S. C. standard, yellow corn with sprouted oats.

TABLE VII.—EGG PRODUCTION, AVERAGE GAIN IN WEIGHT, AND HATCHABILITY DATA IN EXPERIMENT VII, PHASE A.

November 1 to June 1.

Lot No.	Average egg production.	Average gain in grams.	Number of hens from which eggs hatched.	Number of eggs set.	Percentage hatched.
41	117	195	8	220	61
42	103	127	8	183	74
43	110	63	10	212	55

These data show that a white corn ration with sprouted oats as a source of vitamin A gave better results than the yellow corn rations, with or without sprouted oats. The poorer results with the yellow corn rations are not in accord with the results in Experiment VI, lots 34, 37, and 38, in which yellow corn rations gave a hatchability of 74, 76, and 72 per cent, respectively. While the number of birds in the above experiment is too few to draw definite conclusions, the results indicate that white corn properly supplemented with vitamin A would make a satisfactory poultry ration.

A somewhat similar four-pen experiment was conducted with Rhode Island Red pullets over the same period as that covered above. The birds fed a ration composed of white corn as one of the principal ingredients and no green feed produced eggs that gave a hatchability of only 38 per cent, while other birds fed the same ration supplemented with alfalfa hay *ad libitum* produced eggs which gave a hatch of 56 per cent. Another lot of pullets fed a ration composed of 20 per cent ground yellow soybeans as the source of protein and vitamin A supplemented with a 3 per cent mineral mixture produced eggs which gave a 69 per cent hatch. A fourth lot of pullets fed the same basal ration in which yellow cornmeal was substituted for white cornmeal produced eggs which gave a 60 per cent hatch. These results indicate that the alfalfa hay and the soybeans served as sources of vitamin A. In order to further test the value of these ingredients as sources of vitamin A they were studied the following year.

PHASE B

The relation of ultra-violet light to egg production as discussed in the preceding experiments raised some important questions in connection with the use of this light in practical poultry production. Does winter sunshine provide an adequate amount of the ultra-violet light for egg production? Can the ultra-violet light be provided from an artificial source? (Fig. 8.) Can cod liver oil take the place of direct sunshine for egg production? Can irradiated feed serve as a source of vitamin D for laying hens? What effect does the lack of direct sunshine have on the chemical composition and the vitamin D content of the eggs produced?

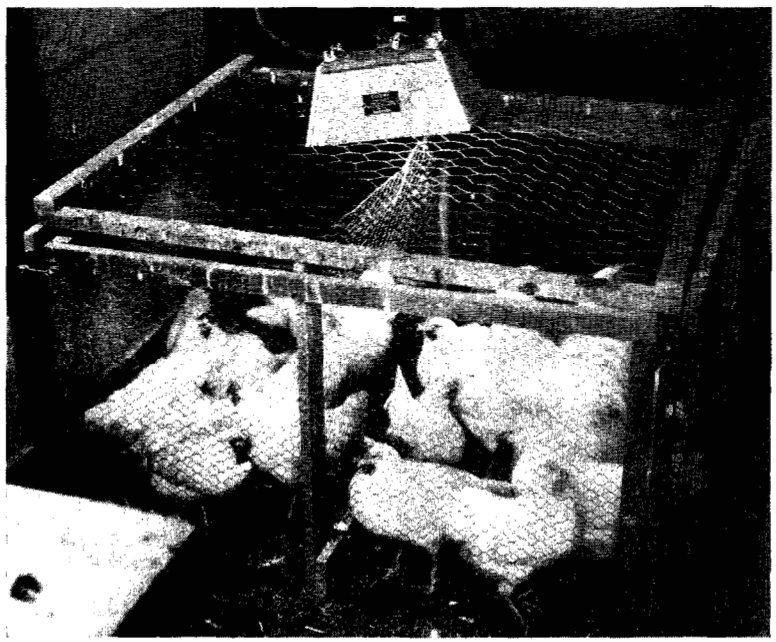

FIG. 8.—The first quartz mercury vapor lamp furnished by the Cooper-Hewitt Company for treating poultry with ultra-violet rays. (See figure 12 for the improved poultry treater.)

To answer these questions, nine lots of hens were used. They all received the standard K.S.C. ration. The composition of which is given in Phase A of this experiment. The light treatment and the supplementary feeds used were as follows:

Lot No.

44. Direct sunshine in outside yard and 30 minutes irradiation per day.
45. Sunshine through glass windows and 30 minutes irradiation per day.
46. Direct sunshine in outside yard.
47. Sunshine through glass window.
48. Sunshine through glass windows and 1 per cent cod liver oil added daily at feeding time.
49. Sunshine through window glass and 1 per cent cod liver oil mixed in feed at the first of each month.
50. Sunshine through glass windows and 2 per cent irradiated cottonseed oil.
51. Sunshine through glass windows; entire ration irradiated.
52. Two per cent irradiated cottonseed oil added to ration (oil treated one hour at 20-inch distance).

TABLE VIII.—EGG PRODUCTION, AVERAGE GAIN IN WEIGHT, AND HATCHABILITY DATA IN EXPERIMENT VII, PHASE B.

November 1 to June 1.

Lot No.	Average egg production.	Average gain in grams.	Number of hens from which eggs hatched.	Number of eggs set.	Percentage hatched.
44	117	498	8	462	71
45	103	364	10	641	70
46	93	362	9	535	73
47	108	272	10	586	56
48	108	227	10	680	75
49	107	272	9	578	67
50	121	318	10	639	59
51	90	145	7	165	64
52	109	150	10	209	58

The egg production, gain in weight, and hatchability of the eggs are shown in Table VIII. These results indicate that the winter sunshine as received by lot 46 supplied an adequate amount of the ultra-violet light, since no benefit was secured by additional irradiations as shown in lot 44. Thirty minutes irradiation daily by a mercury arc lamp gave good egg production and hatchability of chicks as indicated in lot 45. The results in lot 47 showed good production but low hatchability, indicating that ordinary window glass filters out much of the beneficial ultra-violet rays present in direct sunshine. One per cent of cod liver oil added to the ration of lots 48 and 49 proved adequate for the vitamin D requirement. In this particular experiment, the oil added daily gave slightly better results than that mixed monthly; however, the differences were not significant. Later experiments, Payne *(32)* and Holmes, Pigott and Menard *(14)*, and Massengale and Nussmeier *(25)* showed that cod liver oil mixed in feeds retained most of its vitamin D potency for a year.

The results from lot 50 which received two per cent of irradiated cottonseed oil, and lot 51 for which the entire mash was irradiated, indicate that the irradiation of feed in these lots did not improve them sufficiently to equal the results in hatchability obtained in the other lots. Mussehl *(29)* and others have since shown that the irradiation of feeds did not greatly enhance their antirachitic values when fed to poultry.

Four lots of growing chicks were used to test the relative antirachitic vitamin content of the eggs from lots 44, 45, 46, and 47. Ten one-week old White Leghorn chicks were used for each lot. They were placed in small pens (24 by 30 inches) in the nutrition room in such a way that all the lots received the same amount of light, but none of them received any direct sunlight through the window. Each lot received the same basal ration, which consisted of yellow corn 80 parts, meatscrap 10 parts, and middlings 10 parts. This particular basal ration was chosen as a number of previous experiments had shown that when one-week old chicks were fed this ration, under the lighting condition in the laboratory, the chicks developed unmistakable signs of rickets in from 4 to 6 weeks. When a supplementary feed containing a liberal amount of the antirachitic vitamins was added to the above ration, the chicks developed normally.

In addition to this basal ration, each lot of chicks received one egg a day from one of the above lots of hens. Group A chicks received one egg a day from lot 44 hens, group B chicks received one egg a day from lot 45 hens, etc. The shells of the eggs were not used. The raw white and yolk of an egg were

mixed fresh each morning with the amount of basal ration that the chicks would eat during the day. The chicks in each lot were allowed basal ration *ad libitum* after they had eaten the portion which had been mixed with the egg. The source of eggs fed is given in Table IX.

TABLE IX.—WEIGHTS OF CHICKS RECEIVING EGGS FROM HENS WHICH HAD RECEIVED VARYING AMOUNTS OF ULTRA-VIOLET LIGHT.

Lot No.	SOURCE OF EGGS FED.	Chick group, No.	Av. chick weights (grams).
44	From hens receiving direct sunlight (+ 30 min. ultra-violet irradiation per day)	A	450
45	From hens receiving 30 min. ultra-violet irradiation and sunshine through glass windows	B	390
46	From hens receiving direct sunlight	C	473
47	From hens receiving only sunshine filtered through glass windows,	D	294

All chicks were wing banded, weighed individually and their general condition was closely observed after signs of rickets developed. The experiment was discontinued at the end of 10 weeks, when the chicks were 11 weeks old. At this time pictures were taken showing the general condition of each lot (fig. 9) after which the chicks were killed for bone and blood analyses. Three bones (femur, tibia, and humerus) from each chick in a lot were carefully cleaned and composited into one sample which was analyzed for ether extract, ash, calcium, and phosphorus. (Table X.)

TABLE X.—COMPOSITION OF BONES OF CHICKS SUPPLIED EGGS FROM HENS WHICH HAD RECEIVED VARYING AMOUNTS OF ULTRA-VIOLET LIGHT.

Group No.	Percentage. (Based on ether extracted material).			
	Ether extract.	Ash.	Calcium.	Phosphorus.
A	16.89	51.4	20.54	9.20
B	5.95	48.1	19.25	8.70
C	16.50	49.5	20.05	9.06
D	1.51	40.7	15.73	7.32

Approximately 4 c. c. of blood were drawn from the heart of each chick in a lot composited into one sample which was analyzed for total calcium and inorganic phosphorus. (Table XI.)

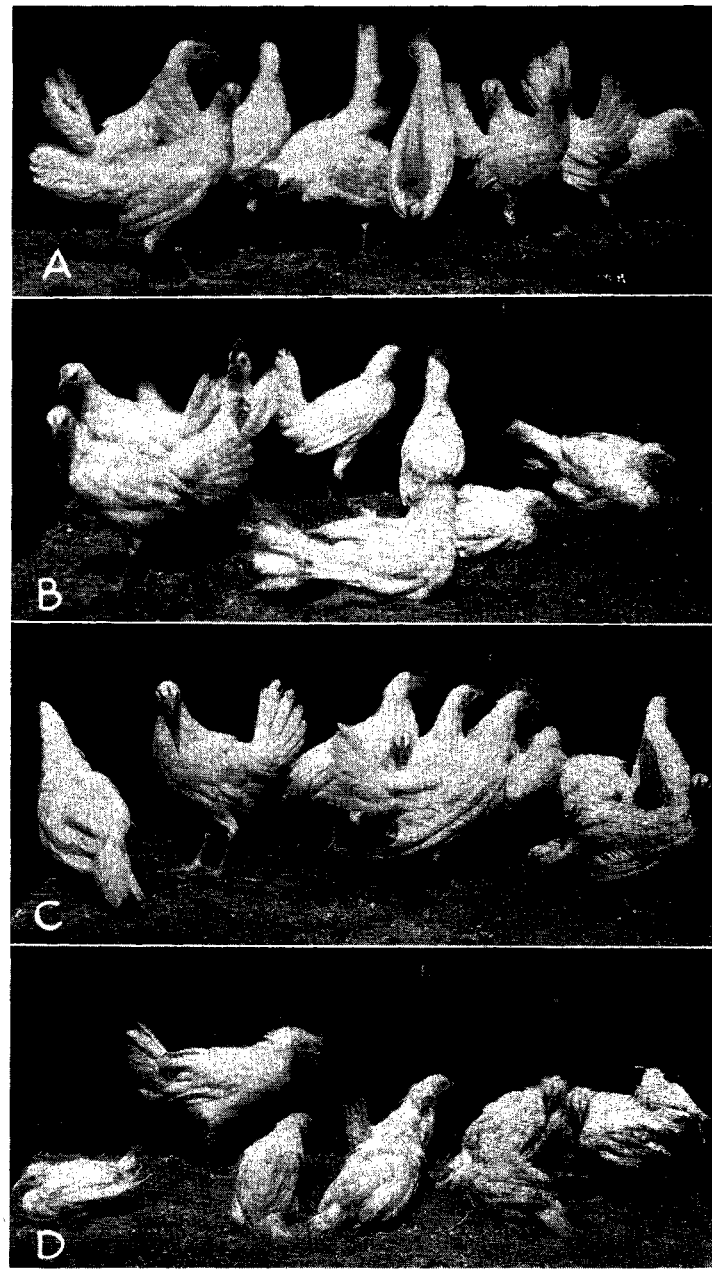

FIG. 9.—White Leghorn chicks used to test the vitamin D content of eggs from hens receiving different treatments. (A) Those receiving one egg a day from hens supplied both direct sunshine and irradiated with ultra-violet light (lot 44). (B) Those receiving one egg a day from hens receiving the irradiation with ultra-violet light (lot 45). (C) Those receiving one egg a day from hens which had been subjected to direct sunshine (lot 46). (D) Those receiving one egg daily from hens which had neither direct sunshine nor ultra-violet rays (lot 47).

TABLE XI.—CALCIUM AND INORGANIC PHOSPHORUS OF BLOOD FROM CHICKS RECEIVING EGGS FROM HENS WHICH HAD RECEIVED VARYING AMOUNTS OF ULTRA-VIOLET LIGHT.

Group No.	Mg. calcium per 100 c. c. plasma.	Mg. inorganic phosphorus per 100 c. c. blood.	Condition of chicks.
A	12.90	5.00	Normal.
B	11.50	3.40	Slight rickets
C	13.00	5.00	Normal.
D	9.67	3.72	Rickets.

The growth of the chicks, the general condition of the lots at the end of the experiment, the bone analyses, and the blood analyses show that the eggs from hens receiving an abundance of ultra-violet light contain an abundance of the antirachitic vitamin, while eggs from hens receiving a limited amount of ultra-violet light contain a relatively smaller amount of the antirachitic vitamin. Whether or not the 30-minute treatment with ultra-violet light from the mercury arc lamp which the hens of pen 44 received enabled them to store more of the antirachitic vitamin in their eggs than the hens of pen 46, which received only the direct sunlight, is not shown by this experiment, as the one egg a day from pen 46 seemed to contain a sufficient amount of the antirachitic vitamin for the 10 chicks. The condition of the keel bones from each lot is shown in figure 10.

The 30-minute ultra-violet treatment which the hens in pen 45 received did not enable them to store sufficient antirachitic vitamin in their eggs to prevent entirely the development of rickets among the chicks supplied eggs from this lot. There was sufficient antirachitic vitamin in their eggs, however, to reduce very materially the severity of rickets produced.

All the chicks in group D developed severe rickets. This shows that the eggs of hens from pen 47 which received sunlight filtered through glass contained very little of the antirachitic vitamin. Four of the chicks in this lot developed tentany. When excited, they would go into spasms which would last from two to five minutes. It will be noted (Table XI) that the calcium content of the blood of the chicks in this lot was lower than that of normal chicks. It has been found by Kramer, Tisdall, and Howland *(24)*, Howland and Kramer *(15)*, and Dunham *(7)* that when infants suffering from rickets develop tentany, their blood calcium is usually much lower than normal.

It was during the spring of 1925 that the first wire enclosed runway, later designated as a "sanitary runway," was first used at the Kansas Agricultural Experiment Station to expose growing chicks to the direct sunshine without their coming in contact with the ground. This is illustrated in figure 11. The sun porch referred to in Experiment III, 1920-'21 was only for laying hens.

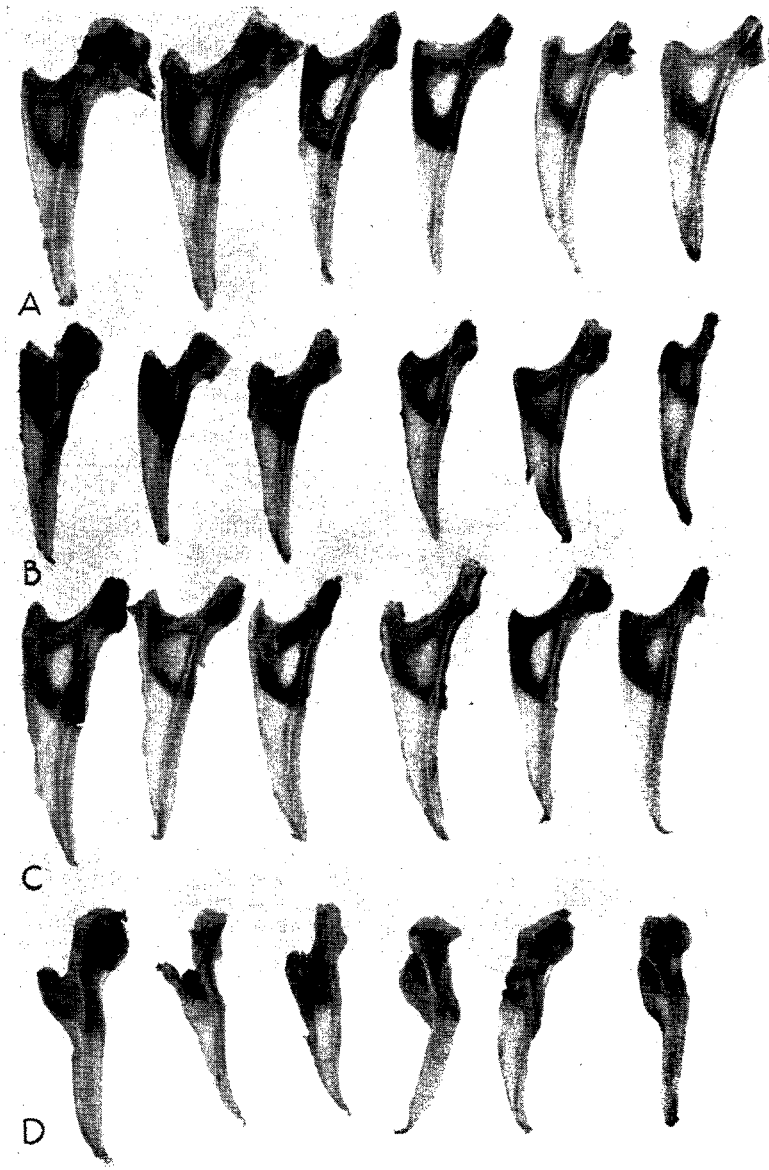

FIG. 10.—The breast bones of chicks shown in figure 9 used to test the vitamin D content of eggs. The straight, well ossified keels in groups (A), (B), and (C) show the eggs contained vitamin D. The poorly ossified group (D) shows that the eggs did not contain a sufficient amount of vitamin D to prevent rickets.

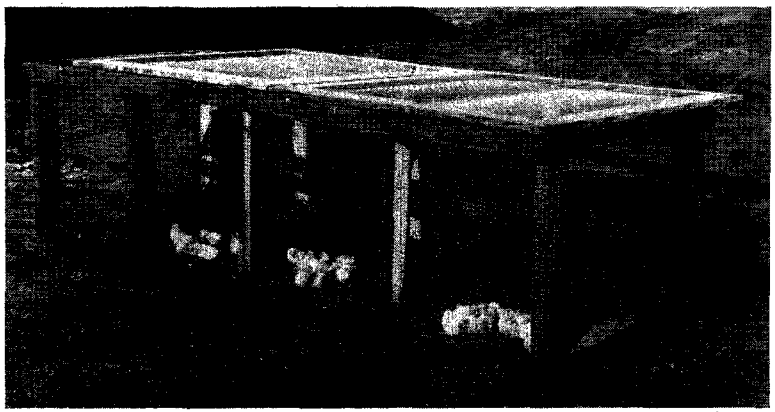

FIG. 11.—The first out-door covered coop used at the Kansas Agricultural Experiment Station for giving chicks 'sun baths."

The Uvi-arc poultry treater with a mercury arc in a quartz tube designed by the Cooper-Hewitt Company of Hoboken, New Jersey, especially for treating chickens and laboratory animals with ultra-vlolet light was used In the spring of 1925. A so-called factory lamp which consisted of a long glass tube surrounding a mercury arc light was also tested the same season. (Fig. 12.)

Hughes and Pycha, *(20)* measured by the acetone methylene blue method the variation of the vitamin D producing energy in the sunshine during 1927 at Manhattan, Kan. (Latitude 39° 12', Longtitude 96° 40'). It was found as shown in figure 13 that the winter sunshine contained about one-eighth as much of the health giving portion of the ultra-violet as the summer sunshine. The amount found on the shortest day of the winter was several times the amount necessary for normal growth and egg production. Russell and Massengale *(33)* have shown that normal growth is secured during the winter months when chicks receive their sunshine through celoglass which filters out about two-thirds of the health giving portion of the sunlight. Goodale *(8)* has shown that a one-minute treatment a day with a mercury arc lamp produced normal results provided the feeds contained a proper mineral balance.

With this information at hand, it is safe to say that there is sufficient sunshine available in Kansas at all seasons of the year to meet the needs of the poultry flock provided the birds have access to the sun's available direct rays. There are times and places especially in the eastern half of the state where the sun does not shine for two or three weeks. In times of prolonged cloudiness, the addition of 0.5 per cent, of one of the vitamin D potent fish oils would be advisable. It is especially important that open front laying houses be provided to admit the sun's direct rays.

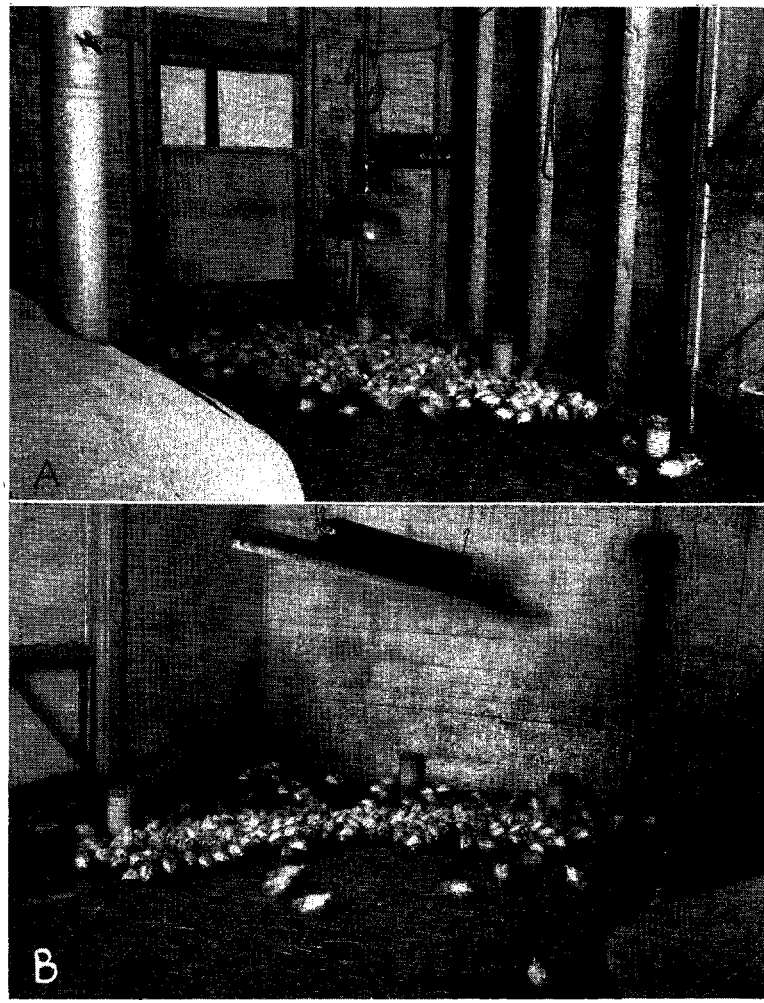

FIG. 12.—(A) The first Uvi-arc poultry treater in use at the Kansas Agricultural Experiment Station. (B) Factory lamp which was found to produce sufficient ultra-violet rays to prevent rickets when chicks were treated several hours daily.

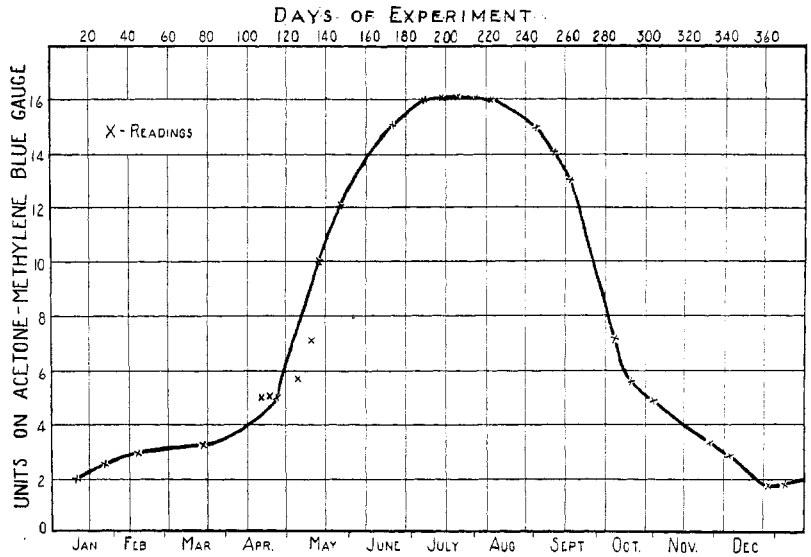

FIG. 13.—The seasonal variations in the "vita" portion of the solar spectrum as measured by acetone-methylene blue method.

EXPERIMENT VIII, 1925-'26, LOTS 53-73

The previous year's work was sufficiently encouraging to justify further study of sources of vitamins A and D. The work was divided into three phases, A, B, and C. The objects were as follows:

Phase A—To find a practical source of vitamin A as a supplement to use with a ration composed largely of white corn.

Phase B—To study the effect of ultra-violet light on egg production and hatchability.

Phase C—To study the relative antirachitic value of various substances containing vitamin D as measured by the development of growing chicks.

PHASE A, LOTS 53-59

Seven lots consisting of 10 pullets and one cockerel each were used in this phase of the experiment. The rations used are given below and the results in this phase of the experiment will be found in Table XII.

Lot No.	53	54	55	56	57	58	59
Scratch grain.	*Pounds.*						
Cracked yellow corn	50	....	....	....	....	50	....
Cracked white corn	....	100	100	100	100	50	100
Wheat	50	....	....	....	....	....	....
Dry mash.							
Ground yellow corn	26⅔	....	....	....	....	40	....
Ground white corn	....	80	80	75	75	40	80
Ground oats	26⅔	....	....	....	....	....	....
Ground wheat	26⅔	....	....	....	....	....	....
Meatscraps	13⅓	15	15	15	15	15	15
Dried buttermilk	6⅔	5	5	5	5	5	5
Yellow soybean meal	....	....	....	5	....	....	....
Ground alfalfa leaves	....	....	....	....	5	....	....
Green sprouted oats	ad. lib.	ad. lib.	....	....	....	....	....

TABLE XII.—EGG PRODUCTION, AVERAGE GAIN OR LOSS IN WEIGHT, AND HATCHABILITY DATA IN EXPERIMENT VIII, PHASE A.

November 1 to July 1.

Lot No.	Average egg production.	Average gain or loss in grams.	Number of hens from which eggs hatched.	Number of eggs set.	Percentage hatched.
53	89	36	8	199	57
54	67	—73	10	199	73
55	47	—381	6	59	63
56	32	—363	5	56	39
57	42	—100	5	53	40
58	58	—227	7	79	51
59	41	—181	4	40	38

The egg production and hatchability results are not consistent. Lot 53 supplied with 50 per cent yellow corn and green feed led in production but the eggs from this group ranked third in hatchability. The birds in lot 54 given white corn and green feed gave much better production and hatchability than lot 59, which received the same ration without green feed. Lots 55 and 59 received identical rations and the production was about the same, but there was a wide variation in the hatchability of the eggs. Lot 56 which received a 5 per cent ground soybean supplement gave very unsatisfactory results. This may be partly explained by the fact that raw soybeans appear to be unpalatable and the birds did not eat the mash readily. The 5 per cent alfalfa leaf meal added to the ration in lot 57 did not prove adequate as was also found in later experiments. Forty-five per cent of yellow corn fed to lot 58 gave better production but lower hatchability than a white corn ration with 5 per cent alfalfa leaf meal. These results in general agree with those obtained in previous experiments which showed the importance of vitamin A for egg production.

PHASE B, LOTS 60-65

In studying the effect of ultra-violet light on the production and hatchability of eggs, six lots of 10 pullets and one cockerel each were used to test three different sources of light. Two lots were confined in the house and given an ultra-violet light treatment for 15 minutes daily from November 1, 1925, to March 24, 1928. The treatments were extended to 20 minutes daily from March 25 to May 1. Two lots were confined to the house for the duration of the experiment, November 1 to May 1. These birds received the sun's rays through ordinary window glass, neither artificial light nor direct sunlight being used. The remaining two lots were given outside range where the available sun's rays came in direct contact with the birds.

The rations fed all pens consisted of the following:

Scratch grain.		*Dry mash.*	
Cracked yellow corn	50 lbs.	Ground yellow corn	40 lbs.
Wheat	50 lbs.	Ground oats	40 lbs.
		Meatscraps	15 lbs.
		Dried buttermilk	5 lbs.

Scratch grain was fed once daily at 4 p.m. The mash was available in open hoppers at all times. Sprouted oats were fed daily. Water, oyster shell, and grit were available at all times.

The male birds were rotated twice weekly to eliminate the influence of individual birds as much as possible.

On three different occasions during the experiment (November 20, February 16, and April 27) ten eggs from each lot were quantitatively analyzed for calcium and phosphorus. The eggs were taken from the same hens on all occasions in order to minimize individual variation. Samples of blood were also taken from the wing vein of each bird, pooled, and analyzed for calcium and phosphorus. April 17 and May 7 at the conclusion of the experiment, five chicks hatched from the eggs from each series were ashed to determine the calcium content. The vitamin D reserve stored in the eggs was also tested by rearing 20 chicks from each light series on vitamin D-free rations and in the absence of the sun's direct rays.

Results

Differences began to appear three months after the experiment started. The confined birds were less active and their feathers were more ruffled. A noticeable difference was not apparent between the ultra-violet treated pens and those having outdoor range. Both groups were active and appeared contented. The results are given in Table XIII.

TABLE XIII.—EGG PRODUCTION, WEIGHT, AND HATCHABILITY DATA, EXPERIMENT VIII, PHASE B.

Lot Nos.	Treatment.	Average egg production.	Percentage of gain or loss in weight.	Number of eggs set.	Percentage hatched.
60 and 61.....	Treated.....	96	6.42	1,059	63
62 and 63.....	Confined.....	73	—2.50	782	49
64 and 65.....	Outside.....	98	7.47	1,136	77

Statistical treatment of these data showed a significant difference between the outside and inside lots but less than a significant difference between the treated and the inside lots. The results for lots 64 and 65 show that the amount of ultra-violet rays from the direct sunshine was adequate for good results. In all probability more satisfactory results would have been obtained from the treated lots had not the mercury quartz lamp failed to burn steadily during the cold weather.

Chemical Analyses of Eggs

Ten eggs from each lot were weighed and measured for volume by the displacement method. They were placed in a two-liter graduated cylinder to which one liter of water was added. The volume of the eggs was determined from the reading of the combined volume of the eggs and the water. The eggs were then dried and separated into shell and content. The shells were then washed with distilled water to remove any remaining egg white. The membranes were allowed to remain in the shells. The shells were then dried at 100° C., weighed, ashed, and analyzed for calcium. The contents of the 10 eggs were weighed, thoroughly mixed with an egg beater, dried at 100° C. and weighed again. Samples were then taken and analyzed for calcium and phosphorus by the usual method. The results of the analyses, which are given in Table XIV, show no significant differences among the eggs from the different lots.

TABLE XIV.—CHEMICAL ANALYSES OF EGGS.

Date.	Lot No.	Volume (10 eggs).	Weight (10 eggs).	Dry weight of shells.	Weight of egg contents.	Dry weight of egg contents.	In egg contents.		In shells.		In dry contents.	
							Calcium.	Phosphorus.	Ash.	Calcium.	Phosphorus.	Calcium.
		C. c.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Per cent.*	*Per cent.*
Nov. 20, 1925.	60	455	483.00	48.01	421.95	102.53	0.272	0.860	24.70	17.64	0.839	0.265
	61	430	460.25	45.72	400.25	102.86	.247	.864	23.48	16.76	.840	.240
	62	430	459.00	46.61	397.00	100.83	.289	.860	23.99	17.13	.853	.287
	63	460	494.30	49.13	431.70	107.75	.298	.918	25.32	18.08	.852	.277
	64	425	453.00	46.21	392.90	99.01	.274	.850	23.70	16.92	.859	.277
	65	415	446.80	46.35	386.75	98.85	.339	.868	23.71	16.93	.878	.343
Feb. 17, 1926.	60	505	535.50	51.30	467.30	114.58	.252	.974	26.16	18.68	.850	.220
	61	520	552.00	53.90	450.00	117.37	.281	1.052	27.04	19.31	.896	.240
	62	480	509.00	50.90	442.90	113.60	.278	1.011	26.28	18.76	.890	.245
	63	525	563.50	52.10	495.40	127.02	.318	1.105	26.54	18.95	.870	.250
	64	480	519.10	51.50	452.70	114.67	.275	.961	27.01	19.28	.838	.240
	65	470	543.50	54.20	474.10	122.22	.379	1.047	28.22	20.15	.857	.310
May 5, 1926.	60	500	542.20	47.20	480.90	120.22	.324	.904	24.44	17.45	.752	.270
	61	500	539.10	47.10	476.10	123.93	.315	1.078	24.62	17.58	.870	.254
	62	490	529.00	52.00	462.80	120.19	.391	.919	26.98	19.26	.765	.325
	63	510	543.80	50.90	477.80	.....	.....	.....	26.55	18.96	.....	.....
	64	505	542.90	51.60	477.00	123.30	.345	1.074	26.97	19.26	.871	.280
	65	490	523.30	54.70	454.30	117.39	.352	1.044	28.21	20.14	.890	.300

It is interesting to note that, under the condition of the experiment, the hens in lots 62 and 63, which received sunshine filtered through ordinary window glass, continued to produce eggs which seemed normal according to chemical analyses. In a preceding experiment (see Table IX) hens that received no ultra-violet light or vitamin D produced eggs with thin shells and with a low calcium and phosphorus content of both the yolk and the white.

Although the chemical analyses showed no significant difference in the eggs from the different lots, the hatching record showed clearly that the eggs from the confined lots did not hatch so well as the eggs from the hens receiving direct sunshine. This was probably due to a deficiency in the vitamin D content of the eggs.

Chemical Analyses of Blood of Hens and Day-old Chicks

Twice during the experiment, April 17 and May 7, blood was secured from the hens for calcium and phosphorus determination. Two cubic centimeters of blood were drawn from the wing vein of each hen and the blood was pooled according to lots for analysis. On May 1, 15 day-old chicks were selected from eggs hatched from each lot of hens, blood was secured by a heart puncture, and pooled for analysis. The results are given in Table XV.

TABLE XV.—RESULTS OF BLOOD DETERMINATIONS FOR CALCIUM AND PHOSPHORUS.

Mg. per 100 c. c.

	Hens.				Chicks.	
Date.....	April 17.		May 7.		May 1.	
Hen lot No.	Calcium in plasma.	Inorganic phosphorus in blood.	Calcium in plasma.	Inorganic phosphorus in blood.	Calcium in plasma.	Inorganic phosphorus in blood.
60.....	22.3	2.60	21.57	3.26	13.36	3.41
61.....	22.6	2.71	21.50	3.04	13.36	3.41
62.....	19.3	2.45	19.50	2.41	12.50	2.78
63.....	20.3	1.69	21.00	2.30	12.50	2.78
64.....	28.0	3.44	23.50	3.62	12.70	2.48
65.....	25.0	3.04	24.25	3.61	12.70	2.48

The blood of the hens receiving direct sunshine (lots 64 and 65) had slightly higher content of both calcium and phosphorus than either of the other lots. The blood of the hens confined and receiving no ultra-violet light treatment ranked the lowest of the three groups for these constituents. The results of the analyses of the eggs (see Table XIV) show that the amount of calcium and phosphorus in the blood of the confined hens was sufficient to produce eggs of normal mineral content.

There were no significant differences in the calcium and phosphorus content of the blood of the day-old chicks hatched from eggs laid by hens from the different lots.

Chemical Analyses of Day-old Chicks

Five day-old chicks which had received no feed were selected from each of the three groups for a calcium determination. The chicks were killed and the entire chick ashed. Calcium was determined on the composite ash from each group of five chicks. The results are given in Table XVI. For comparison there is included in the table the average amount of calcium found in the contents of the eggs from each of the three groups. In the last column of the

TABLE XVI.—CALCIUM CONTENT OF CHICKS AND EGGS.

Lot Nos.	TREATMENT OF HENS.	Average calcium in egg content.	Average calcium per chick.	Amount calcium derived from the shell.
		Gm.	*Gm.*	*Gm.*
60 and 61.....	Received ultra-violet light.....	0.027	0.138	0.111
62 and 63.....	Sunshine through glass windows.....	.028	.116	.088
64 and 65.....	Direct sunshine.....	.033	.143	.110

table is given the amount of calcium which the chick derived from the egg shell. This value is obtained by subtracting the amount of calcium in the content of an egg, similar to the one from which the chick hatched, from the amount of calcium found in the day-old chick.

It is evident from these results that the light treatment had a greater effect on the calcium content of the day-old chick than it had on the amount of calcium in the eggs. The chicks from the two groups receiving ultra-violet light, direct sunshine in one case and light from a mercury arc lamp in the other, utilized about 25 per cent more calcium from the shell during the incubation period than was utllized by the chicks from the group receiving their light through glass windows.

The difference in the utilization of calcium by, the embryo in the different groups was perhaps due to the difference in the vltamin D content of the egg. It appears that under the conditions of this experiment the confined hens were able to produce eggs with normal mineral content but so deficient in their vitamin D content as to interfere with the mineral metabolism of the chick embryos.

Vitamin D Reserve

In order to test the vitamin D reserve of the chicks from the three groups, 20 day-old normal chicks were selected from each group and were brooded in the absence of direct sunshine. They received a feed free from vitamin D. At the end of the period, which was 26 days in duration, 19 of the 20 chicks from the group where the hens received no ultra-vlolet light showed definite signs of rickets, while only two of the chicks from the treated group had developed this disorder. These results are proof that the ultra-violet light which the hens receive synthesizes vitamin D. This vitamin is then stored in the yolk of the egg. Chicks hatched from eggs containing a good supply of vitamin D are able to live longer without a supply of this vitamin than chicks hatched from eggs that are deficient in vitamin D.

PHASE C, LOTS 66-73

This phase of the experiment was divided into series A and series B. Forty-five Rhode Island Red chicks from the college flocks were used in each of four pens for series A. They were started on the experiment January 2 and continued until eight weeks of age. Forty-five Rhode Island Red chicks were also used in each of four pens for series B. They were hatched February 25 and kept on the experiment for eight weeks. All chicks were confined in their pens, 8 by 10 feet in size, during the experiment. The college chick ration consisting of a scratch grain and mash mixture was fed to all groups with the variations listed in Table XVII.

Seven points were investigated as follows: (1) The antirachitic value of light from a mercury arc in a quartz tube (Uvi-arc poultry treater); (2) the antirachitic value of light from a mercury arc in a glass tube (Cooper-Hewitt factory lamp); (3) direct sunlight through an open window; (4) sunlight through a glass window; (5) the vitamin D potency of cod liver oil; (6) irradiated cottonseed oil; and (7) irradiated Wesson oil.

All chicks that died during the experiment were examined by the poultry disease specialist of the Department of. Bacteriology. A representative chick was taken when eight weeks of age from each pen in series B for X-ray pictures to show the relative condition of bone development. At the close of the experiment five representative chicks were selected from each pen for chemical analysis. The following determinations were made: Ash, calcium, and phosphorus content of bones and the calcium and inorganic phosphorus content of the blood. The tibia, femur, and humerus bones were used for the bone analysis and blood samples were obtained by bleeding the birds from the heart with a hypodermic needle.

Series A, Lots 66-69

The cottonseed oil for lot 66 was irradiated for one hour by a quartz tube mercury vapor lamp on a 220-volt direct current. An iron pan, 14 by 24 inches in size, which was agitated during the exposure, held 100 c. c. of the oil, 18 inches from the lamp. One week's supply was mixed at a time, using two c. c. of oil to 100 grams of feed.

The "work lamp" used in lot 68 consisted of a mercury arc in a glass tube approximately one inch in diameter by 40 inches long. The lamp burned on a 110-volt alternating current. It was suspended 4½ feet above the chicks. The mash hopper was directly under the lamp. Since the lamp was designed for a room temperature of 70º F., it was sometimes difficult to start in extremely cold weather. The lamp burned on an average of eight and one-half hours daily. The mercury quartz lamp, referred to as the "Uvi-arc Poultry Treater," used in lot 69, was operated 15 minutes daily at a distance of 30 inches above the chicks. It was run on a 110 volt alternating current.

Each pen had a glass window 3 by 6 feet which was kept closed throughout the experiment, no attempt being made to exclude the ultra-violet rays from passing through the glass.

Series B, Lots 70-73

The cod liver oil used in lot 71 was mixed with the scratch grain and mash at the rate of one-half c. c. to 100 grams of feed. A high-grade commercial oil tested for vitamin D potency was used. Several days' supply was mixed at one time.

Conditions were the same as in lot 68, series A, for the "work lamp'' except that in lot 72 it was operated nine and one-half hours daily.

Wesson Oil is the commercial name of a refined cottonseed oil. It was treated for 40 minutes in the manner described for the cottonseed oil in lot 66, series A. The oil was added in the ratio of two c. c. of oil to 98 grams of feed.

The direct sunshine in lot 70 passed through an open window 3 by 4½ feet in size. The sunlight covered a maximum area on the floor of about 16 by 32 inches. The sun spot was on the floor from about 10 a. m. to 4 p. m. The weather report from the department of Physics at the college showed 63 per cent sunshine in Manhattan during the period of the experiment. The first month was very favorable for brooding, but the last month was cloudy and for a period of three weeks the chicks received very little sunshine.

DISCUSSION

Bacillary white diarrhea appeared among the chicks of series A and was responsible for a loss of almost 50 per cent of the original number. All chicks that died previous to the 16th day and those that showed symptoms of the disease were eliminated from the records. This left 25 chicks in each lot in series A to continue the work. The results obtained in Phase C of the experiment are reported in Table XVII.

TABLE XVII.—THE EFFECT OF IRRADIATED OIL, DIFFUSED SUNSHINE, DIRECT SUNSHINE, ULTRA-VIOLET LIGHT, COTTONSEED OIL, AND COD LIVER OIL ON THE WEIGHT OF CHICKS AND THE COMPOSITION OF THEIR BLOOD.

Lot No.	Treatment of rations and chicks.	Weight at 56 days of age.	Chemical analyses of blood.		Remarks.
			Calcium, mg. per 100 c. c. plasma.	Inorganic phosphorus, mg. per 100 c. c. of blood.	
SERIES A.		*Gm.*			
66	2 per cent irradiated cottonseed oil	210	8.50	3.14	Marked rickets. High mortality.
67	Sunshine diffused through window glass	158	8.50	2.75	Marked rickets. High mortality.
68	Ultra-violet light, glass tube, 8¼ hours daily	441	12.50	3.79	Normal.
69	Ultra-violet light, quartz tube, ¼ hour daily	442	12.20	3.56	Normal
SERIES B.					
70	Direct sunshine through open window	585	13.00	5.26	Normal.
71	One-half of 1 per cent cod liver oil	628	13.50	5.76	Normal.
72	Ultra-violet light, glass tube, 9½ hours daily	651	13.00	5.00	Normal.
73	2 per cent irradiated cottonseed oil	204	9.25	4.17	Marked rickets. High mortality.

In this experiment the chicks were kept under practical brooding conditions, whereas the previous work on the relation of ultra-violet light to the normal development of chicks had been done in the nutrition laboratory under more or less artificial conditions. The results of this work showed clearly that by the use of either ultra-violet light or vitamin D chicks could be brooded in confinement, as shown in figure 14.

It was also found (lots 68 and 72) that the ordinary Cooper-Hewitt work lamp, which is a mercury arc in a glass tube, provided a sufficient amount of ultra-violet light to produce satisfactory results. The minimum exposure for good results with this light was not determined.

The irradiated cotton seed oil (lots 66 and 73) gave poorer results than was expected judging from its potency in preventing rickets in rats (37). This is in accord with the results in Phase B of this experiment in which irradiated cotton seed oil had very little potency when fed to laying hens.

The results of lot 70 show clearly that the amount of direct sunshine which the chicks received through the open window was sufficient to produce normal growth. Where a reasonable amount of sunshine is available, it is not necessary to provide other means for preventing rickets in the practical brooding of chicks.

EXPERIMENT IX, 1926-'27, LOTS 74-77

In order to work with larger numbers of birds and thus reduce the error from individual variations, the house in which this experiment has been conducted from the beginning was remodeled in 1926 and divided into four pens each 20 feet square. (Fig. 15.) The birds were confined to their respective pens until near the close of the experiment when they were given the use of small sanitary runways equipped with wire floor 10 to 12 inches above the ground. The object of these runways was to give more direct sunshine during the summer when the sun did not enter the experimental houses in this latitude. (See page 29.)

Fig. 14.—Chicks grown under practical methods showing that either direct sunshine or cod liver oil added to the ration was effective in preventing rickets. The chicks were confined in the brooder house. Group (A), lot 70, received direct sunshine through an open window, (B), lot 71, was supplied cod liver oil as a source of vitamin D, and (C), lot 67, received sunshine through a glass window.

FIG. 15.—The house shown in figure 1 after it was remodeled in 1926 for Experiments IX, X, and XI. A straw loft was installed and the large openings in front admitted direct sunshine and improved the ventilation.

Studies were made of certain green feeds and substitutes such as dry alfalfa leaves with and without succulents, sprouted oats and germinated oats, to determine the effect upon production, hatchability, and the health of the birds.

The rations used for the four lots were as follows:

Lot No.	74	75	76	77
White cornmeal	50	50	50	50
Meatscraps	20	20	20	20
Wheat bran	10	10	30	30
Ground oats	10	10	.....	.....
Alfalfa leaves	10	10	.....	.....
Mangel beets	.....	Ad lib.	.....	.....
Sprouted oats (green sprouts 2"-3")	.....	.....	1 sq. in. a bird daily.	.....
Germinated oats (white sprouts ¼"-½")	.....	.....	.....	1 sq. in. a bird daily

All pens received shelled white corn for scratch grain, grit, oyster shell, and water *ad libitum.*

BIRDS USED

Seventy-five White Leghorn hens and pullets and five males were used in each of the four pens. The experiment started November 1 and continued to July 31. Many of the hens died or were removed during the experiment and a few were missing at the conclusion of the work. Egg production was calculated on the hen-day basis. A hen's connection with the experiment ended the day she died or was removed. The total number of hen-days was calculated for each month and for the duration of the experiment and from that the average number of hens, average egg production, and percentage of production were calculated as follows:

In pen 75 there were 17,532 hen-days, and from November 1 to July 31 there were 273 days. The number 17,532 divided by 273 equals 64.22, or the average number of hens for the period. There were 4,692 eggs laid which number di-

vided by 64.22 gives an average production of 73.06 a hen. This number divided by 273 equals 26.76 or the percentage production of this pen for the entire period. The bird-days for the males was calculated in the same way to arrive at the feed consumption. Seven hens were missing at the close of the experiment. They were entered as being in the pens one-half time or 136 days each.

FEED CONSUMED

The scratch grain was fed in a straw litter daily and the mash was fed dry in open hoppers being available at all times. The grain was fed at a rate that compelled the birds to eat about equal parts of scratch feed and mash.

Feed consumption was calculated on a per bird basis the same as egg production described previously. The cockerel-days were added to the hen-days to give the total bird-days for each pen. The amount of feed was computed for the duration of the experiment. The results are presented in Table XVIII. A record of the amount of mangel beets, and sprouted oats consumed was not kept.

TABLE XVIII.—AVERAGE FEED CONSUMED PER BIRD FOR 273 DAYS, EXPERIMENT IX.

Lot No.	74	75	76	77
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*
Scratch grain	24.0	24.3	22.8	24.4
Mash	24.5	20.9	20.5	17.7
Totals	48.5	45.2	43.3	42.1

While the amount of feed consumed is in proportion to the number of eggs produced, the difference between some of the lots is very slight. The mash consumption is also greater among the heavier producing birds. These figures bear about the same relation to each other that would be expected on normal rations.

TABLE XIX.—TOTAL AND AVERAGE EGG PRODUCTION, EXPERIMENT IX.

Lot No.	74	75	76	77
Number of females at beginning of experiment	75	75	75	75
Average number of females during the experiment	65	64	60	45
Total number of eggs produced	4,981	4,675	3,844	2,197
Average number of eggs produced	77	73	64	48
Percentage of egg production	28	27	23	18

EGG PRODUCTION

Individual egg records were obtained by trapnesting the hens throughout the experiment. The eggs laid on the floor were added to the pen total each month. The results are given in Table XIX.

In calculating average production, every hen was considered whether she laid or not. For example, in pen 74 there were five hens that did not lay an egg in the trapnests and five that each laid less than five eggs. It is possible that some of these contributed to the 204 floor eggs gathered and added to the grand total production.

When using egg-production as a measure of the different rations, it will be observed that lots 74 and 75 were about of equal value. The addition of a succulent in the form of mangel beets did not improve the ration. It was

thought that dry alfalfa leaves might be improved by the addition of a more palatable succulent feed such as mangels, which were relished by the birds, but the results did not support this belief. One square inch of green sprouted oats per bird daily was apparently not enough to supply the vitamin A requirements in an otherwise vitamin A-free ration. The average production was less in lot 76 than in lots 74 and 75 that received green alfalfa leaves, and the

TABLE XX.—HENS GROUPED ACCORDING TO EGG PRODUCTION, EXPERIMENT IX.

Lot No.	Eggs produced for duration of experiment grouped as follows:				
	0-50 (a).	51-100.	101-150.	151-200.	Total.
	Number of hens in each group.				
74	33	21	19	2	75
75	32	31	9	3	75
76	42	21	12	0	75
77	59	12	4	0	75
Percentage distribution of hens in each group.					
74	44	28	25	3	100
75	43	41	12	4	100
76	56	28	16	0	100
77	79	16	5	0	100

(a) Hens that had no eggs to their credit were included in this group.

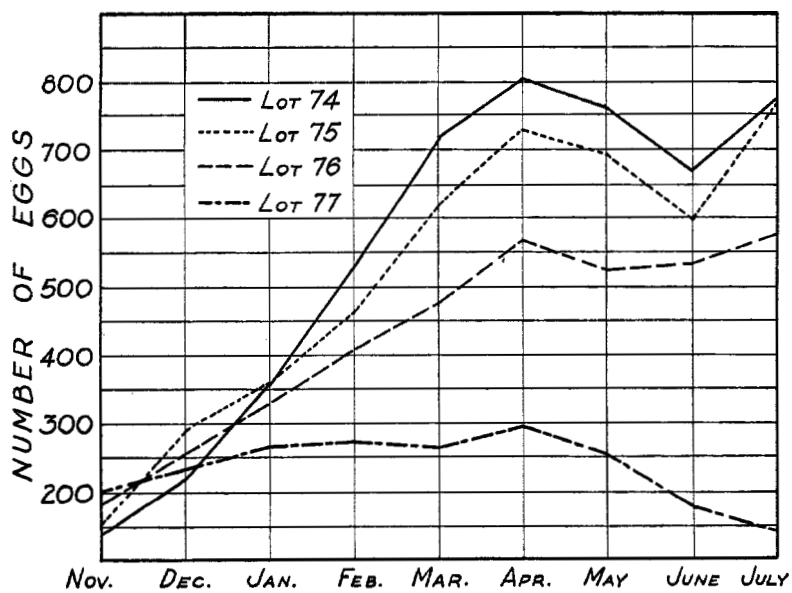

FIG. 16.—A graphic presentation of egg production by months in the four lots, Experiment IX.

number of high producers was somewhat less. The low production for lot 77 indicated that germinated oats was inadequate as a substitute for alfalfa leaves or green sprouted oats. The figures in the mortality table (Table XXV) show the difierence to be in the vitamin content of the ration. Table XX gives the distribution of birds according to the number of eggs produced.

Figure 16 shows the production of eggs by months emphasizing particularly the length of time required for inadequate rations to manifest their effects on the hens. The lots finished in just the reverse position occupied at the close of the first month's production. Lot 74, which was lowest for the month of November, was highest for July, and the others followed in numerical order as shown in figure 16. Lot 77 on the ration deficient in vitamin A maintained good production through November and December, but it dropped well below the others for the third month and thereafter. The vitamin A reserve carried by the pullets when they entered upon the experiment was apparently sufficient to supply the body needs for six weeks to two months.

Utilization of Calcium for Egg Production

In the study of the utilization of calcium for egg production, the following work was done: (1) An analysis of the blood of growing chicks, both cockerels and pullets, was made each month from the time they hatched until they matured; (2) analyses were made of the blood of mature hens before, during, and after molting and setting; (3) a comparison was made of the blood of capons and cocks; (4) a fairly complete mineral! analysis was made of the blood of laying hens and mature cocks. For this purpose 400 c. c. of blood was collected by drawing 10 c. c. from each of 40 hens from the wing vein by means of a syringe.

The calcium content of the blood of normal chickens, except hens during the time they were in egg production, was found to be practically the same as that of other animals. As the pullets matured as shown by the comb development, the calcium content of the blood increased. During the time of egg production the calcium content of the blood remained high, being from two to three times the ordinary amount. When production ceased, either from molting or setting, the calcium content dropped to the normal level, then raised to a high level again when egg production began. During egg production the amount of calcium in the blood did not remain constant, as is usually the case, but fluctuated as much as 10 milligrams from week to week. The cause of the fluctuation has not been determined. The results of the mineral analysis of the blood of laying hens and cocks are given in Table XXI.

TABLE XXI.—MINERAL ANALYSIS OF THE BLOOD OF COCKS AND LAYING HENS.

Grams in 1,000 grams of plasma.

Determination	1.	2.	1.	2.
ELEMENT.	Composite from 40 laying hens.		Composite from 25 cocks.	
Calcium	0.241	0.245	0.145	0.150
Magnesium	.045	.....	.039	.....
Sodium	3.399	3.433	3.555	3.385
Potassium	.272	.284	.257	.252
Phosphorus	.329	.343	.134	.111
Chlorine	3.777	3.752	4.114	4.002
Sulphur	.940	.....	.821	.....

It will be seen from Table XXI that both the calcium and phosphorus contents of the blood are higher for hens than for cocks. The increase in calcium is due to an increase of the inorganic salts of calcium. This is not true for phosphorus, as other determinations show the inorganic phosphorus to be no higher in the blood of laying hens than in the blood of nonlaying hens or cocks. The increase must, therefore, be due to some organic phosphorus compound. It would appear that the increase in calcium is to provide for the inorganic calcium of the eggshell, and the increase of phosphorus provides for the organic phosphorus found in the yolk of the eggs.

TABLE XXII.—PRODUCTION, FERTILITY, AND HATCHABILITY RESULTS, EXPERIMENT IX.

Lot No.	74	75	76	77
Number of females from which eggs were saved	56	54	47	17
Number of eggs set	995	889	700	330
Number of eggs fertile	775	791	588	312
Percentage of eggs fertile	78	89	84	92
Number of chicks dead in shell	235	207	268	104
Percentage of chicks dead in shell	30	26	46	33
Number of chicks hatched	540	584	320	208
Percentage of fertile eggs hatched	70	74	54	67
Percentage of total eggs hatched	54	66	46	63

HATCHABILITY OF EGGS

The study of the hatchability of eggs was a second means used in comparing results from the different lots. Eggs were set from all hens that were laying between April 12 and May 17. Table XXII gives the results on hatchability.

While the eggs from lots 74 and 75 showed less mortality in shell and higher

TABLE XXIII.—HENS GROUPED ACCORDING TO HATCHABILITY OF EGGS, EXPERIMENT IX.

Lot No.	Per centage hatchability of eggs grouped as follows:				
	0-25.	26-50.	51-75.	76-100.	Total.
	Number of hens in each group.				
74	1	19	16	20	56
75	2	6	22	24	54
76	15	14	10	8	47
77	2	2	7	6	17
	Percentage distribution.				
74	2	34	28	36	100
75	4	11	41	43	99
76	32	30	21	17	100
77	12	12	41	35	100

hatchability than lots 76 and 77, the difference is not great. The 17 hens in lot 77 were thrifty, vigorous individuals as judged by their size and gain in weight as recorded in Table XXIV, and by the fertility of eggs. It appears that birds which are able to survive on an inadequate ration are usually vigorous individuals, otherwise they would not live. The weaker birds died or were out of production when the hatching season began.

Since individual hatching records were kept on the eggs of each bird, it was possible to group the hens according to the percentage hatchability of eggs for each lot. These results are given in Table XXIII.

In Table XXIII, lot 75 shows superior results. Eighty-four per cent of the hens in this lot gave a hatchability of 51 per cent or more, while lot 74 shows 64 per cent above this figure and lots 76 and 77 had 38 and 76 per cent in the upper two groups, respectively. The birds in lot 77 again demonstrated their vitality by placing this large percentage of their number in the high groups. The male birds were not rotated in these pens and it is possible they were not of equal vigor although they compared favorably from external appearance.

WEIGHTS OF BIRDS

All birds were individually weighed at the beginning and at the conclusion of the experiment. All feed was removed from the birds in the late afternoon and the weights were taken in the forenoon of the following day. The average weights in Table XXIV include only the first and last weights of those birds that completed the experiment.

TABLE XXIV.—AVERAGE WEIGHT OF FEMALES, EXPERIMENT IX.

Lot No.	74	75	76	77
Number of hens which finished experiment	52	51	40	12
	Gm.	*Gm.*	*Gm.*	*Gm.*
Average weight August 1, 1927	1,455	1,414	1,461	1,620
Average weight October 29, 1926	1,342	1,295	1,321	1,333
Gain	113	119	140	287
Percentage of gain	8.4	9.4	10.5	21.5

The percentage of gain in weight is in the reverse order of the percentage of eggs produced. The birds in lot 77 produced the fewest eggs and they made the greatest gains in weight. This fact indicates that the 12 birds that completed the experiment in this lot were unusually sturdy as they thrived in spite of a lack of vitamin A in the ration. The birds in this particular experiment were not heavy egg producers, which probably explains why they gained so much in weight. Heavy layers are inclined to lose rather than gain in weight as they approach the end of their laying year.

MORTALITY OF BIRDS

The mortality which was high in all lots was exceedingly heavy in lot 77 which received the germinated oats. Birds in advanced stages of disease and those that died were taken to the Department of Bacteriology where a poultry disease specialist made an autopsy of each bird and submitted a written report of his findings. The results are given in Table XXV.

While a few cases of A-avitaminosis developed in lots 74 and 75, a much greater number died from this disease in lots 76 and 77. The exact percentage of total birds found to be affected by this trouble was 54 and 73 for lots 76 and 77, respectively. This indicates that one square inch of green sprouted oats a bird daily is not adequate to prevent A-avitaminosis and a similar amount of germinated oats proved of very little if any value in preventing this trouble. Salpingitis or inflammation of the oviduct accounted for nine deaths

TABLE XXV.—REPORT OF AUTOPSIES ON BIRDS THAT DIED.

Lot No.	74	75	76	77	Total.
Number of birds at beginning of experiment	75	75	75	75	
CONDITION FOUND.					
A-avitaminosis	3	8	19	46	76
No diagnosis	2	1	3	6	12
Salpingitis	4	3	1	1	9
Ruptured ova	3	2	0	2	7
Diphtheria	1	0	4	2	7
Worms, round and tape	0	2	2	2	6
Accidently killed	3	1	0	1	5
Tumor	2	1	1	0	4
Hemorrhage	0	2	1	1	4
Ophthalmia	0	1	2	0	3
Pneumonia	1	0	1	1	3
Nephritis	1	0	1	0	2
Peritonitis	0	1	0	0	1
Ruptured uterus	0	1	0	0	1
Cirrhosis of liver	1	0	0	0	1
Abscesses	1	0	0	0	1
Necrosis of liver	1	0	0	0	1
Inanition	0	1	0	0	1
Enteritis	0	0	0	1	1
Totals	23	24	35	63	145
Percentage of mortality	31	32	47	84	.....

in all lots. Ruptured ova and diphtheria took seven each, worms were found in six, tumors and hemorrhages occurred in four each, and other deaths were caused by miscellaneous conditions reported in Table XXV.

SUMMARY

The more important figures in the previous tables are brought together in a summary table for easy comparison. These results are presented in Table XXVI.

TABLE XXVI.—SUMMARY OF RESULTS, EXPERIMENT IX.

Lot No.	74	75	76	77
Number of hens at beginning of experiment	75	75	75	75
Average number of hens	65	64	60	45
Number of hens at close of experiment	52	51	40	12
Pounds of feed consumed per bird for average number of hens	48.5	45.2	43.3	42.1
Percentage of egg production for average number of hens	28	27	23	18
Percentage of fertile eggs hatched	70	75	57	66
Percentage of gain in weight of birds finishing experiment	8.4	9.4	10.5	21.5
Percentage of mortality	31	32	47	84

The differences that exist between the results in lots 74 and 75 are not significant. However, the results for the birds in these two lots surpassed by a fairly good margin the results for the hens in lot 76, which would indicate that 4.4 and 4.1 per cent of alfalfa leaves, the amounts actually consumed in the total rations for lots 74 and 75 respectively, were superior to one square inch of green sprouted oats fed each bird daily. The germinated oats as used in lot 77 apparently contained very little if any vitamin A. Therefore, this product cannot be depended upon as a source of this vitamin. The main object of feeding germinated oats would be to increase the palatability and possibly the digestibility.

EXPERIMENT X, 1927-'28, LOTS 78-81

A quantitative study of alfalfa leaf meal as a source of vitamin A was made during the season of 1927-'28. In the previous experiments alfalfa leaf meal was found to be a satisfactory source of vitamin A, but no attempt had been made to determine the optimum amount to use. The following experiment was planned to give information regarding the quantity necessary to provide an adequate supply of vitamin A.

RATIONS

All-mash rations were used as a means of forcing each bird to consume the feed in identical proportions. In previous experiments there was evidence that some of the birds, and especially the males, derived most of their nourishment from the scratch feed, which was quite inadequate when consisting of a single grain, as white corn or hominy grits.

The all-mash ration was so prepared that all constituents in the feed except vitamin A were kept as constant as possible. To accomplish this, a synthetic meal was prepared which had the same composition as alfalfa leaf meal except that it had no vitamin A. The fiber for the synthetic meal was provided by adding finely ground sweet clover stems. The mineral was obtained by burning alfalfa hay and using the ash. White corn meal and meat scraps provided sources of other nutrients. The results of the analysis of the synthetic meal are shown in Table XXVII.

TABLE XXVII.—COMPOSITION OF ALFALFA LEAF MEAL AND SYNTHETIC MEAL.

	Crude protein.	Crude fiber.	Ash.
	Per cent.	*Per cent.*	*Per cent.*
Alfalfa leaf meal	24.38	15.57	11.63
Synthetic meal	24.15	15.57	11.41

The rations fed consisted of a basal mixture to which was added either the synthetic meal resembling alfalfa or a genuine alfalfa meal.

The basal ration consisted of:

Ground white corn	65 lbs.
Meat scraps	10 lbs.
Wheat bran	10 lbs.
Total	85 lbs.

The synthetic meal was prepared by mixing together:

Ground white corn	40 lbs.
Meat scraps	29 lbs.
Sweet clover stems	26 lbs.
Alfalfa ash	5 lbs.
Total	100 lbs.

The rations used for the four lots were as follows:

Lot No.	78	79	80	81
Basal mash ration	85	85	85	85
Alfalfa leaf meal	15	10	6	0
Synthetic meal	0	5	10	15
Total	100	100	100	100

The feed was available at all times in open mash hoppers. Clean tap water, oyster shell, and grit were always accessible.

By using the synthetic product with varying amounts of alfalfa leaf meal, it was possible to feed rations of about the same chemical composition to all

lots, as presented in Table XXVIII. Since the analyses were practically the same for all lots, and since each bird had to eat the finely ground particles of feed as mixed, it was felt that results should be more uniform than in the previous experiments.

TABLE XXVIII.—COMPOSITION OF COMPLETE RATIONS.

Lot No.	78	79	80	81
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Crude protein	18.2	18.1	18.1	18.1
Nitrogen-free extract	57.7	57.7	57.6	57.2
Fiber	4.2	4.2	4.2	4.5
Ash	5.5	5.5	5.9	5.9

BIRDS USED

The four lots of females were kept in pens 20 feet square in the same house utilized in Experiment IX. The management was also similar to that followed in the previous experiment. Seventy-five White Leghorn pullets and hens and five male birds were placed in each lot on November 1, 1927, and a Kamala tablet was given each bird as a precaution against internal parasites. This treatment together with an outbreak of chicken pox caused heavy mortality in all groups. Birds that did not die were left in a weakened condition. December 1, the remaining birds were examined individually and all that appeared normal were replaced in the lots and the number in each pen was increased to 54 by adding two-year-old hens. A later recount revealed 55 hens in lot 79. Due to the above circumstances all records started December 1, except the weights of the original birds which were started November 1.

The hens in lots 78, 79, and 80 were kept in their respective pens until June when they were given the use of sanitary runways (10 by 12-foot wire-bottom cages) for direct sun treatment. Since only a few birds remained in pen 81, they were not given the sun bath. In this latitude the sun's rays are so nearly vertical in the summer that they did not enter the front of the experimental house.

Each bird was trapnested and the eggs were pedigree hatched. The methods of recording mortality and general management were the same as previously described. There were no substitutions and feed consumption was placed on a hen-day basis. The results as reported in the following tables were a great improvement over those in Experiment IX in spite of the outbreak of disease and the handicap in starting.

FEED CONSUMED

The feed consumed per bird for eight months was about normal for Leghorns. There is very little waste when feeding all-mash and it is more sanitary than throwing grain in the litter. While this method is satisfactory from the experimental point of view, it greatly reduces the amount of exercise. The litter becomes matted and damp when there is no incentive for birds

TABLE XXIX.—AVERAGE FEED CONSUMED PER BIRD, EXPERIMENT X.

Lot No.	78	79	80	81
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*
All-mash feed	54.50	55.4	49.7	45.50
Oyster shell	1.74	1.1	1.3	0.61

to scratch and stir it about. The average amount of feed consumed in the various lots is given in Table XXIX. The amount eaten varied 9.9 pounds per bird from the lowest lot, 81, to the highest lot, 79. This is consistent with the average egg production as given in Table XXX.

EGG PRODUCTION

The egg production was very satisfactory in view of the large number of two- and three-year old hens in the experiment and the appearance of pox among the pullets at the beginning of the experiment. Table XXX gives the production results.

TABLE XXX.—TOTAL AND AVERAGE EGG PRODUCTION, EXPERIMENT X.

Lot No.	78	79	80	81
Number of hens at beginning of experiment	54	55	54	54
Average number of hens during the experiment	52	53	49	42
Total number of eggs produced	5,745	6,241	5,070	3,033
Average number of eggs produced	110	118	103	73
Percentage of egg production	45	48	42	30

The method of calculating results was the same as outlined for Experiment IX. Lot 79, which received 10per cent alfalfa leaf meal, excelled lots 78 and 80, which were fed the 15 and 5 per cent respectively. All three lots ranked well above 81 which received a diet deficient in vitamin A but containing 15 per cent of the synthetic meal. Statistical methods could not be used with these figures or those in Experiment IX since too many birds in the inadequate lots died before the work was concluded.

TABLE XXXI.—HENS GROUPED ACCORDING TO EGG PRODUCTION, EXPERIMENT X.

Lot No.	Eggs produced for duration of experiment grouped as follows:				
	0-50.	51-100.	101-150.	151-200.	Total.
	Number of hens in each group.				
78	5	19	28	2	54
79	4	12	34	5	55
80	8	17	28	1	54
81	22	30	2	0	54
Percentage distribution of hens in each group.					
78	9	35	52	3	99
79	7	22	62	9	100
80	15	31	52	2	100
81	41	55	4	0	100

Table XXXI gives the distribution of birds according to the number of eggs produced. The figures show much smaller percentages of birds in the 0-50 group and larger percentages in the third group (101-150) than were found in the previous experiments. Nine per cent of the birds in lot 79 produced more than 151 eggs each, while 96.3 per cent in lot 81 laid less than 100 eggs each. This indicates the importance of an adequate amount of vitamin A in the ration.

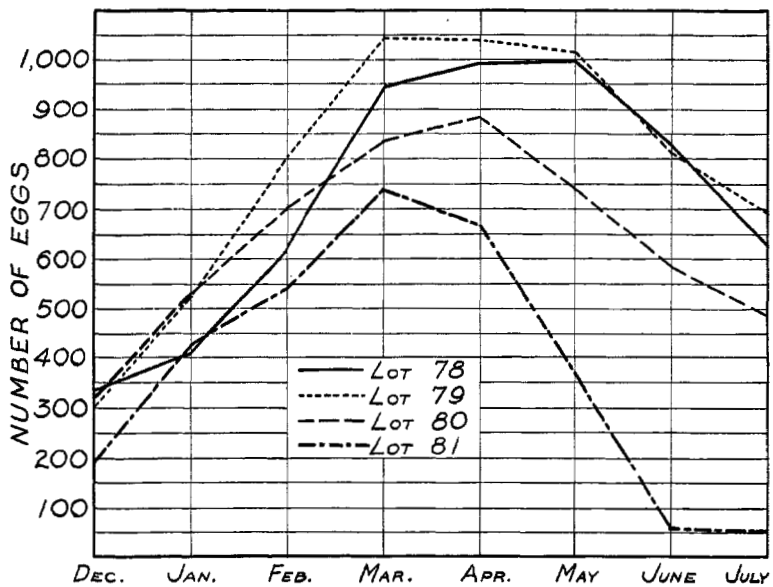

FIG. 17.—A graphic presentation of egg production by months in the four lots, Experiment X.

The graphs in figure 17 indicate a similarity in production the first three months of the experiment, after which there was a marked decline in production in lots 81 and 80. The production in lot 81 held up fairly well for December and January, but it dropped below all others the third month and continued to lag for the remainder of the experiment. Five per cent of alfalfa leaf meal did not appear to be sufficient to maintain a maximum production as shown in the graph for lot 80. The production in this group dropped well below that shown for lots 78 and 79 the fifth month. The production curve for lot 79 held the lead for five months, or from February to May inclusive, thus indicating that 10 per cent alfalfa leaf meal was probably more satisfactory than 15 per cent when judged by the total egg production for each lot.

HATCHABILITY OF EGGS

Eggs were pedigree hatched from each lot from April 3 to May 8. The birds had been mated from the beginning of the experiment so the effects of the feed should have been the same on both males and females. Table XXXII gives the results which were obtained by combining the individual figures for each lot.

TABLE XXXII.—EGG PRODUCTION, FERTILITY, AND HATCHABILITY RESULTS, EXPERIMENT X.

Lot No.	78	79	80	81
Number of hens from which eggs were saved	52	53	46	47
Number of eggs set	889	907	790	755
Number of eggs fertile	822	868	699	672
Percentage of eggs fertile	93	96	89	89
Number of chicks dead in shell	287	306	266	363
Percentage of chicks dead in shell	35	35	38	54
Number of chicks hatched	535	562	433	309
Percentage of fertile eggs hatched	65	65	62	46
Percentage of total eggs hatched	60	62	55	41

Eggs were set from all the hens that laid during the hatching period. The figures in Table XXXII for the first three lots do not differ greatly, indicating that 5, 10, or 15 per cent of alfalfa leaf meal in a vitamin A free ration gave fair hatchability. However, the poor results in lot 81 showed the need of this vitamin if good hatchability is to be obtained. A grouping of the hens according to distribution of hatchability is shown in Table XXXIII.

TABLE XXXIII. HENS GROUPED ACCORDING TO HATCHABILITY OF EGGS, EXPERIMENT X.

Lot No.	Percentage hatchability of eggs grouped as follows:				
	0-25.	26-50.	51-75.	76-100.	Total.
	Number of hens in each group.				
78	3	7	27	15	52
79	3	10	21	19	53
80	3	9	23	11	46
81	13	14	17	3	47
	Percentage distribution.				
78	6	13	52	29	100
79	6	19	39	36	100
80	6	20	50	24	100
81	28	30	36	6	100

These figures support the previous results in that they show that the hatchability of eggs is affected by the vitamin A content of the ration. The percentage of hens with a hatchability record above 50 per cent for lots 78, 79, and 80 was 81, 76, and 74 respectively, compared with lot 81 in which only 42 per cent exceeded that figure. In other words, the distribution of hens is in the same order as the amount of alfalfa leaf meal in the ration, although the difference is not great in the first three lots.

WEIGHTS OF BIRDS

The average weights in grams at the beginning and the conclusion of the experiment of all birds that survived the entire period are given in Table XXXIV.

TABLE XXXIV.—AVERAGE WEIGHTS OF FEMALES, EXPERIMENT X

Lot No.	78	79	80	81
Number birds at close of experiment	50	50	48	8
	Gm.	*Gm.*	*Gm.*	*Gm.*
Average weight November 1, 1927	1,425	1,468	1,439	1,584
Average weight August 1, 1928	1,404	1,459	1,456	1,658
Gain or loss	—21	—9	17	74
Percentage of gain or loss	—1.49	—0.6	1.16	4.5

The hens in lots 78 and 79 lost weight while those in the last two pens made slight gains. The five birds in lot 81, which lived through the experiment, had a much higher average weight both at the beginning and the conclusion of the work than those in the other lots. The fact that they were larger birds may account for their ability to live on an inadequate ration. The ability to maintain or gain body weight in this experiment did not compare favorably with the birds in Experiment IX. Substantial gains were made in the previous instance. This may be explained by the heavier production in the last experiment and to the use of an all-mash ration. It is more difficult to maintain body weight on all-mash rations than when both grain and mash are fed. The birds do not eat so much mash as scratch grain before going to roost and the former passes through the digestive tract rapidly, leaving the crop empty most of the night.

MORTALITY OF BIRDS

An autopsy of each bird that died was made by a poultry disease specialist in the Department of Bacteriology. When lesions of A-avitaminosis were found in the esophagus and excessive amounts of urates in the ureters or the kidneys of the birds examined, they were diagnosed as having A-avitaminosis. Deposits of urates through the muscles and organs were added symptoms of this condition. Table XXXV shows the distribution of birds that died and the autopsy findings.

TABLE XXXV.—REPORT OF AUTOPSIES ON BIRDS THAT DIED.

Lot No.	78	79	80	81	Total.
Number birds at beginning of experiment	54	55	54	54	
CONDITION FOUND.					
A-avitaminosis	1	0	0	39	40
Peritonitis	1	0	3	0	4
Worms, round or tape	0	1	0	3	4
Opthalmia	0	3	0	0	3
Ruptured ova	1	0	1	0	2
Pneumonia	0	0	1	0	1
Post mortem, decomposition	1	0	0	1	2
Internal hemorrhage or abscess	0	0	0	2	2
Diphtheria	0	0	1	1	2
Impacted crop	0	1	0	0	1
Totals	4	5	6	46	61
Percentage of mortality	7	9	11	85	.....

Table XXXV is self-explanatory. Most of the mortality was due to A-avitaminosis and all but one case of this affliction was in lot 81 which did not receive vitamin A. Many of the birds showed more than one disorder, for example, peritonitis and ruptured ovum; or pneumonia and internal hemorrhage from abscessed kidney. In all such cases only the first disorder given on the autopsy sheet was tabulated. The one listed may or may not have been responsible for death of the bird.

SUMMARY

The more important figures in each of the preceding tables have been compiled in a summary table, Table XXXVI.

TABLE XXXVI.—SUMMARY OF RESULTS, EXPERIMENT X.

Lot No.	78	79	80	81
Number of hens at beginning of experiment	54	55	54	54
Average number of hens	52	53	49	42
Number of hens at close of experiment	50	50	48	8
Pounds of feed consumed per bird	54.5	55.4	49.7	45.5
Percentage of egg production	45	48	42	30
Percentage of eggs hatched	65	65	62	46
Percentage of gain in weight for hens at close of experiment,	—1.5	—0.6	1.2	4.5
Percentage of mortality	7.4	9.1	11.1	85.1

When it is remembered that the results of the chemical analyses of the rations in the above lots were almost identical, as given in Table XXVIII, and that the only difference was in the small amount of alfalfa leaf meal carrying vitamin A in all lots except 81, the importance in the poultry ration of this health-giving vitamin is evident. The losses in Kansas from a lack of vitamin A were enormous before its importance was recognized. These losses have now been almost eliminated in this state by the use of yellow, corn, green succulent feed or green alfalfa hay. The figures in Table XXXVI show that a small amount of alfalfa leaf meal will suffice. While the differences are not great in the first three lots in which 15, 10, and 5 per cent, respectively, was used, the results slightly favor lot 79 which received a ration composed of 10 per cent leaf meal. That amount appears adequate in a ration otherwise deficient in vitamin A.

In order to determine the vitamin A reserve of the chicks which were hatched from eggs from lots 78, 79, 80, and 81 which received varying amounts of vitamin A, all the chicks from the last five hatches were fed a feed deficient in this component. As the feed contained very little vitamin A, the length of time the chick would live would depend on the vitamin A reserve in its body at hatching time. The chicks from each hatch were brooded together. The feed consisted of a mash composed of ground white corn, wheat bran, and meat scraps. Ultra-violet light was supplied to meet the vitamin D requirements. The test was continued until all the chicks were dead. (Fig. 18.) Table XXXVII shows the results of this test.

It is very evident from the results of the test that the vitamin A content of the feed which the hens received had a marked effect on the vitamin A reserve of the chicks from the eggs produced. The chicks from lot 79 where the hens received 10 per cent alfalfa as a source of vitamin A lived just as long as those from the lot receiving 15 per cent alfalfa. Chicks from the lot receiving no alfalfa had an average life of only 11 days, which showed that that they were well on the way to vitamin A starvation when they were hatched. In fact, the eyes of some of the chicks from this lot showed the

FIG. 18.—The above chicks represent the number left from a lot of 200 after being on a vitamin A-free diet for four weeks. They show the nervous symptoms characteristic of the advanced stages of A-avitaminosis.

TABLE XXXVII.—HATCHABILITY AND VITAMIN A RESERVE IN EGGS FROM THE VARIOUS LOTS, EXPERIMENT X.

Lot No.	Number of fertile eggs set.	Number of chicks hatched.	Percentage of fertile eggs hatched.	Average number of days before death on vitamin-A free feed.
78	636	421	66.2	24.3
79	778	475	61.1	24.5
80	521	264	50.7	17.5
81	45	19	42.2	11.4

effect of the lack of vitamin A when they were hatched. No doubt the vigor of the commercial hatchery chicks is greatly influenced by the feed which is fed the hens producing the hatching eggs.

ALFALFA LEAF MEAL IN THE POULTRY RATION

It might be appropriate at this time to point out the value of alfalfa as a feed and some of the factors affecting its quality. Salmon, Swanson, and McCampbell *(35)* found the average per cent of alfalfa leaves on the plant over a period of eight years (1914-1921) for the different cuttings to be as follows: when cut, in the bud stage, 53.4 per cent leaves, in the 10th-blossom stage 51.1 per cent, in the full-bloom stage 48.4 per cent and when cut in the seed stage only 41.6 per cent leaves. The percentage of leaves decreases and the stems increase as the plant matures. There was a tendency for the proportion of leaves to increase as the season advanced, as, for example, in the bud-stage cuttings, the leaves of the first cutting averaged 49 per cent as compared with 55 per cent for the fifth cutting and 65 per cent for the sixth. The yield of dry matter in leaves for one season per acre when cut in the different stages was found to be 2,508 pounds for the bud-stage cutting, 2,936 for the tenth-bloom cutting, 2,988 full-bloom, and 2,137 for the seed-stage cutting.

Nutritive Value of the Hay

The analyses of composite samples of the green leaves and alfalfa hay cut at different stages of growth showed the composition as given in Table XXXVIII.

TABLE XXXVIII.—COMPOSITION OF ALFALFA.

MATERIAL.	Stage of cutting.	Ash.	Crude protein.	Crude fiber.	Nitrogen free extract.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Leaves sampled green	Bud-stage	11.53	26.58	15.71	43.29
	10th-bloom	10.88	25.73	16.05	43.99
	Full-bloom	10.81	24.14	15.47	46.23
Field-cured hay	Bud-stage	8.65	18.37	23.35	38.92
	10th-bloom	8.35	17.85	24.09	38.92
	Full-bloom	7.99	16.21	25.80	38.90

It will be noted that the percentages of ash and protein in both the leaves and the hay were largest in the bud stage and decreased with the later stages of cuttings. Conversely, the percentage of crude fiber in the hay was least in the bud stage and increased with the later stages. There was but little change in the fiber of the pure leaves. While these figures indicate that alfalfa would be of greater value as a poultry feed when cut in the bud or pre-bud stage, it was found in the above experiment that cutting in the bud stage decreased the vigor of growth, the stand, the yield of alfalfa hay, and permitted the encroachment of grasses. It would not seriously injure the stand to put up the first cutting in the pre-bud stage for poultry feeding purposes and permit the succeeding crops to grow to the usual 10th-blossom stage before cutting.

The practice of cutting alfalfa in the pre-bud stage and dehydrating the entire plant for poultry feeding is growing in popularity. Dehydrating at high temperatures does not destroy the vitamin A content of the plant like bleaching in the sun as pointed out by Hauge *(11)* who reported that one sample of green alfalfa dried at a temperature of 200° C. and another sample dried rapidly at an extremely high temperature produced a dark green product and were about equally effective in preserving vitamin A of the plant. The field cured sample showed definite bleaching, being light green in color. The vitamin A content of the artifically dried samples was many times that of the sun-cured sample.

Russell *(34)* concluded that alfalfa leaves from plants dried by artificial heat contained at least seven times as much vitamin A as the leaves from hay that was cured in the field so that the greater part of its green color was lost. When alfalfa was dried in the sun in New Jersey, without exposure to dew or rain, there was an increase in the antirachitic potency of the leaves, but it was accompanied by a decrease in the vitamin A content. One should not infer from this work that sun-cured alfalfa is not valuable for vitamin A. It can be made an excellent source when care is taken in curing it. The hay for poultry feeding should be cured quickly in the shade when possible and not allowed to become wet or to bleach before it is stacked or placed in the mow. Alfalfa leaf meal has been used in all of the later experiments herein reported. This product should not be confused with commerical alfalfa meal which is much lower in proteins and higher in crude fiber. Payne *(31)* found alfalfa meal unpalatable when fed to laying hens at the rate of 16.6 per cent of the mash mixture or about 8 per cent of the total ration.

Palmer and Kennedy *(30)* report that many have assumed that vitamin A is one of the yellow plant pigments. Several papers they state have appeared

in support of this idea, in which vitamin A has been shown to occur more or less abundantly only in the plant organs which are relatively richly pigmented with yellow color. Kemster *(22)* states that feed rich in Xanthophyll are also rich in vitamin A and eggs with highly pigmented yolks possess an abundance of vitamin A. Under normal conditions the degree of yellow color in the yolk is a fair index to the vitamin A content of the egg, and feeding tests have demonstrated that pale-yolked eggs fed to chicks will produce less satisfactory growth than eggs with highly colored yolks. This latter statement agrees with results obtained by the authors as reported in Table XXXVII. However, Mattikow *(26)* in a more recent and exhaustive study of the literature on coloring matter in egg yolks expresses the belief that the concomitant vitamin properties of eggs with highly colored yolks should be further verified. The present belief is that golden colored egg yolks indicate richness in vitamin A, although it should be understood that the absence of color does not necessarily mean the absence of this vitamin. There are rare cases where vitamin A is supplied by feeding fresh, colorless fish oils or other non-pigmented substances. The fact that pale-yolked eggs as a rule are deficient in this important vitamin has been overlooked by many consumers.

EXPERIMENT XI, 1928-'29, LOTS 82-85

The object of this experiment was to determine whether or not alfalfa leaf meal would improve a ration containing 65 per cent of yellow corn and, if it caused improvement, what amount would give best results. It had been shown the previous year that 10 per cent of alfalfa leaf meal was slightly more desirable as a source of vitamin A than 5 or 15 per cent in a ration otherwise deficient in this vitamin. It was decided in this experiment to use 10 per cent alfalfa leaf meal as the upper level and to compare that amount with 5 per cent and none at all. The three rations in which yellow corn was used were to be compared with the ration of white corn used in lot 79 which gave the best results the previous year. The same building was used and the general management was the same as that followed in the previous experiment.

RATIONS

All-mash rations were used in the four different lots as follows:

Lot No.	82	83	84	85
Yellow corn, ground	.....	65	65	65
White corn, ground	65	.....	.....	.....
Meat and bone scraps	10	10	10	10
Wheat bran	15	15	15	15
Alfalfa leaf meal	10	10	5	.....
Synthetic meal	.....	.....	5	10
Totals	100	100	100	100

The synthetic meal used in lots 84 and 85 was the same as the formula given in Experiment X, page 47. The above rations were not analyzed chemically. The sun's direct rays which entered the open-front house during the winter and spring months were depended upon for the ultra-violet ray requirements.

BIRDS USED

One hundred White Leghorn females and six males were placed in each of the four lots November 1, 1928. Twenty-five in each lot were hens that had finished one year's production and 75 were pullets. The birds were confined to their 20 by 20-foot pens for the duration of the experiment. There were

no disease outbreaks other than slight colds. All hens were trapnested throughout the experiment and the eggs were pedigreed from each hen during the hatching season. Egg production was calculated on a hen-day basis and feed consumption was figured on a bird-day basis including the males. The experiment ended August 1, 1929.

FEED CONSUMED

The all-mash system of feeding used in the previous experiment was continued. This method was believed to be conducive to more uniform results, to prevent waste, and to provide more sanitary conditions than litter feeding, as none of the grain came in contact with the contaminated litter and floor. The average amount consumed per bird in the different lots is given in Table XXXIX.

TABLE XXXIX.—AVERAGE FEED CONSUMED PER BIRD, EXPERIMENT XI.

Lot No.	82	83	84	85
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*
All-mash feed	52.9	52.80	50.20	45.80
Oyster shell	1.3	1.08	.92	.90

These figures are less than is normally consumed, amounting to about four or five pounds of grain per bird. The average is about one pound less per bird than was consumed in Experiment X in eight months. It approaches more nearly the amount consumed by the birds in Experiment IX where the egg production averaged less than in this experiment.

TABLE XL.—TOTAL AND AVERAGE EGG PRODUCTION, EXPERIMENT XI.

Lot No.	82	83	84	85
Number of hens at beginning of experiment	100	100	100	100
Average number of hens during experiment	84	88	91	84
Total number of eggs produced	7,857	8,272	8,903	6,725
Average number of eggs produced	93	94	98	80
Percentage of eggs produced	34	34	36	29

EGG PRODUCTION

The average number of hens and the number and percentage egg production are given in Table XL. The average egg production is rather low compared with that in Experiment X. A number of these pullets were in production when the experiment started and the moving and handling caused many of them to molt and take a winter pause as indicated in figure 19. The fact also that most of the birds lost considerable weight, as shown in Table XLIV, indicates that they did not consume a sufficient amount of the all-mash feed for both good production and the maintenance of body weight.

The small difference in number of eggs laid is in favor of lot 84 which received the 5 per cent of alfalfa leaf meal. It is interesting to note that the production in lot 82 fed white corn and 10 per cent alfalfa leaf meal surpassed the results in lot 85 and compared favorably with lots 83 and 84. This indicates that white corn with an adequate vitamin A supplement has as high a feeding value as yellow corn with the same supplement. It also shows that

a ration composed of 65 per cent of yellow corn gave poorer results than similar rations supplemented with five and 10 per cent alfalfa leaf meal. Either 65 per cent of yellow corn did not supply a sufficient amount of vitamin A or the alfalfa leaf meal supplied desirable nutrients other than this vitamin.

Hauge, Carrick and Prange *(13)* reported that 25 per cent of yellow corn in the ration adequately met the vitamin A requirements of growing chicks to 10 weeks of age. They did not compare the ration with this amount of yellow corn with a ration to which additional vitamin A had been supplied in the form of alfalfa leaf meal. Halnan *(9)* stated that an excess of corn was laxative to poultry.

The number of eggs produced and the percentage distribution for the various lots according to egg production by each hen are given in Table XLI.

TABLE XLI.—HENS GROUPED ACCORDING TO EGG PRODUCTION. EXPERIMENT XI.

Lot No.	Eggs produced for the duration of experiment grouped as follows:				
	0-50.	51-100.	101-150.	151-200.	Total.
	Number and percentage of hens in each group.				
82	24	43	32	1	100
83	22	44	32	2	100
84	18	41	39	2	100
85	28	53	19	0	100

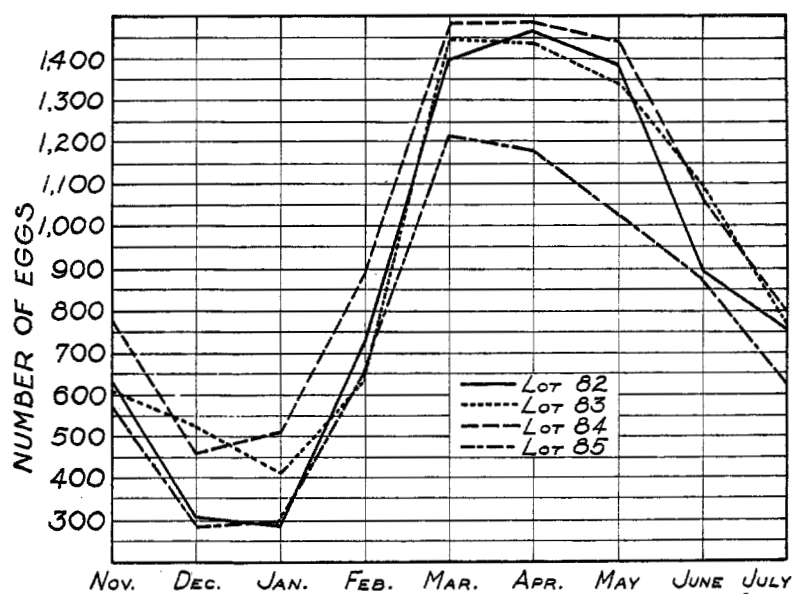

FIG. 19.—A graphic presentation of egg production by months in the four lots, Experiment XI.

The figures in Table XLI show that 81 per cent of the hens in lot 85 produced 100 eggs or less, compared with lots 82, 83, and 84 which had 67, 66, and 59 hens, respectively, in the two lower groups. Figure 19 shows the effects of the winter molt on egg production. The production curves are somewhat parallel until the completion of the fourth month when it is evident the vitamin A reserve in lot 85 was exhausted.

The birds in all lots went into a partial molt after the experiment started which accounts for the slump in production in December and January The hens in lot 84 led in production every month except December and June and lot 85 was the lowest in production every month except January.

HATCHABILITY OF EGGS

Between April 2 and May 14, 15 to 20 eggs were incubated from each female. A complete hatching record was kept for each bird. Six males were maintained in each lot from the beginning of the experiment until June 1, when they were removed and sold. In case of sickness or death among the males, substitutions from a reserve pen were made at the time of removal. The results are presented in Table XLII.

TABLE XLII.—EGG PRODUCTION, FERTILITY, AND HATCHABILITY RESULTS, EXPERIMENT XI.

Lot No.	82	83	84	85
Number of hens from which eggs were saved	76	79	80	71
Number of eggs set	1,504	1,492	1,528	1,368
Number of eggs fertile	1,317	1,314	1,347	1,106
Percentage of eggs fertile	88	88	88	81
Number of chicks dead in shell	178	164	224	294
Percentage of chicks dead in shell	14	12	17	27
Number of chicks hatched	1,139	1,150	1,123	812
Percentage of fertile eggs hatched	86	88	83	73
Percentage of total eggs hatched	76	77	73	59

The uniform fertility and high hatchability is noteworthy. Lot 85 which received yellow corn as the only source of vitamin A gave the lowest fertility and hatchability. This again indicates that 65 per cent of yellow corn either

TABLE XLIII.—HENS GROUPED ACCORDING TO HATCHABILITY OF EGGS, EXPERIMENT XI.

Lot No.	Percentage hatchability of eggs grouped as follows:					
	0-25 (a).	26-50.	51-75.	76-99.	100.	Total.
	Number and percentage of hens in each group.					
82	24	1	6	54	15	100
83	21	1	8	49	21	100
84	21	1	17	47	14	100
85	33	4	23	33	7	100

(a) All hens in this group had zero hatchability except one in lot 84 and four in lot 85. Most of these hens died before the hatching season started.

does not contain a sufficient amount of vitamin A for maximum hatchability or that alfalfa leaf meal must possess qualities other than vitamin A which aid hatchability. A distribution of birds according to the hatchability of their eggs is given in Table XLIII.

It is remarkable that so many hens had a perfect hatchability of fertile eggs set and that so large a number in each lot placed in the 76 to 99 per cent group. In a previous three-year hatchability study at the college poultry farm, only one per cent of the hens had perfect hatches. Lot 85 had more in the lower and fewer in the higher groups than any of the others. These figures support those in the previous table in showing that the ration in lot 85 was not adequate.

WEIGHTS OF BIRDS

Each bird was weighed on a gram scales at the beginning and conclusion of the experiment. The average weights for November 1 included only those birds that lived to August 1. The weights are given in Table XLIV.

TABLE XLIV.—AVERAGE WEIGHT OF FEMALES, EXPERIMENT XI.

Lot No.	82	83	84	85
Number of birds at close of experiment	80	79	83	77
	Gm.	*Gm.*	*Gm.*	*Gm.*
Average weight November 1, 1928	1,467	1,469	1,492	1,441
Average weight August 1, 1929	1,353	1,306	1,391	1,295
Loss	114	163	101	146
Percentage loss	7.8	11.1	6.8	10.1

It was unusual for all lots to lose weight and especially since all rations contained such a high percentage of corn, which is known to be fattening. It is evident from these losses in weight and from the feed consumption figures in Table XXXIX that the feed intake was not adequate. The males for tho above lots that lived through the experiment lost 3.4, 10.4, 10.1, and 4.6 per cent in weight, respectively.

Kennard and Bethke *(23)* found no difference in the weight of birds fed scratch grain and mash in equal parts, or those fed the same ration in the form of all mash. It is, however, a common belief among poultrymen that laying hens do not "fill up" on mash before going to roost as they do on whole grain and, therefore, they will do better when scratch grain is supplied each evening than where they depend upon mash feed alone.

MORTALITY OF BIRDS

The mortality was a little higher than normal for all lots. It appeared to be due to a variety of causes. Colds, roup, and prolapsed oviducts accounted for most of the deaths. Since the cause for a large number of the deaths could be determined from external symptoms, many of the birds were not examined by the disease specialist. The number of birds that died is shown in Table XLV. In a number of cases the birds were removed to a hospital when attacked by colds and after recovering they were disposed of instead of being returned to their respective lots. All such cases were included in the mortality figures.

TABLE XLV.—MORTALITY OF FEMALES, EXPERIMENT XI.

Lot No.	82	83	84	85
Number of birds at beginning of experiment	100	100	100	100
Number of birds that died	20	21	17	23
Percentage of mortality	20	21	17	23

TABLE XLVI.—SUMMARY OF RESULTS, EXPERIMENT XI.

Lot No.	82	83	84	85
Number of hens at beginning of experiment	100	100	100	100
Average number of hens	84	88	91	84
Number of hens at close of experiment	80	79	83	77
Pounds of feed consumed per bird	52.9	52.8	50.2	45.8
Percentage of egg production	34.0	34.0	36.0	29.0
Percentage of eggs hatched	86.0	88.0	83.0	73.0
Percentage of loss in weight for hens at close of experiment,	7.8	11.1	6.8	10.1
Percentage of mortality	20.0	21.0	17.0	23.0

SUMMARY

As in the previous experiment, the more important results in the foregoing tables are brought together in a summary table (Table XLVI) for convenient comparisons.

The differences are insignificant in the first three lots. The slight increase in egg production in lot 84 on a lower feed consumption and the low mortality would indicate, however, that 5 per cent of alfalfa leaf meal would be adequate and probably better than a larger amount where yellow corn is used as the basis of the ration.

The alfalfa leaf meal used in these experiments proved to be a practical, economical, and adequate source of vitamin A for rations either deficient in or possessing limited amounts of this vitamin. The results seem to justify the conclusion that 10 per cent of alfalfa leaf meal of the quality used in these experiments is adequate in vitamin A deficient rations or that 5 per cent will suffice in rations composed of 65 per cent yellow corn.

CONCLUSIONS

1. Rations deficient in vitamins A, B, or D will reduce the egg production and hatchability of breeding flocks.

2. Vitamin C is not essential in poultry rations; therefore, succulent feeds that contain this vitamin are not necessary.

3. Alfalfa leaf meal proved to be an excellent source of vitamin A. Ten per cent of the total ration was found to be adequate in a ration otherwise deficient in this vitamin.

4. Five per cent of the total feed intake of alfalfa leaf meal proved adequate when 65 per cent of the ration consisted of yellow corn and 10 per cent was sufficient when white corn comprised 65 per cent of the ration.

5. Poultry rations prepared from the common grains possess an adequate supply of vitamin B.

6. There is sufficient sunshine in Kansas at all seasons to meet the vitamin D requirements provided the birds are housed or managed so as to receive the benefits of the available direct rays of the sun.

7. Ordinary window glass screens out practically all of the ultra-violet rays that are effective in producing vitamin D.

8. Ultra-violet light from suitable lamps can be used to meet the vitamin D requirements of poultry.

9. The irradiated feeds tested in this experiment did not prove to be a satisfactory source of vitamin D for poultry.

10. The cod-liver oil used was found to be an adequate source of vitamin D for growing chicks and laying hens.

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