TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR,
College Station, Texas

BULLETIN NO. 633 MAY 1943

EFFECT OF SULPHUR ON CHICK NUTRITION

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B37—543—4M—L180

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Sulphur is used rather extensively in the control of coccidiosis. Its use in feeding chickens to prevent coccidiosis has, under some conditions, interfered with normal nutrition. It was the plan of these experiments to study the feeding of sulphur on the requirements of chicks vitamins A, D and riboflavin.

ne result of these experiments, are in agreement with the work of rs, in that chicks fed sulphur away from sunlight require four s as much vitamin D carrier as chicks fed no sulphur. On the other chicks fed sulphur did well if allowed two hours of direct noon-unlight distributed over a week's time.

he feeding of sulphur did not increase the requirements for carotene boflavin.

other words, the feeding of sulphur to chicks running in the sun- did not make it necessary to increase the vitamin content of the feeds.

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Ross M. Sherwood, J. Russell Couch,* Lee James,* and C. W. Carter

The rather extensive use of sulphur in the feed for the prevention of coccidiosis in chicks has increased the interest in the effect of this product on animal nutrition and especially vitamin requirements. Sulphur was fed to chicks at the Ohio Station as early as 1921. At that time Phillip, Carr, and Kennard (1) reported that the feeding of 2 per cent of flowers of sulphur in the diet produced faster growth up to eight weeks of age than did the control diet but that the mortality was slightly increased in the sulphur fed group. When the birds were fourteen weeks of age, the controls were slightly heavier than the sulphur fed birds.

Hendricks (2) did not find significant differences in length of wing and tail feathers of experimental hens fed various inorganic sulphur compounds as compared with the controls.

Holmes and co-workers (3) reported that the feeding of sulphur to chicks not receiving sunlight caused rickets unless additional amounts of fish liver oil were fed.

Goff and Upp (4) reported that commercial sulphur flour retarded growth less than other grades of sulphur. Goff and Upp (5) reported that ¼ per cent of 400-D fish liver oil failed to promote normal calcification and growth in chicks fed sulphur flour but that the percentage of bone ash in the tibia bones was higher when ½ per cent of 400-D fish liver oil was fed than when only ¼ per cent of 400-D fish liver oil was fed. Leg weakness was noted only in chicks receiving 7 to 10 per cent of flowers of sulphur.

Goff (6) reported that 5 per cent flowers of sulphur was fed to birds four weeks old or older for a period of two weeks without deleterious effects.

More information was needed on the effect of the feeding of sulphur on nutrition and especially on other vitamins than vitamin D. The studies reported in this bulletin were made possible by funds supplied by the Freeport Sulphur Company.

PROCEDURE

The general procedure for the thirteen different experiments reported in this bulletin dealing with sulphur studies are very similar. The projects in the Poultry Division are numbered consecutively as instituted. The thirteen sulphur experiments were not instituted at the same time and do not bear consecutive numbers. The chicks in these studies were either Single Comb White Leghorns or New Hampshires. In the ex-

*Major J. Russell Couch and Captain Lee James are on leave for service in our armed forces.

periments where day-old chicks were used, the lots were made up at random using only chicks of medium size. In the experiments where two-week old chickens were used, the lots were made up according to the gains for the first two weeks of age, the chicks having been kept under like conditions and fed the same diet for this two-week period.

All of the chicks were confined in battery brooders and housed away from sunlight. In the experiments where the birds were to be exposed to sunlight, they were placed in the sunlight in well ventilated open air sunning pens for the time required. They were never exposed over thirty minutes at one time. The chicks were weighed at the beginning and at the close of the experiment and at two-week intervals during the experiment.

The basal diet for Experiments 68, 72, 77, 80, 84, and 85 later referred to as basal diet 1 was 6 per cent of dried skimmed milk, 4 per cent of 50 per cent protein meat and bone scraps, 6 per cent of 41 per cent protein soybean oil meal, 2 per cent of 43 per cent protein cottonseed meal, 20 per cent of wheat gray shorts, 5 per cent of pulverized whole oats, 55 per cent of ground kafir, 1½ per cent of oyster shell, and ½ per cent of salt. With experiments 90, 96, and 111, the basal diet later referred to as basal diet 2 was 6 per cent of 67 per cent protein fish meal, 6 per cent of 41 per cent protein soybean oil meal, 6 per cent of 43 per cent protein cottonseed meal, 20 per cent of wheat gray shorts, 5 per cent of dehydrated alfalfa leaf meal, 5 per cent of pulverized whole oats, 48¼ per cent of ground kafir, 2 per cent of oyster shell, 1¼ per cent of poultry bone meal, and ½ per cent of salt. With Experiments 127, 134, 136, and 143, the basal diet later referred to as basal diet 3 was 6 per cent of 67 per cent protein fish meal, 6 per cent of 41 per cent protein soybean oil meal, 6 per cent of 43 per cent protein cottonseed meal, 20 per cent of wheat gray shorts, 5 per cent of dehydrated alfalfa leaf meal, 10 per cent of pulverized whole oats, 43 per cent of ground milo maize, 2 per cent of oyster shell, 1 per cent of poultry bone meal, and 1 per cent of salt. All of the feed that the chicks ate was weighed to them daily. Tap water was before the chicks at all times. All lots in an experiment had the same length of feeding period which varied with experiments from eleven to fourteen hours per day. Each experimental lot contained twenty-five chicks, and in most cases, the experiments were run in duplicate.

The bone ash determinations were made by the Division of Chemistry of the Texas Agricultural Experiment Station.

The term, "feed efficiency," for a given diet as used in this bulletin, is a value secured by dividing the total number of pounds of feed consumed by the number of pounds gain in live weight for the group receiving the diet.

EXPERIMENTAL RESULTS

Study of Types and Amounts of Sulphur

The four types of sulphur used in the chick feeding studies are of different particle size and also contain different percentages of amorphous and crystalline sulphur. The relative surface area is estimated by Dr. P. D. Peterson of the Freeport Sulphur Company to be flowers of sulphur 3, commercial sulphur flour 4, 325 mesh dusting sulphur 6, and micronized sulphur 10. In most of the earlier experiments the coarser sulphur flour was used while in later experiments 325 mesh dusting sulphur was used. The studies of the types and amounts of sulphur most satisfactory were conducted to answer questions resulting from changing recommendations for disease control studies.

In Experiments 96 and 111, the chicks were started on basal diet 2 at two weeks of age. Groups were made up according to gains in weight during their first two weeks at which time all were fed the same diet. The chicks used were New Hampshires. The diets fed Experiment 96 contained ½ per cent of 400-D fish liver oil; while the diets fed Experiment 111 contained only ¼ per cent of the same oil. This difference in amount of fish liver oil was used in order to study the sulphur under satisfactory and unsatisfactory vitamin D conditions. The chicks were not exposed to sunlight. It was a study of types and amounts of sulphur and their effect on gains, feed efficiency, and calcification and was not a study of the effect of sulphur on vitamins.

Table 1 comparing various amounts of three types of sulphur shows that the gains and feed efficiency were less satisfactory in the group in which 5 per cent of any of the three types of sulphur was fed than in the respective groups receiving 2½ per cent of sulphur. The per cent of bone ash indicates that the amount of vitamin D was adequate. In this experiment, there was an indication that the results with 5 per cent of sulphur were less favorable with the finer ground sulphur than with the coarser sulphur. With 2½ per cent of sulphur, this difference was not evident.

In Experiment 111, the data as given in Table 1 show no noticeable difference in gains between the amounts and fineness of grinding but do show that the amount of vitamin D was inadequate for a diet containing sulphur. As larger amounts and finer sulphur were used, the amount of feed required to produce a pound of gain increased.

Effect of Amounts of Sulphur on Chick Growth

It was the plan in Experiment 127 to determine the effect of 2, 2½, 3, 4, and 5 per cent of 325 mesh dusting sulphur and flowers of sulphur on gains in live weight and feed efficiency. The vitamin D for this experiment was supplied by including ½ per cent of 400-D fish liver oil in basal diet 3. The chicks were not exposed to sunlight. New Hampshire chicks were used in this experiment, which started when the chicks were two weeks of age and was conducted for eight weeks. Table 2 shows that 5 per cent of either type of sulphur gave less satisfactory gains and feed efficiency than the smaller amounts of sulphur.

Table 1. Effect of different levels and fineness of sulphur

	Kinds and Amounts of Sulphur Fed											
Sulphur flour (80 mesh)	0	1¼	2½	5	0	0	0	0	0	0	0	0
Dusting sulphur (325 mesh)	0	0	0	0	1¼	2½	5	0	0	0	0	0
Micronized sulphur	0	0	0	0	0	0	0	⅝	1¼	2½	5	0
Experiment 96 (½% fish liver oil, 400-D potency):												
Mean gain in grams	976	903	857	822	849	873	796	957	868	847	722	967
Feed efficiency	3.15	3.18	3.51	3.73	3.41	3.44	3.75	3.26	3.63	3.51	4.15	2.96
Per cent bone ash	50.50	49.16	49.99	50.09	51.40	50.42	49.55	50.11	50.34	51.78	50.86	50.50
Experiment 111 (¼% fish liver oil, 400-D potency):												
Mean gain in grams	865	478	473	506	457	491	491	481	456	490	460	705
Feed efficiency	3.10	3.72	3.88	4.04	3.87	4.19	4.34	3.91	3.97	4.02	4.62	3.23
Per cent bone ash	50.27	39.65	42.27	42.73	41.95	41.73	42.79	39.40	42.88	43.42	41.35	48.95

Table 2. Effect of different amounts and kinds of sulphur

	Kinds and Amounts of Sulphur Fed										
325 mesh dusting sulphur	2	2½	3	4	5	0	0	0	0	0	0
Flowers of sulphur	0	0	0	0	0	0	2	2½	3	4	5
Experiment 127:											
Mean gain in grams	775	789	775	795	742	775	796	706	764	819	744
Feed efficiency	3.49	3.53	3.53	3.62	3.88	3.18	3.31	3.24	3.40	3.49	3.64

The Effect of Sulphur Flour on Carotene Requirements

This study was planned to determine whether the feeding of 80 mesh sulphur flour to chicks increases the amount of carotene needed in the feed. Five experiments were started and four were completed using levels of 75, 100, and 125 micrograms of carotene, from alfalfa leaf meal, per 100 grams of feed. Basal diet 1 was fed both with and without sulphur flour. The levels of carotene are low enough so any significant adverse effects of sulphur should readily be observed either by poorer gains, mortality, or gross symptoms of vitamin A deficiency.

Data secured at other stations indicated that the vitamin D requirements of chicks fed diets containing sulphur was between 150 and 200 units per 100 grams of feed. In Experiments 68 and 72, using New Hampshire chicks, 3/8 per cent of 400-D fish liver oil in which the vitamin A had been destroyed by heat and aeration was supplied to the chicks. This would contain approximately 150 A. O. A. C. units of vitamin D per 100 grams of feed. No sunlight was supplied.

Table 3 gives the gains in live weight of the New Hampshire chicks of Experiments 68 and 72 also the per cent bone ash and the feed efficiency for the birds in Experiment 68. Experiment 68 was for ten weeks, and Experiment 72 was for six weeks. The bone ash analysis for Experiment 68 shows definitely that the birds did not receive enough vitamin D. This deficiency was enough to account for the poorer gains made by the chicks receiving sulphur flour as compared with those that did not receive sulphur flour. These data and detailed notes on rickets showed definitely that 3/8 per cent of 400-D fish liver oil is not sufficient. This was not learned until Experiment 72 had been conducted for approximately six weeks. Experiment 72 was closed at the end of six weeks, because no data could be secured on the effect of the feeding of sulphur on the vitamin A requirement of chicks if the basal diet was deficient in vitamin D.

Table 3. Effect of sulphur on carotene requirements of chicks fed diets containing 3/8 per cent of 400-D fish liver oil

	No Sulphur Fed			5% Sulphur Flour Fed		
Mg. carotene per 100 gms. feed	75	100	125	75	100	125
Experiment 68:						
Mean gain in grams	752	790	865	517	595	571
Feed efficiency	3.44	3.47	3.24	4.96	4.63	4.62
Per cent bone ash	----	----	51.07	----	----	42.90
Experiment 72:						
Mean gain in grams	331	343	359	267	261	268

Other series of experiments were conducted in which the vitamin D

was supplied by exposure of the birds to sunlight. In some cases fish liver oil in which the vitamin A had been destroyed by heat and aeration was fed, and in other cases no oil was given.

Experiments 77 and 80 were conducted with New Hampshire chicks, and Experiment 84 was conducted with both New Hampshire and Leghorn chicks. The birds in Experiment 77 were exposed to 2 hours of direct sunlight per week between the hours of 10 a. m. and 2 p. m., and those in Experiment 80 were exposed to 1.9 hours of sunlight per week, and in Experiment 84 to 1.6 hours of sunlight. The exposure to sunlight was in periods of not to exceed thirty minutes a day. The birds in Experiment 77 received ⅜ per cent of 400-D fish liver oil in which the vitamin A had been destroyed by heat and aeration; birds in Experiments 80 and 84 received no fish liver oil.

Table 4, which gives the gains and feed efficiency for the birds in Experiments 77, 80, and 84, shows no indication that any of the carotene was destroyed. No symptoms of vitamin A deficiency were noted. It is true that the feed efficiency was less satisfactory in the group where sulphur was fed than when sulphur was not fed. It must be remembered, however, that sulphur is inorganic material, thus the diets containing sulphur contained less organic material for growth than those not containing sulphur. That would partially account for the less satisfactory feed efficiency of some of the lots where sulphur was fed as compared with lots where sulphur was not fed.

Table 4. Effect of Sulphur on carotene requirements of checks receiving adequate amounts of vitamin D

	No Sulphur Fed			5% Sulphur Flour Fed		
Mg. carotene per 100 gms. feed	75	100	125	75	100	125
Experiment 77:						
Mean gain in grams	759	781	749	728	753	791
Feed efficiency	3.29	3.34	3.40	3.94	3.63	3.90
Experiment 80:						
Mean gain in grams	718	670	712	720	753	789
Feed efficiency	3.37	3.42	3.19	3.59	3.54	3.55
Experiment 84:						
(Reds)						
Mean gain in grams	632	650	658	582	740	675
Feed efficiency	3.26	3.39	3.33	4.25	3.70	3.54
(Leghorns)						
Mean gain in grams	501	488	532	477	604	521
Feed efficiency	3.48	3.89	3.73	4.49	4.29	4.31

Experiment 85, Table 5, was similar to Experiments 77, 80, and 84, except that only 50, 75, and 100 micrograms of carotene per 100 grams of feed were used instead of 75, 100, and 125 used in the previous studies.

The chicks used were Leghorns; the experiment started when the chicks were first hatched. The data in Table 5 show that there were no adverse effects of sulphur on gains and the feed efficiency was as satisfactory when the amount of organic feed material is considered. Table 5 shows the feed efficiency when figured as described under the heading "Procedure" in this publication and the efficiency when the feed other than sulphur was used in the computation. This second figure is 95 per cent of the original figure.

Table 5. Effect of sulphur with feeds containing low levels of carotene

	No Sulphur Fed			5% Sulphur Flour Fed		
Mg. carotene per 100 gms. feed	50	75	100	50	75	100
Experiment 85:						
Mean gain in grams	525	577	549	585	607	617
Feed efficiency	3.61	3.46	3.55	3.79	3.75	3.63
Feed efficiency on basis of feeds other than sulphur	3.61	3.46	3.55	3.60	3.56	3.45

There is no indication from any of these experiments that the feeding of sulphur caused the destruction of carotene in these diets. Although there are some irregularities in the gains, the birds on levels as low as 50 micrograms of carotene per 100 grams of feed made good gains with sulphur. These are low levels of carotene, and the fact that no vitamin A deficiencies resulted indicate that sulphur does not increase the requirements of carotene as it does the requirements of vitamin D.

Effect of Sunlight with Diets Containing Sulphur

In Experiment 90, New Hampshire chicks were fed sulphur in basal diet 2 with and without exposure to 4 hours of sunlight per week between 10 a. m. and 2 p. m. A control lot was fed no sulphur but was exposed to 4 hours of sunlight per week. All lots received ⅛ per cent 400-D fish liver oil. This experiment was conducted in quadruplicate. Table 6 shows that there was no difference in gains with the chicks receiving sunshine whether they received sulphur or not. There was

Table 6. Effect of sunlight with and without sulphur

	4 hours sunlight per week No sulphur	4 hours sunlight per week 5% sulphur flour	No sunlight 5% sulphur flour
Experiment 90:			
Mean gain in grams	822	824	649
Feed efficiency	3.39	3.43	3.89
Per cent bone ash	52.95	51.88	42.31

no difference in feed efficiency when the amount of organic food material is considered, neither was there any significant difference in the amount of bone ash in the tibia bones. When no sunshine was supplied with diets containing sulphur, the gains, the per cent of bone ash, and the feed efficiency were poor. This is in line with other work, which has shown that ⅛ per cent of 400-D fish liver oil is not sufficient as the sole source of vitamin D for birds fed sulphur.

Amount of Sunlight Needed With Sulphur

The question arose as to just how much sunlight is needed when 2½ per cent of 325 mesh dusting sulphur was included per 100 pounds of basal diet 3. In Experiment 134, different amounts of direct sunlight were supplied between 10 a. m. and 2 p. m. The chickens used in this study were New Hampshires; the experiment started when the chicks were two weeks old and continued for eight weeks. These data as presented in Table 7 indicate that as little as 1 to 2 hours of direct sunlight per week between 10 a. m. and 2 p. m. in July and August is all that is required in this part of the country even with chickens receiving sulphur. It is possible that 3 hours exposure is too much during this hot season. The birds appeared to suffer from the heat even though this 3 hour period was broken up into six periods of rather uniform length per week. The feed efficiency for these chickens was very favorable for chickens receiving sulphur.

Table 7. Effect of different amounts of sunshine with sulphur

Hours of sunlight per week	½	1	1½	2	2½	3
Experiment 134 (2½% 325 mesh dusting sulphur):						
Mean gain in grams	732	772	700	780	752	690
Feed efficiency	3.15	3.16	3.24	3.30	3.17	3.30

Requirements of Other Sources of Vitamin D

In order to check the requirements of other sources of vitamin D than fish liver oil when fed in diets with sulphur, Experiment 136 was conducted using 100 to 300 A. O. A. C. chick units of vitamin D from irradiated animal sterol. This was fed in basal diet 3 with 2½ pounds of 325 mesh dusting sulphur included per 100 pounds of feed to White Leghorn chicks from two weeks to ten weeks of age. The data as given in Table 8 show that it requires as much as 175 A. O. A. C. units of vitamin D in the form of irradiated animal sterol to secure satisfactory growth with a reasonably low feed efficiency. This is in very close agreement to all other work reported.

Table 8. Requirements of irradiated animal sterol when fed with sulphur

A. O. A. C. chick units of irradiated animal sterol	100	125	150	175	200	300
Experiment 136:						
Mean gain in grams	566	588	521	618	608	635
Feed efficiency	4.94	5.25	5.41	4.63	4.86	4.71

Effect of Sulphur on the Riboflavin Requirements of Chickens

In Experiment 143, basal diet 3 with 2½ per cent of 325 mesh sulphur included per 100 pounds of feed was fortified with 0, 200, 300, and 400 micrograms of riboflavin per 100 grams and was fed to White Leghorn chicks from two to ten weeks of age. Table 9 shows that the addition of riboflavin did not increase the rate of gain of the chicks or improve the feed efficiency. The basal diet is calculated to contain 200 micrograms of riboflavin per 100 grams of feed; this is below the amount recommended by Norris and co-workers (7). The fact that the basal diet did not contain excessive amounts of riboflavin and that no greater gains were secured from added riboflavin makes it rather evident that the 2½ per cent of sulphur has not destroyed the riboflavin or raised the riboflavin requirements of this diet.

Table 9. Effect of Riboflavin on rations containing sulphur

Micrograms of riboflavin added per 100 grams of feed	0	200	300	400
Experiment 143:				
Mean gain in grams	681	661	653	660
Feed efficiency	3.50	3.71	3.65	3.61

Summary and Conclusion

The feeding of diets containing 2½ per cent of 325 mesh dusting sulphur or 5 per cent of 80 mesh sulphur flour to chicks up to ten weeks of age did not show any significant destruction of carotene. Levels of 50 to 125 micrograms of carotene per 100 grams of diet were studied with and without sulphur. Gains in live weight, units of feed required to produce a unit of gain in live weight, and clinical vitamin A symptoms either in live birds or dead ones were observed and studied.

The feeding of diets containing 2½ per cent of 325 mesh dusting sulphur or 5 per cent of 80 mesh sulphur flour to chicks up to ten weeks of age raised the vitamin D requirements of the feed for chicks from 50 A. O. A. C. chick units to 175 or 200 A. O. A. C. chick units per 100 grams of the diet. These results are the same whether the vitamin D in the feed was supplied by fortified fish liver oil or by irradiated animal

sterol. Gains in live weight units of feed required to produce a unit of gain in live weight, number of cases of rickets or other symptoms of vitamin D deficiency also per cent of ash in the tibia bones were studied in drawing these conclusions.

Birds receiving a diet containing 2½ per cent of 325 mesh dusting sulphur up to ten weeks of age require approximately two hours of direct noonday sunlight distributed over a week's time to insure satisfactory gains in live weight with a low amount of feed to produce a unit of gain and to insure satisfactory calcification of bones and freedom from rickets.

Diets containing 2½ per cent to 4 per cent of 325 mesh dusting sulphur or flowers of sulphur produced more rapid gains in chicks to ten weeks or age with lower amounts of feed than diets containing larger amounts of sulphur.

Chicks fed to ten weeks of age on a diet containing 2½ per cent of 325 mesh dusting sulphur, adequate amounts of vitamins A and D, and minimum amounts of riboflavin grew as rapidly as other chicks fed a similar diet, except supplemented by 200, 300, or 400 micrograms of riboflavin per 100 grams of diet. This indicates that 2½ per cent of 325 mesh dusting sulphur does not raise the requirements for riboflavin in chick diets.

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