ION

ing Institute for Cancer Re- York, for very kindly pre- ple of reference 16-*epi*-estriol sential for this work.
urther indebted to Dr. D.S. ester Research Foundation, Mass., and Dr. J. Raeside, rinary College, Guelph, Ont., pful suggestions.

REFERENCES

. Chemical determination of estro- in urine. Methods of Biochemical or D. Glick), Interscience Publish- York.

Knupper and G. Pangels, 1959. on 16-Ketooestron in menschlichen a Endocrinologica, 30: 247–258.

. Ph.D. Thesis, McGill University, e., Canada.

H. Common, W. A. Maw and R. M. Presence of oestrone, oestradiol and tracts of ovaries of laying hens. on), 181: 351–352.

R. Spitzer and G. H. Twombley nversions of 16-oxygenated estro- synthesis of estriol-16-C[14] and its n man. J. Biol. Chem. 231: 787–

W. Zaharia and R. H. Common, tion of crystalline estradiol-17β gs of laying hens. Poultry Sci. 38:

D. S. Layne and R. H. Common, ation of estrone, estriol and an un- oid from estradiol in the laying hen. 8: 685–687.

1958. The biochemistry of the estro- es. Proc. Fourth International Con- chemistry Symposium No. IV,

. G. D. Watson and M. Panattoni, ation of a ketonic dihydroxy Kober m the urine of pregnant women. 0: 12–18.

. The separation of a estratrienic bolite in crystalline form, by ex- paper chromatograms. Chimica -11. (cited from Chem. Abstr. 47:

., and A. A. Sandberg, 1956. Stud- nolic steroids in human subjects. I. n of 16-C[14]-estrone to C[14]-16-keto- Biochem. 63: 478–480.

The Tolerance of Growing Chickens for Dietary Copper

ARNON L. MEHRING, JR., JOHN H. BRUMBAUGH,[1]
ANGUS J. SUTHERLAND[2] AND HARRY W. TITUS
Lime Crest Research Laboratory, Limestone Products Corporation of America, Newton, New Jersey

(Received for publication September 14, 1959)

IT HAS long been known that copper is an essential mineral element in the nutrition of animals. The fact that excessive amounts of copper are poisonous is widely recognized, too. A review of published reports, however, indicates that the level in the diet at which copper begins to become toxic and some of the effects of toxic levels upon particular species are not so well known.

Boyden, Potter and Elvehjem (1938) reported that 500 or more p.p.m. of copper or at least 100 times the normal intake is necessary to cause toxicity in rats. Kaufman *et al.* (1952) observed a moderately toxic effect when 0.1 percent $CuSO_4 \cdot 5H_2O$ (approximately 250 p.p.m. Cu) was included in the diet of rats for eight months, but not when it was included for only three or four months.

Cunningham reported, (Chilean Nitrate Educational Bureau, 1948a), that doses of copper sulfate of 80 grams or less were not poisonous to yearling heifers or to adult cows, but that a single dose of 400 grams was lethal to all cattle. The average lethal dose ranged between 200 and 400 grams.

Barber *et al.* (1957) fed diets containing 0.1 percent $CuSO_4 \cdot 5H_2O$ (approximately 250 p.p.m. Cu) to swine and observed no ill effects, but when the level of $CuSO_4 \cdot 5H_2O$ was increased to 0.5 or 1.0 percent there was a rapid depression of appetite and reduction of growth rate. When the larger quantities of added $CuSO_4 \cdot 5H_2O$ were reduced to 0.1 percent or were omitted, growth was resumed satisfactorily.

Hinshaw and Lloyd (1930) added $CuSO_4 \cdot 5H_2O$ to the drinking water of turkeys, and observed that as little as one part in 1,600 parts of water was injurious because the turkeys refused to drink the water and eat their feed in normal amounts. The degree of "starvation" that resulted increased as the concentration of copper was increased in the water. Vohra and Kratzer (1957) added 910 p.p.m. of copper, as $CuSO_4 \cdot 5H_2O$, to lysine-deficient diets of turkey poults, and observed that they grew as well, up to 24 days of age, as those receiving no added copper. However, levels of 2,400 p.p.m. copper killed all the poults.

Underwood *et al.* (1956) added copper sulfate to the drinking water of chicks in dilutions of 1 to 1,000 and 1 to 1,500, and observed that there was slightly less consumption of water than when the chicks were supplied plain water, but they found no significant difference in the weights of the chicks after a period of eighteen days. Mayo *et al.* (1956) reported significant reductions in growth of chicks up to four weeks of age when 324 p.p.m. copper in one experiment, and 520 p.p.m. copper in another, were included in the diet of chicks. A marked increase in mortality resulted when the chicks received 1,270 p.p.m. copper in their diet. Arthur, Motzok and Branion (1958) supplied levels of 100, 200, and 500 p.p.m. copper in the

[1] Present address: Lindsey-Robinson and Company, Roanoke, Virginia.

[2] Present address: Johns-Manville Corporation, Manville, New Jersey.

diets of chicks, and observed no ill effects up to the age of eight weeks.

This experiment was undertaken for the purpose of learning what levels of copper, in the form of copper oxide, are toxic to growing chickens when they are consuming a practical, corn-soybean oil meal diet to which the copper oxide has been added; and to observe the ability of chicks to recover from toxic levels when the added copper is omitted from their diets.

EXPERIMENTAL

Chicks of a production-bred strain of New Hampshires, the growth of which is slower than that of chicks of a typical broiler strain, were used for this experiment. A few more than the required number of chicks were hatched, and the extremely light and heavy chicks were discarded. The remaining two hundred and sixty day-old chicks were distributed at random into thirteen lots of twenty chicks each in such a way that the live weights of the chicks in any lot were as nearly as possible like those of the chicks in all the other lots. For the first four weeks, the chicks were kept in metal starting batteries in a room in which the temperature was maintained at 75° ± 2°F. and the humidity was held at 50 ± 5 percent. For the remainder of the experiment, the chicks were kept in metal developing batteries in another room in which the temperature was held at 70° ± 2°F. and the humidity was kept at 50 ± 5 percent. Both rooms were without windows and were artificially illuminated for fourteen hours of each day. Throughout the experiment, the chicks were supplied with distilled water in stainless-steel water pans, and their feed was provided in stainless-steel feed troughs.

A practical-type, corn-soybean oil meal, all-mash diet was used as the basal diet. The formula of this diet is given in Table 1. Chemical analysis of the basal diet indicated that it contained 26 p.p.m. of copper. Two lots of chicks were fed this diet without added copper, and the remaining eleven lots received the same diet after the addition of graded quantities of copper in the form of copper oxide. The levels of copper in the diets of the respective groups of chicks are given in Table 2. The highest level of copper that was fed was calculated to be 1,176 p.p.m. Analysis indicated that the diet contained 1,180 p.p.m. of copper.

Table 1.—*Formula of the basal diet*

Ingredient	Percent
Ground yellow corn	61.67
Soybean oil meal (44% protein)	30.75
Fish meal (Menhaden)	3.00
Calcite flour	1.67
Dicalcium phosphate	1.59
Riboflavin supplement[1]	.538
Salt	.400
25% dry mixture choline chloride	.150
Trace-mineral pre-mix (Delamix[2])	.100
Vitamin B_{12} supplement[3]	.050
Vitamin A supplement (Nopcay "10"[4])	.033
Vitamin E supplement (Myvamix[5])	.025
Vitamin D_3 supplement[6]	.020
Niacin	.002
50% dry mixture procaine penicillin	.0011
10% dry mixture folic acid	.0004
Calcium pantothenate	.0003
Menadione sodium bisulfite	.0002
Total	100.0000

[1] Contained 227 milligrams riboflavin per pound.
[2] Contained 6% manganese, 0.12% iodine, 2% iron, 0.2% copper, 0.02% cobalt, 0.01% zinc.
[3] Contained 6 milligrams vitamin B_{12} per pound.
[4] Contained 10,000 I.U. vitamin A per gram.
[5] Contained 20,000 I.U. vitamin E per pound.
[6] Contained 1,500 I.C.U. vitamin D_3 per gram.

At ten weeks of age, two male chicks and two female chicks were selected at random from each lot. Their livers and spleens were removed. The four livers from each lot and the four spleens from each lot were combined into separate composite samples. Each sample was analyzed for its content of copper, molybdenum, and sulfate.

When the chicks were ten weeks old,

TABLE 2.—*Average live weight, feed efficiency, and mortality of the chicks receiving graduated levels of copper in their diet for the first ten weeks, but no added copper thereafter*

Lot number	Copper added to the feed 0–10 wks.	Total copper in the feed 0–10 wks.		Average live weight[1] at age of				Feed efficiency[2] for period of		Mortality during first 10 weeks
		Calculated	Analyzed	10 weeks	12 weeks	14 weeks	16 weeks	0–10 weeks	10–16 weeks	
	p.p.m.	p.p.m.	p.p.m.	grams	grams	grams	grams			percent
1	0	—	26	1,083.8	1,390.3	1,601.7	1,785.4	.335	.078	5
13	0	—	26	1,078.2	1,423.2	1,686.2	1,879.6	.335	.090	0
2	10.8	36.8	—	1,103.0	—	—	—	.349	—	0
3	26.0	52.0	—	1,076.8	—	—	—	.348	—	5
4	47.5	73.5	—	1,065.6	—	—	—	.340	—	5
5	78.0	104.0	—	1,080.0	—	—	—	.344	—	0
6	121.1	147.1	—	1,099.5	—	—	—	.340	—	0
7	182.0	208.0	—	1,112.7	—	—	—	.341	—	5
8	268.1	294.1	—	1,109.5	—	—	—	.352	—	0
9	390.0	416.0	403	1,117.0	—	—	—	.350	—	10
10	562.2	588.2	570	1,016.6	1,304.8	1,595.9	1,793.6	.342	.088	5
11	806.0	832.0	749	757.9	1,032.2	1,374.6	1,542.1	.334	.121	15
12	1,150.4	1,176.4	1,180	555.6	888.2	1,185.9	1,482.5	.303	.134	40

[1] Average of the average for the males and the average for the females.
[2] Unit gain in live weight per unit of feed consumed.

the experiment was terminated for all but five lots of chicks, the two basal lots and the three lots the growth of which had been impaired as a result of the high level of copper in their diets. These five lots of chicks were fed the basal diet without added copper for another six weeks to determine whether the chicks could recover from the toxic effects of the copper.

At sixteen weeks of age, samples of livers and spleens were again taken from each of the remaining lots of chicks in the same manner as before. The tissues were analyzed for content of copper, molybdenum, and sulfate.

RESULTS AND DISCUSSION

A marked depression in the growth rate of the chicks occurred on the three diets containing the largest quantities of copper. Levels of copper of 588, 832, and 1,176 p.p.m. exerted a toxic effect on growth; and the greater the quantity of copper in the diet, the poorer was the growth made by the chicks. The average live weights of the chicks at ten weeks of age are presented in Table 2. It appeared that the minimum toxic level of copper is about 500 p.p.m. At ten weeks of age, the average live weight of the chicks in lot 10, which received the diet containing 588 p.p.m. of copper, was 94.0 percent of the average live weight of the chicks of lots 1 and 13, that received no added copper in the diet. The average live weight of the chicks of lot 11, which received the diet containing 832 p.p.m. of copper, was 70.1 percent of the average live weight of the chicks fed the basal diet (no added copper); and the average live weight of the chicks in lot 12, which received the diet containing 1,176 p.p.m. of copper, was only 51.4 percent of the live weight of the chicks fed the basal diet.

The five lots of chicks that were fed the basal diet without added copper from ten until sixteen weeks of age were weighed at two-week intervals. Table 2 gives the average live weights. Between the ages of ten and sixteen weeks, the chicks, the growth of which had been retarded by the higher levels of copper, grew more rapidly than the chicks that had been fed the basal diet. The greater the depression in growth, the more rapid was the rate of growth after ten weeks. At sixteen weeks of age, the average live weight of the chicks of lot 10, which had received the diet containing 588 p.p.m. of copper, increased to 97.9 percent of the average live weight of the chicks of lots 1 and 13, that had received the basal diet.

The average live weight of the chicks of lot 11, which had received the diet containing 832 p.p.m. of copper, increased to 84.2 percent of the average weight of lots 1 and 13; and the average live weight of the chicks of lot 12, which had received the diet containing 1,176 p.p.m. of copper, increased to 80.9 percent of the average weight of lots 1 and 13, the two lots fed the basal diet.

The feed efficiencies for the period of ten to sixteen weeks of age for each of the five lots of chicks that were fed the basal diet without added copper are given in Table 2. The efficiency was greater for those lots the growth of which had been retarded, but since the chicks were smaller and since efficiency is a function of live weight, it was to be expected that the retarded lots of chicks would be more efficient during this period. The efficiency was nearly twice as great for the chicks that had received the diet containing 1,176 p.p.m. of copper to the age of ten weeks as for the chicks that had received only the basal diet, but it still was only about half as great as it was for the chicks in the basal lots when they were at the same live weights.

The mortality in each lot of chicks up to ten weeks of age is given in Table 2. Most of the deaths occurred in the lots that were fed the diets containing the highest levels of copper. Forty percent of the chicks in lot 12, which received the diet containing 1,176 p.p.m. of copper up to ten weeks of age, died by the tenth week.

The effect of the level of copper in the diet on storage of copper in the livers and spleens of the chicks is apparent in Table 3. The data in Table 3 indicate that the copper content of the livers of the chicks increased in each instance in which copper was added to the diet. The copper content of the livers was much greater at the higher levels of dietary copper. The chicks of lot 12 (1,176 p.p.m. Cu), for instance, stored four times as much copper in their livers as the chicks of lot 10 (588 p.p.m. Cu), although they received only twice as much copper in their diet. Similarly, the chicks of lot 11 (832 p.p.m. Cu), stored about three times as much as the chicks of lot 9 (416 p.p.m. Cu).

At sixteen weeks of age, after the chicks had not received supplementary copper in their diet for six weeks, much of the excess copper had been eliminated form the livers. The copper content of the

TABLE 3.—*Content of copper, molybdenum, and sulfate of composite samples*[1] *of livers and spleens taken from chicks at ten and sixteen weeks of age*

Lot number	Total calculated level of copper in the feed 0–10 weeks	Copper content[2]				Molybdenum content[2]				Sulfate content[2]			
		Liver		Spleen		Liver		Spleen		Liver		Spleen	
		10 weeks	16 weeks	10 weeks	16 weeks	10 weeks	16 weeks	10 weeks	16 weeks	10 weeks	16 weeks	10 weeks	16 weeks
	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.		p.p.m.
1 / 13	26[3]	13.9	81.5 / 98.0	4.1	28.4 / 40.0	3.1	5.5 / 8.2	1.5	1.8 / 1.8	14.0	43.2 / 44.8	Amount of tissue too small to detect quantity of sulfate.	29.6 / 38.4
2	36.8	50.0	—	7.6	—	7.9	—	2.5	—	17.6	—		—
3	52.0	49.0	—	13.0	—	14.6	—	3.3	—	58.0	—		—
4	73.5	52.5	—	7.0	—	8.4	—	1.7	—	36.0	—		—
5	104.0	56.0	—	21.6	—	8.6	—	1.5	—	20.0	—		—
6	147.1	55.5	—	14.0	—	10.0	—	1.6	—	34.0	—		—
7	208.0	139.0	—	36.0	—	7.9	—	1.2	—	36.0	—		—
8	294.1	147.0	—	10.2	—	5.1	—	1.5	—	19.6	—		—
9	416.0	176.0	—	8.8	—	8.5	—	2.0	—	39.2	—		—
10	588.2	184.0	115.0	12.0	27.8	12.2	7.1	2.5	1.6	31.2	48.0		40.0
11	832.0	595.0	98.0	14.0	31.4	15.2	7.1	2.4	1.5	64.0	40.0		37.2
12	1,176.4	820.0	264.0	16.0	42.0	21.6	10.0	8.6	2.9	568.0	140.0		26.0

[1] Composite samples consisted of livers and spleens from two males and two females selected at random. The composites from the two lots of chicks on the basal diet without additional copper were combined at ten weeks for both livers and spleens, but were kept separate at sixteen weeks.
[2] Dry matter basis.
[3] Determined by analysis.

s of age is given in Table 2. deaths occurred in the lots ed the diets containing the s of copper. Forty percent of n lot 12, which received the ng 1,176 p.p.m. of copper up s of age, died by the tenth

of the level of copper in the ge of copper in the livers and e chicks is apparent in Table in Table 3 indicate that the nt of the livers of the chicks each instance in which copled to the diet. The copper the livers was much greater er levels of dietary copper. of lot 12 (1,176 p.p.m. Cu), . stored four times as much eir livers as the chicks of lot n. Cu), although they received s much copper in their diet. e chicks of lot 11 (832 p.p.m. about three times as much as lot 9 (416 p.p.m. Cu).

weeks of age, after the chicks eived supplementary copper for six weeks, much of the r had been eliminated form The copper content of the

mposite samples[1] of livers weeks of age

content[2]		Sulfate content[2]			
Spleen		Liver		Spleen	
10 eks	16 weeks	10 weeks	16 weeks	10 weeks	16 weeks
p.m.	p.p.m.	p.p.m.	p.p.m.		p.p.m.
.5	1.8 / 1.8	14.0	43.2 / 44.8	Amount of tissue too small to detect quantity of sulfate.	29.6 / 38.4
.5	—	17.6	—		—
.3	—	58.0	—		—
.7	—	36.0	—		—
.5	—	20.0	—		—
.6	—	34.0	—		—
.2	—	36.0	—		—
.5	—	19.6	—		—
.0	—	39.2	—		—
.5	1.6	31.2	48.0		40.0
.4	1.5	64.0	40.0		37.2
.6	2.9	568.0	140.0		26.0

s selected at random. The composites from weeks for both livers and spleens, but were

livers of the chicks of lot 12, which had received 1,176 p.p.m. of copper, was only about three times a great as that of the chicks of lots 1 and 13 that had not received extra dietary copper.

The copper content of the spleens was not so greatly affected by the level of copper in the diets of the chicks as was the copper content of the livers. All lots of chicks that received extra dietary copper stored more copper in their spleens than the lots that did not receive extra dietary copper. However, there was no consistent increase in storage of copper in the spleens. At sixteen weeks of age, there was no more copper in the spleens of the chicks that had been fed the diets containing the highest levels of copper than in the spleens of the chicks that had received the basal diet.

The livers and spleens were analyzed for both molybdenum and sulfate because several investigators had shown an interesting reciprocal relationship to exist between the metabolism of copper and molybdenum, which in turn may be affected by the sulfate content of the diet.

Reports by Dick, as discussed by Underwood (1956); Dick and Bull (Chilean Nitrate Educational Bureau, 1948b); and Allcroft and Lewis (1956) indicated that the feeding of molybdenum to sheep and cattle decreases the storage of copper in the livers of the animals. Dick concluded from his experiments, however, that this influence of molybdenum upon copper storage exists only in the presence of high levels of inorganic sulfate. Wynne and McClymont (1956), reported that an increase in either molybdenum or sulfate (in the form of Na_2SO_4) reduced the storage of copper in the livers of sheep, and that when both were added together, an even greater reduction of storage of copper occurred.

Reports by Ferguson, Lewis and Watson, (Chilean Nitrate Educational Bureau 1948c), and Henderson (1957), indicated that the ill effects of high levels of molybdenum in the feed consumed by cattle were corrected by the administration of copper sulfate. Similarly, Comar, Singer and Davis (1949) observed that the toxic effects of 80 p.p.m. of molybdenum in the diets of rats were corrected when 35 p.p.m. of copper were added to the diet which contained only 2 p.p.m. of copper. Arrington and Davis (1953) reported that 200 p.p.m. of copper corrected the toxic effects of 1,000 p.p.m. of molybdenum in the diets of rabbits.

The few reports on the effects of copper on molybdenum in poultry do not indicate the same relationship, however. Arthur, Motzok and Branion (1958) fed toxic levels of molybdenum (200, 350, and 500 p.p.m.) to chicks up to the age of eight weeks. The addition of 500 p.p.m. of copper to the diet did not reduce, but increased the toxic effects of molybdenum. Davies *et al.* (1958) fed 500 p.p.m. of molybdenum to chicks and the toxic effects of the molybdenum were not reduced by the addition of 200 or 500 p.p.m. of copper.

In the experiment reported here, an interrelationship among copper, molybdenum, and sulfate existed as evidenced by the increased storage of molybdenum and sulfate by the chicks fed high levels of copper, despite the fact that no additional molybdenum or sulfate was added to the diets.

It may be noted in Table 3 that the molybdenum content of the livers and spleens of the chicks that received the highest level of copper was several times as great as that of the chicks that received the basal diet. In general, it appeared that the molybdenum content increased in both the liver and spleen when additional copper was fed, but no large increase occurred until the highest level, 1,176 p.p.m., was fed. When the chicks were sixteen weeks of age, and the added copper had been omitted from the diets for six weeks, the molybdenum content of the livers and spleens of the chicks that received the highest level of copper was still greater than that of the chicks in lots 1 and 13 that had not received added copper in their diet.

The sulfate content of the livers of the chicks that received the highest level of copper up to ten weeks of age was markedly increased. At sixteen weeks of age, after the chicks had been fed the basal diet without added copper for six weeks, the sulfate content of the livers was only several times greater than that of the control lots. Very small increases occurred in the sulfate content of the livers of the chicks that had been fed the diets containing the other levels of copper. The samples of spleens taken at ten weeks were too small to permit detection of sulfate. At sixteen weeks, no greater quantity of sulfate existed in the spleen of the chicks fed high levels of copper than in the spleens of the control chicks.

Thus, it appears that when additional copper is fed to chicks, more of the molybdenum and sulfate of the diet are retained by the chicks.

The data on feed efficiency, presented in Table 2, suggest that levels of copper below the toxic level of about 500 p.p.m. may have had some beneficial effect. The copper may have acted as a chemical antibiotic. The efficiency was greater for each lot of chicks that received less than the toxic quantity of copper than for the two lots of chicks that received the basal diet.

This observation, that copper may have acted as a chemical antibiotic, is somewhat similar to ones made by several investigators working with swine. Barber, Braude and Mitchell (1955) reported that the rate of gain of pigs was improved as much when 250 p.p.m. of copper as copper sulfate was added to their diets as when 4.5 mg. of aureomycin was added to their diets. Barber *et al.* (1957) reported that swine fed diets containing 0.1 percent $CuSO \cdot 5H_2O$ (approximately 250 p.p.m. Cu) improved in rate of growth similarly to pigs that were fed diets containing 10 grams of oxytetracycline or 20 grams of chlortetracycline per ton of feed. Lucas and Calder (1957) fed 0.1 percent $CuSO_4 \cdot 5H_2O$ in the diets of pigs and noted greater improvement in growth and feed efficiency than when 5.36 mg. of penicillin per pound of feed was added. If copper functions in a manner similar to antibiotics in the diets of swine, it is quite possible that it may have functioned in the same manner in the diet of chickens in this experiment.

SUMMARY

A corn-soybean oil meal diet containing graded quantities of copper, in the form of copper oxide, was fed to growing chickens. The maximum level of copper fed was estimated to be 1,176 p.p.m. (1,180 p.p.m. by analysis). The chicks were fed this diet to the age of ten weeks, at which age the two control lots of chicks and those lots the growth of which had been depressed by the higher levels of copper were given the basal diet without supplementary copper for six additional weeks.

The minimum toxic level of copper appeared to be about 500 p.p.m. The chicks, the growth of which was depressed by the higher levels of copper in the diet, grew more rapidly after the added copper was omitted from their diet at ten weeks of age. The chicks that received the highest level of copper (1,176 p.p.m.) in their diet weighed only 51.4 percent as much, at ten weeks of age, as the chicks that received the basal diet only. At sixteen weeks of age, after receiving the basal diet

50 p.p.m. of copper as cop-
as added to their diets as
. of aureomycin was added
-. Barber *et al.* (1957) re-
vine fed diets containing 0.1
r·$5H_2O$ (approximately 250
nproved in rate of growth
igs that were fed diets con-
ms of oxytetracycline or 20
tetracycline per ton of feed.
.lder (1957) fed 0.1 percent
in the diets of pigs and
improvement in growth and
r than when 5.36 mg. of
pound of feed was added.
ctions in a manner similar
in the diets of swine, it is
that it may have functioned
anner in the diet of chickens
nent.

SUMMARY

ean oil meal diet containing
ties of copper, in the form of
was fed to growing chickens.
n level of copper fed was
e 1,176 p.p.m. (1,180 p.p.m.
The chicks were fed this diet
ten weeks, at which age the
its of chicks and those lots
which had been depressed
levels of copper were given
et without supplementary
additional weeks.

am toxic level of copper ap-
bout 500 p.p.m. The chicks,
which was depressed by the
of copper in the diet, grew
after the added copper was
their diet at ten weeks of
ks that received the highest
(1,176 p.p.m.) in their diet
51.4 percent as much, at
age, as the chicks that re-
sal diet only. At sixteen
fter receiving the basal diet without added copper for six weeks, the chicks that had received the highest level of copper in their diet weighed 80.9 percent as much as the chicks in the control lots.

There was an increase in the storage of copper, molybdenum, and sulfate in the livers and spleens of the chicks that were fed the diets that contained added copper. The storage of each was much greater in those instances in which the higher levels of copper were added to the basal diet. The levels of copper, molybdenum, and sulfate in the livers and spleens were more nearly normal after the high-copper diets were replaced by the basal diet for six weeks.

There was an improvement in the feed efficiency of those lots of chicks that were fed the diets that contained added copper, up to the toxic level; and this suggests that the copper may have exerted an effect similar to that of antibiotics.

REFERENCES

Allcroft, R., and G. Lewis, 1956. Relationship of copper, molybdenum and inorganic sulphate content of feeding stuffs to the occurrence of copper deficiency in sheep and cattle. Landbouwk. Tijdschr. 68: 711–22. (abstracted in Nut. Abst. Rev. 26: No. 5382, 1956.)

Arrington, L. R., and G. K. Davis, 1953. Molybdenum toxicity in the rabbit. J. Nutrition, 51: 295–304.

Arthur, D., I. Motzok and H. D. Branion, 1958. Interaction of dietary copper and molybdenum in rations fed to poultry. Poultry Sci. 37: 1181.

Barber, R. S., R. Braude and K. E. Mitchell, 1955. Antibiotic and copper supplements for fattening pigs. Brit. J. Nutrition, 9: 378–381.

Barber, R. S., R. Braude, K. G. Mitchell, J. A. F. Rook and J. G. Rowell, 1957. Further studies on antibiotic and copper supplements for fattening pigs. Brit. J. Nutrition, 11: 70–79.

Chilean Nitrate Educational Bureau, 1948a. Bibliography of the Literature on the Minor Elements and their Relation to Plant and Animal Nutrition, 4th ed., vol. 1, p. 334.

Chilean Nitrate Educational Bureau, 1948b. Bibliography of the Literature on the Minor Elements and their Relation to Plant and Animal Nutrition, 4th ed., vol. 1, p. 726.

Chilean Nitrate Educational Bureau, 1948c. Bibliography of the Literature on the Minor Elements and their Relation to Plant and Animal Nutrition, 4th ed., vol. 1, p. 727.

Boyden, R., V. R. Potter and C. A. Elvehjem, 1938. Effect of feeding high levels of copper to albino rats. J. Nutrition, 15: 397–402.

Comar, C. L., L. Singer and G. K. Davis, 1949. Molybdenum metabolism and interrelationships with copper and phosphorus. J. Biol. Chem. 180: 913–922.

Davies, R. E., R. N. Burroughs, B. L. Reid and J. R. Couch, 1958. Molybdenum interrelationships in chick nutrition. Poultry Sci. 37: 1196.

Henderson, J. A., 1957. Conditioned copper deficiency in Canadian cattle. Can. J. Comp. Med. Vet. Sci. 21: 332–336. (abstracted in Chem. Abst. 52: 4813–4814, 1958.)

Hinshaw, W. R., and W. E. Lloyd, 1930. Studies on the use of copper sulphate for turkeys. Poultry Sci. 10: 392–393.

Kaufman, N., J. A. Cartaya, P. L. White, D. M. Hegsted and T. D. Kinney, 1952. An attempt to produce hemochromatosis experimentally and the effect of high levels of copper and choline in the diet. J. Nutrition, 46: 433–444.

Lucas, I. A. M., and A. F. C. Calder, 1957. Antibiotics and a high level of copper sulfate in rations for growing bacon pigs. J. Agr. Sci. 49: 184–199.

Mayo, R. H., S. M. Hauge, H. E. Parker, F. N. Andrews and C. W. Carrick, 1956. Copper tolerance of young chickens. Poultry Sci. 35: 1156-1157.

Underwood, E. J., 1956. Trace Elements in Human and Animal Nutrition. Academic Press, Inc., New York pp. 109, 134, 139.

Underwood, P. C., J. H. Collins, C. G. Durbin, F. A. Hodges and H. E. Zimmerman, Jr., 1956. Critical tests with copper sulfate for experimental moniliasis (crop mycosis) of chickens and turkeys. Poultry Sci. 35: 599–605.

Vohra, P., and F. H. Kratzer, 1957. The effect of dietary copper and molybdenum on turkey poults. Poultry Sci. 36: 1096–1097.

Wynne, K. N., and G. L. McClymont, 1956. Copper-molybdenum-sulphate interaction in induction of ovine hypercupraemia and hypocuprosis Australian J. Agric. Res. 7: 45–56. (Abstracted in Nut. Abst. Rev. 26: No. 3985, 1956).

POULTRY SCIENCE

Volume 39

Published by
THE POULTRY SCIENCE ASSOCIATION

Guelph, Ontario, Canada
1960