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Four experiments were conducted to determine if additional supplementation of zinc and/or copper above the NRC requirement levels would result in improved growth of broilers. In Experiment 1, the additional supplementation with 40 ppm zinc, 4 ppm copper, or the combination of these two in a corn-soybean meal ration containing normal trace mineral supplementation produced a significant growth response in broiler chicks reared in a galvanized battery to four weeks of age. In Experiment 2, no growth response was observed in floor reared broilers fed rations similar to those fed in Experiment 1. The possibility of coprophagy by floor reared broilers may be responsible for this difference. No significant treatment differences in feed efficiency or mortality were observed in either Experiment 1 or 2. In Experiment 3, broilers were reared on the floor and fed corn soybean meal rations with zinc to copper ratios of 9 to 28, as well as two different levels of iron, iodine and cobalt. No significant differences in growth, feed conversion and mortality were observed at seven weeks of age, however, the birds fed the ration with the widest zinc-to-copper ratio (28) were the smallest. In Experiment 4, three strains of broilers were reared on litter and fed two different levels of supplemental zinc and copper, but the ratio of zinc to copper was maintained. None of the strains grew significantly better or used more feed as a result of the treatments. The birds with the Hubbard genetic background were generally numerically heavier than the Peterson x H & N strain, regardless of treatment.

The supplementation with additional zinc and/or copper for floor reared broilers did not result in significant growth improvement or feed efficiency.

Supplementation of Zinc and Copper in Practical Broiler Rations and the Effect on Performance

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REVIEW OF LITERATURE

Deficiency Symptoms of Zinc

The essentiality of zinc for animals was first demonstrated with mice by Bertrand and the Bhattacherjee in 1934. In poultry, the need for unidentified minerals was supported by Morrison et al. in 1955 and 1956. From the period of 1934 to 1955, the specific requirement for zinc in poultry had not been identified (Titus, 1932; Insko et al., 1938; and Lyons et al., 1938). O'Dell and Savage (1957a) and O'Dell et al. (1958) reported poor growth, shortening and thickening of the long bones, reduced bone ash in the dry, fat-free tibia, poor feathering, enlarged hock joints, scaly skin and feet, loss of appetite, reduced feed utilization and labored respiration as zinc deficiency symptoms of growing chickens. These investigators used a semi-purified diet of Drackett assay protein which was supplemented with 50 ppm zinc. The chicks were reared in ordinary zinc-coated batteries with tap water supplied in galvanized troughs. Some or all of these symptoms have been observed by other workers (Morrison and Sarratt, 1958; Patrick, 1958; Roberson and Schaible, 1958a; Young et al., 1958; Zeigler et al., 1958; Rahman et al., 1961; and Supplee and Shaffner, 1965). Keinholz et al. (1961) observed labored respiration of chicks hatched from eggs laid by hens fed zinc-deficient diets. Poor growth, leg abnormalities and poor feathering are the most common outward signs of zinc deficiency.

Metabolic Importance of Zinc

Zinc is involved in many of the recognized metabolic pathways of animals, usually as a constituent of an enzyme or as an enzymatic activator. Protein digestion is influenced by the action of carboxypeptidase A, an enzyme which contains 1 g atom of zinc per mole (Vallee *et al.*, 1960). Hsu *et al.* (1966) found a lower carboxypeptidase A activity in zinc-deficient rats when compared with controls, suggesting a possible depressive effect of a low dietary level of zinc on protein digestion. Protein utilization was improved with the addition of zinc in chickens (Ogunumodede, 1974) and in Japanese quail (Atkinson *et al.*, 1972).

Carbohydrate metabolism requires several enzymes that involve zinc structurally or otherwise. Carbonic anhydrase contains 0.33 percent zinc and catalyzes the dehydration of carbonic acid and participates in the elimination and incorporation of carbon dioxide (Keilin and Mann, 1939). This zinc metalloenzyme also plays a role in egg shell formation (Benesch *et al.*, 1944). Alcohol dehydrogenase, glutamic dehydrogenase and lactic dehydrogenase are examples of some of the zinc containing dehydrogenases important in carbohydrate metabolism.

Insulin, a pancreatic hormone which regulates carbohydrate, lipid and amino acid metabolism, contains zinc. Scott and Fisher (1935) have shown zinc to be necessary for the crystallization of insulin, but Ballee (1959) showed zinc to be nonessential for the activity of insulin.

In a review by Vallee (1959), the role of zinc as an activator for several enzymes is identified.

Zinc deficiency is reported to reduce the alkaline phosphatase activity in the chick (Davies and Motzok, 1971; and Hove *et al.*, 1940).

Nucleic acid metabolism is affected by the amount of zinc present in the tissues. Turk (1966) found no relationship between zinc and nucleic acid or protein metabolism but gave several possible explanations for this lack of response. Rubin (1972) found that ethylene-diaminetetreacetate (EDTA), a chelating agent, inhibits deoxyribonucleic acid (DNA) synthesis in chick embryos, but that this inhibition can be reversed by the addition of zinc. Zinc occurs in several enzymes associated with nucleic acid synthesis including ribonucleic acid (RNA) polymerase, DNA polymerase and terminal deoxynucleotidyl transferase of *E. coli*. Zinc appears to be more important in RNA synthesis than in DNA synthesis and probably functions in the initiation of the RNA synthesis rather than in the elongation (Rubin and Koide, 1973).

It is thought that zinc combines with certain binding proteins in the digestive tract which may aid or hinder its absorption. Metallothionein, a ubiquitous protein in the tissues of many species of animals, may be one of these binding proteins. Metallothionein functions in the detoxification of heavy metals and also may serve to store zinc in a manner analogous to ferritin for iron (Chen et al., 1974). Richards and Cousins (1976) suggest that zinc-binding protein, probably metallothionein, serves a regulatory function in zinc metabolism since tissue metallothionein levels respond to the level of zinc in rats. This result was supported in growing chickens by Oh et al. (1979). Even though metallothionein may function in the storage of zinc, long-term storage appears to be very limited in most animals. It has been shown repeatedly in numerous species that feeding a low zinc diet to growing animals rapidly leads to a reduced growth rate.

O'Dell et al. (1977) suggested that zinc may be involved in prostaglandin metabolism of rats, but Bettger et al. (1980) could find no relationship of the prostaglandins to zinc deficiency in the chick.

Zinc Requirement for Growing Chickens

O'Dell and Savage (1957b) reported a significant increase in the growth rate of chicks fed 50 ppm of zinc as a supplement to a basal isolated soybean protein diet. Roberson and Schaible (1958a) found that 100 ppm zinc gave a significant growth response over washed or unwashed isolated soybean protein diets. Morrison and Sarrett (1958) found that chicks fed a soybean protein diet exhibited zinc deficiency symptoms even though the ration contained 30 ppm zinc. No deficiency symptoms were observed when a casein-gelatin type ration containing the same level of zinc was fed. Moeller and Scott (1958) found that 20 ppm supplemental zinc was necessary when cerelose-Drackett protein was fed and only 10 ppm zinc was necessary when added to a cerelose-egg white protein diet. Young *et al*. (1958) found that no more than 55 ppm total zinc in a soybean protein diet was necessary to completely prevent deficiency symptoms. Zeigler *et al*. (1958) showed that between 15 and 20 ppm zinc were necessary for optimal growth of heavy breed chicks using either a purified soy protein or a purified casein protein diet. In 1959, Edwards *et al*. reported that supplementation of practical corn-soybean meal diets containing 40 ppm zinc was beneficial. The National Research Council (1977), after reviewing the literature, recommended 40 ppm zinc as the requirement level for growing chickens (0 to 8 wks). It must be remembered that NRC values allow for no margin of safety and that many factors can affect the requirement. There are a considerable number of factors which play a role in studies with zinc.

Factors Affecting the Zinc Requirement

Mehring *et al*. (1956) found no response to feeding graded levels of 15 to 778 ppm zinc to New Hampshire chickens. The practical type corn-soybean meal basal diet fed by these investigators contained 36 ppm zinc and tap water contributed 6-9 ppm zinc to the ration. In view of the requirement level of zinc, the treatment levels used should not be expected to show a significant growth response.

The environment can contribute a great deal to the amount of zinc the chick receives. The use of zinc-galvanized batteries and other common poultry equipment is a common practise. Edwards et al. (1958) observed variable zinc deficiency symptoms in birds raised in galvanized batteries when compared to the severe deficiency symptoms observed when birds were reared in plastic or stainless steel cages. Less environmental contamination resulted when a galvanized battery was coated with an epoxy resin and feed and water were given in stainless steel troughs. Tap water left in galvanized drinking pans for a normal length of time contained 3 ppm zinc (Mehring et al., 1956). This amount of zinc was adequate to give a small growth response in zinc-deficient chicks. Sullivan (1962) found that distilled water had 19 x less zinc than did tap water. Roberson and Schaible (1958a) used glass water founts and tried to isolate the battery room from dust contamination in their concern to limit zinc contact.

The type of protein also has an influence on the zinc requirement. The inclusion of isolated soybean protein in poultry diets appears to increase the zinc requirement when compared to casein protein. Zeigler *et al*. (1961) found that the total zinc requirement for young chicks fed purified casein protein was 12-14 ppm. When isolated soybean protein replaced casein, the requirement increased to 27-29 ppm total zinc. Prior to 1960, several investigators reported that the zinc in soybean meal appeared to be less available to poultry than that in animal proteins (O'Dell and Savage, 1957a; Morrison and Sarrett, 1958; and Moeller and Scott, 1958). Smith *et al*. (1962) supported this same hypothesis in swine. O'Dell and Savage (1960) observed that the addition of phytic acid to casein, an animal protein, decreased the availability of zinc to the chick. Phytic acid forms an insoluble complex with both plant and animal proteins. Likuski and Forbes (1964) concluded that phytic acid decreases the availability of dietary zinc in the presence of amino acids as the nitrogen source which conflicts with the report of O'Dell and Savage (1960) that phytic acid complexes with protein. Specific amino acids are known to be chelators which may bind zinc (Gurd and Wilcox, 1956).

Autoclaving the diet or plant protein source makes the zinc more available (Supplee *et al*., 1958; Kratzer *et al*., 1959; Lease *et al*., 1960; and Nielson *et al*., 1966a). The heat at autoclaving readily hydrolyzes phytic acid. The discovery that the addition of EDTA to plant protein diets increased the availability of zinc led to the thought that EDTA competes with phytic acid for the available zinc and forms a more soluble complex (Kratzer *et al*., 1959; Lease *et al*., 1960; Smith et al., 1962; Scott and Zeigler, 1963; O'Dell et al., 1964; and Vohra et al., 1964). Nielson et al. (1966a) reported that the addition of chelating agents with stability constants for zinc between 11.1 and 18.2 to isolated soybean protein diets alleviated all zinc deficiency symptoms. Currently, almost all practical poultry rations contain considerable quantities of soybean meal and zinc supplementation is of concern. Nielson et al. (1966b) suggested that some other complicating factor may be present in soybean protein in addition to phytic acid which affects zinc metabolism. They found that the use of casein or egg white protein produced different zinc deficiency symptoms than those observed with soybean protein. No leg abnormalities were observed although the keratosis was more severe and there was more mortality.

Another factor that may influence the requirement for zinc in poultry is the source of zinc supplement. The zinc found in zinc sulfate, zinc carbonate, zinc oxide and zinc metal is relatively available to Plymouth Rock cockerels (Edwards, Jr., 1959). Roberson and Schaible (1960) concluded that the sulfate, carbonate and oxide forms of zinc were equally available to the chick when fed at levels of 10 to 20 ppm in a soybean ration. However, Sullivan (1961) reported that zinc in zinc chloride was less available than the zinc in zinc sulfate or zinc carbonate in turkey poults. Zinc oxide was a relatively poor source of zinc for poults. Zinc acetate has been used as a supplement occasionally, but zinc oxide, zinc sulfate and zinc carbonate are more commonly used.

Variability and availability of zinc in feed ingredients may influence the requirement of zinc in poultry. Table 1 illustrates the variability between different feed ingredients. In addition, differences may exist between different crops of the same feed ingredient.

TABLE 1. Zinc and copper levels in selected feed ingredients.[1]

Ingredient	Zinc	Copper
	(ppm)	(ppm)
Corn, yellow	10	3.2
Soybean meal, solvent	60	21.5
Wheat, soft	28	6.9
Wheat middlings	150	18.1
Bone meal, steamed	306	8.3
Fish meal, Menhaden	147	10.8

[1]NRC, 1977, pp. 42-44.

Practical corn-soybean meal diets are expected to be marginal or barely adequate in total zinc content. The availability of zinc from plant protein sources has been well established to be lower than the availability of zinc in animal proteins (Moeller and Scott, 1958; Morrison and Sarrett, 1958; Smith et al., 1962; and Lease et al., 1960). Feed mixing can introduce contamination into critical experimental diets, especially if large residues are left in the mixer between mixes. In addition contact of the feed ingredients with galvanized equipment in the feed mill could add some zinc to the feed.

Maternal contribution of zinc to the embryo through the egg is a factor. The largest concentration of total egg zinc is found in the yolk (Romanoff and Romanoff, 1949; Sullivan, 1962). The amount of zinc in the egg affects both the development embryo and the growing chick. Edwards _et al_. (1959) observed that chicks produced from hens fed zinc-deficient diets grew slower than normal and that this slow growth is probably the first sign of a zinc deficiency in hends. Turk _et al_. (1959) reported a decreased hatchability of eggs from hens fed soybean protein diets low in zinc (8-9 ppm) and that the chicks hatched were weak, poorly feathered and usually died within a few days.

Impaired embryonic development in eggs produced by zinc-deficient hens (Blamberg _et al_., 1960) led Keinholz _et al_. (1961) to conduct experiments which characterized the lesions as impaired skeletal development. Supplementation of maternal diets with 55 ppm zinc prevented abnormal embryonic development.

Zinc has interrelationships with other minerals. High levels of calcium interfere with zinc metabolism (O'Dell _et al_., 1958). A calcium-phytate-zinc complex was hypothesized by O'Dell _et al_. (1964) to be responsible for a decreased biological availability of zinc. Intestinal alkaline phosphatase activity responds negatively to low levels of zinc (Prasad, 1967; Davies and Motzok, 1971; and Wight and DeWar, 1979) and to high levels of calcium (McCuaig and Motzok, (1973). High levels of calcium, therefore, produce symptoms which mimic zinc deficiency. Other recognized interactions with zinc include phosphorous, cadmium, copper, manganese, iron, cobalt and nickel.

Deficiency Symptoms of Copper

The presence of copper in animals was demonstrated in 1833 by Boutigny, but the nutritional importance was not uncovered until 1928. It was then that Hart and coworkers (1929-30) identified copper and iron as being necessary for hemoglobin formation in anemic rats. A lack of sufficient copper in poultry diets was shown by Hill and Matrone (1961) to reduce growth, to lower hemoglobin concentration, to lower heart cytochrome oxidase activity and to result in depigmentation of feathers of New Hampshire chicks. Carlton and Henderson (1962) noticed leg weaknesses develop in chickens fed a copper deficient diet. The bone lesions were characterized by a thickened epiphyseal cartilage and a reduction in blood vessel penetration of the thickened cartilage. These lesions are noticeably different from those observed in mammals.

Achromotrichia of darkly pigmented feathers is a sensitive indicator of copper deficiency. The copper containing enzyme, polyphenoloxidase, catalyzes the synthesis of melanin from the amino acid, tyrosine. The severity of copper inadequacy can be shown visually by the degree of depigmentation (Hill and Matrone, 1961).

Metabolic Importance of Copper

Several enzymes have copper in their structures or require copper for activation. Frieden (1973) compiled a list of enzymes and proteins which contain copper (Table 2).

TABLE 2. Distribution of copper in some enzymes.

Protein; enzyme	Source; Function
Ceruloplasmin	Fe mobilization; ferroxidase O_2 carrier in vertebrates
Tyrosinase	Pigmentation; sclerotization
Superoxide Dismutase	Protection against superoxide
Lysine Oxidase	Cross linking; collagen and elastin
Galactose Oxidase	Sugar metabolism
Cytochrome Oxidase	Terminal oxidase in most cells
Dopamine-B-hydroxylase	Epinephrine biosynthesis

Examination of this table shows the importance of copper containing enzymes in protein, carbohydrate and lipid metabolism.

Cytochrome oxidase is involved in the electron transport system. The two molecules of copper undergo transitions from Cu(II) to Cu(I) to transport electrons to oxygen. The electron transport chain is the final stage of energy (ATP) production in animal cells.

Hemoglobin, an iron blood protein, requires copper for adequate levels to be synthesized. A copper deficient diet can result in anemia due to a reduction in iron utilization which results in lowered hemoglobin levels. McNaughton and Day (1979) determined that the requirement for copper is lower for maximum hemoglobin formation than for optimal growth.

Lysine oxidase is involved in the chemical crosslinking of polypeptide chains, a characteristic important to the structural integrity of the fibrous proteins, elastin and collagen (Chou *et al.*, 1969). The incidence of aortic rupture, aneurism, in poultry has been related to the copper levels in the diet (O'Dell *et al.*, 1966).

Copper Requirement for Growing Chickens

The National Research Council (1977) suggests a level of 4 ppm copper as a minimum for growing chickens, but recent work may suggest a requirement nearer 10 ppm (Scott *et al.*, 1976).

Feeding of relatively high levels of copper sulfate (1-2 lbs/ton feed) has been carried out from time to time with poultry. Although the results have been variable, an expected growth response similar to that observed in swine (Barber *et al.*, 1955) was noticed in broilers (Fisher, 1973). Jenkins *et al.* (1970) observed variable results in feeding 250 ppm copper to broiler chicks. The level of methionine, total sulfur amino acids, or molybdenum may be involved in determining the causative factor of the growth response (Jensen and Maurice,1978, 1979; Robbins and Baker, 1980; and Cunha, 1980). Copper sulfate feeding may function similarly to an antibiotic or fungicide which alters the flora of the gastro-intestinal tract (Jensen, 1977).

Factors Affecting the Copper Requirement

In practical rations, copper is usually present in adequate levels. It has been shown that copper deficiency anemia in chicks is not always easy to observe (Gallagher, 1957; and Hill and Matrone, 1961). Table 1 shows the variability of copper levels of representative feed ingredients. The copper found in feedstuffs is readily available to poultry.

McNaughton et al. (1974) reported that the copper in cupric sulfate was more available than the copper in cuprous oxide or cuprous iodide. Copper sulfate is inexpensive and is used almost exclusively for supplementation.

Copper is not as ubiquitous as zinc, and, therefore, contamination is less likely. Most rations of practical importance are considered adequate in copper, but are supplemented minimally.

Relationship of Zinc and Copper

Smith and Larson (1946) first discovered in rats that zinc may be an antagonist of copper. The relative level of zinc to copper affects the availability of these two trace metals. Magee and Matrone (1960) reported that high levels of dietary zinc depressed the utilization of zinc and copper. Hill and Matrone (1962) concluded that zinc levels near the requirement level can be toxic in the sense that a copper antagonism exists. Hamilton et al. (1979) reported that the zinc/copper antagonism in Japanese quail is most pronounced when the copper is marginal or deficient. Since it is often difficult to observe copper deficiency anemia, the addition of zinc under experimental conditions may accentuate a copper deficiency.

The similarity of configuration and coordination number of zinc and copper ions may explain partially this relationship.

Superoxide dismutase was mentioned previously as an enzyme involving copper. It also involves zinc. The copper portion of the enzyme catalyzes the dismutation of superoxide anion (O_2^-) and the zinc provides stability to the enzyme (Paynter *et al.*, 1979). The level of copper or zinc can influence the mechanism for scavenging O_2^- produced from peroxidation of polyunsaturated tissue lipids.

The ratio of zinc to copper has been suggested to influence growth in rats. Rats grew better with a zinc/copper ratio of 5 rather than 40 (Klevay, 1973). A high zinc/copper ratio has been associated with a higher level of cholesterol synthesis in rats (Klevay, 1973; Murthy and Petering, 1976). Klevay (1975) proposed that the zinc/copper ratio may influence the incidence of coronary heart disease in humans. Caster and Doster (1979) found no relation of plasma cholesterol levels to zinc/copper ratios ranging from 2 to 220 when fed to rats. In laying hens, the zinc/copper ratios used had no effect on cholesterol metabolism (Helwig *et al.*, 1978). The extension to other species of Klevay's hypothesis concerning heart disease in humans cannot be proven based on the work to date. No consistent increase in cholesterol levels was observed in women given diets with different zinc/copper ratios (Freeland-Graves *et al.*, 1980). It appears that plasma cholesterol levels are more influenced by copper than by zinc in rats (Murthy and Petering, 1976; Petering *et al.*,

1977) and humans (Freeland-Graves _et al._, 1980). The importance of zinc and copper ratios for growing chickens needs investigation.

Evidence for the essentiality of zinc and copper in poultry rations has been reviewed. From time to time, borderline deficiency symptoms may occur. Broilers being grown at the Oregon State University Poultry Science Experiment Station in 1976 exhibited some symptoms of marginal zinc deficiency even though the corn-soybean meal ration was supplemented with trace minerals. These symptoms included enlarged hocks, a tendency for the birds to crouch related to a characteristic shortening and thickening of the long shank bones and split wing, a defect in the wing feathering pattern.

The possibility exists that the faster growing broilers being bred today may have different nutritional requirements than the broilers produced in the past. Considering the close interrelationship of zinc and copper, these studies were carried out to evaluate the effects of additional supplementation of either zinc, copper or combinations of the two trace elements in broiler feeds.

EXPERIMENTAL PROCEDURES

Four separate experiments were conducted to determine if additional supplementation with zinc and/or copper was beneficial for commercial broilers. Experiment 1 was carried out in a Wesbuilt galvanized battery for four weeks. The battery was located in an insulated room with positive pressure ventilation. Brooding temperature was met initially at 37.8°C (100°F) and then was manually reduced 2.2°C (5°F) per week to 29°C. Room temperature was maintained close to 23.9°C (75°F) by space heaters. Feed and tap water were available *ad libitum* in galvanized troughs.

The broiler chicks in Experiment 2, 3 and 4 were reared to seven weeks of age in floor pens which were located in an insulated, windowless room with positive pressure ventilation. Each pen measured approximately 1.2 m x 2.4 m (4 ft. x 8 ft.) and was covered with approximately 7.6 cm (3 inches) of wood shavings. One 250-watt infrared heat lamp which was controlled by thermostat was placed in each pen. Room temperature was set initially at 26.7°C (80°F) and the temperature setting was reduced manually 2.2°C (5°F) per week to a low of 13.3°C (56°F). Room exhaust vents were opened as necessary for increased air flow in an effort to create a more optimal environment.

The compositions of the basal starter and finisher rations used in all four experiments are shown in Table 3. Feed was provided *ad libitum* in hanging adjustable tube feeders (30 cm or 12 in.

TABLE 3. Composition of basal rations for boilers.

Ingredient	Starter	Finisher
	(%)	(%)
Corn, yellow	56.30	61.47
Fat, animal	4.00	4.00
Soybean meal, solv. (47.5%)	32.25	27.50
Meat and bone meal	5.00	5.00
Alfalfa meal, dehyd. (17%)	1.00	1.00
Defluorinated phosphate	.42	.25
Limestone flour	.35	.13
Salt (iodized)	.25	.25
Trace mineral permix[1]	.05	.05
Vitamin premix[2]	.20	.20
d,l Methionine (98%)	.13	.10
Zoamix (25%)[3]	.05	.05
Calculated Analysis		
Protein, %	22.98	21.18
M. E. (kcal/kg)	3117.61	3176.71
Calcium, %	.97	.82
Avail. Phos., %	.48	.44
Methionine, %	.49	.44
Meth. + Cyst., %	.87	.79

[1]Trace minerals in premix were varied according to experimental design.

[2]Contributes/kg of ration the following: Vit. A, 3300 I.U.; Vit. D, 1100 I.C.U.; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22.0 mg; choline, 190.9 mg; Vit. B_{12}, 5.5 mcg; Vit. E, 1.1 I.U.; Vit. K, 0.55 mg; and folacin, .22 mg.

[3]Provided gratuitously by Salsbury Laboratories, Charles City, Iowa.

diameter), and tap water was continually available in plastic (Little Giant) cups. One egg flat containing a small quantity of feed was used in each pen for the first four days of each experiment to encourage feed consumption. Conversion of the starter to finisher feed was accomplished on the same day for all pens.

Zinc oxide (ZnO) was used as the source of zinc except in Experiment 2 where zinc was provided by zinc acetate ($Zn(C_2H_3O_2)_2 \cdot 2H_2O$). Copper was provided as copper sulfate ($CuSO_4 \cdot 5H_2O$) in all experiments.

Lights were provided continually throughout the experimental period for all four tests. The light intensity was approximately 5.38 lux.

In Experiment 1, separate bulk male and female body weights and feed consumption by pen were taken at four weeks of age. The same measurements were taken at four and seven weeks of age in Experiments 2, 3 and 4. Mortality was recorded daily and dead birds were taken to the Oregon State University Veterinary Diagnostic Laboratory to determine the cause of death. The incidences of perosis and crooked toes were noted in Experiment 2 and a subjective feather score was made in Experiments 2 and 4. The feather score was made at six and seven weeks of age by observing each pen of birds as a group and assigning a score based on 1 = normal, 2 = slightly abnormal and 3 = abnormal. The presence of split wing or a split wing-like condition largely influenced the assignment of the feather score.

One-way analyses of variances were carried out for the data on male, female and combined sex body weights, feed conversion, mortality, feather score and incidence of perosis and crooked toes for Experiments 1, 2, and 3 (Steel and Torrie, 1960), and two-way analyses of variances for data from Experiment 4 were used where dietary treatment and strain were independent variables. When significant differences in treatment means were observed, Duncan's multiple range test (Steel and Torrie, 1960) was used.

Experiment 1

A four-week broiler growth study was carried out to determine the effect of additional zinc or copper above that found in a normal supplemented broiler ration. Day-old broiler chicks were obtained from a commercial hatchery and were feather-sexed. Each pen contained eight male and six female chicks. They were weighed at day-old and randomly assigned to twelve pens. Pen body weights were adjusted to eliminate large variations in group starting weights.

The basal ration was a practical corn-soybean meal starter ration which contained supplemental zinc and copper at levels of 27.5 ppm and 2 ppm, respectively. Dietary treatments were the following:

Treatment	Description
1	Corn-soybean meal (Control)
2	As #1 + 20 ppm Zinc
3	As #1 + 40 ppm Zinc
4	As #1 + 4 ppm Copper
5	As #1 + 20 ppm Zinc and 4 ppm Copper
6	As #1 + 40 ppm Zinc and 4 ppm Copper

Each treatment was duplicated.

Experiment 2

The contamination of zinc from the galvanized battery used in Experiment 1 was questioned. In this experiment, broiler chicks were reared in floor pens with treatments similar to Experiment 1. Eight hundred thirty-two Hubbard x Hubbard strain broiler chicks were hatched in a Jamesway Model 252B incubator at the Oregon State University Poultry Science Department and were feather-sexed. Twenty-six chicks were randomly assigned to each of 32 floor pens. Each pen of 13 male and 13 female chicks was randomly assigned to one of eight dietary treatments which were replicated four times. Each chick was provided .11 m^2 (1.2 ft^2) of floor space. The dietary treatments were as follows:

Treatment	Description
1	Corn-soybean meal (Control)
2	As #1 + 20 ppm Zinc
3	As #1 + 40 ppm Zinc
4	As #1 + 60 ppm Zinc
5	As #1 + 4 ppm Copper
6	As #1 + 20 ppm Zinc and 4 ppm Copper
7	As #1 + 40 ppm Zinc and 4 ppm Copper
8	As #1 + 60 ppm Zinc and 4 ppm Copper

The levels of zinc and copper in the basal ration were 27.5 ppm and 2 ppm, respectively. These dietary treatments were similar to those used in Experiment 1.

Experiment 3

The supplementation of other trace minerals may influence the effect of zinc or copper supplementation. In addition, the ratio of zinc to copper in broiler feeds may influence the response observed. A new trace mineral premix (B) was designed which provided the following levels of minerals in comparison to the trace mineral premix (A) used in Experiments 1 and 2.

Trace Mineral	Premix A (ppm)	Premix B (ppm)
Zinc	27.5	30.0
Copper	2.0	6.0
Iron	20.0	60.0
Manganese	60.0	60.0
Iodine	1.2	1.0
Cobalt	0.2	0.4

The five dietary treatments were:

Treatment	Description	Zn/Cu Ratio
1	Corn-soybean meal with premix A	13
2	As #1 + 30 ppm Zinc	21
3	As #1 + 60 ppm Zinc	28
4	Corn-soybean meal with premix B	9
5	As #4 + 30 ppm Zinc and 3 ppm Copper	14

Hubbard x Hubbard strain hatching eggs were obtained from a commercial source and were incubated in a Model 252B Jamesway incubator. The resulting chicks were feather-sexed at day-old and 11 males and 11 females were assigned to each pen. Each bird was allowed .14 m^2 (1.5 ft^2) of floor space. Initial bulk pen body weights were readjusted to eliminate large initial body weight differences. A total of 660 chicks were used to allow six replications of each treatment.

Experiment 4

Different strains of broilers may respond differently to varying supplemental levels of either zinc or copper. Hubbard x Hubbard, Peterson x H & N and Peterson x Hubbard strains of broilers were obtained from a commercial source at day-old. The Peterson x H & N strain broilers were vent-sexed, whereas the other strains were feather-sexed. Each pen or replicate contained 11 males and 11 females. Each dietary treatment-strain combination was replicated three times. The dietary treatments were as follows:

Treatment	Description
1	Corn-soybean meal without zinc or copper
2	As #1 + 60 ppm Zn and 6 ppm Cu
3	As #1 + 90 ppm Zn and 9 ppm Cu

There was no zinc and copper supplementation in the basal corn-soybean ration. The ratio of supplemental zinc to copper was maintained at approximately 10 in Treatments two and three.

Feed samples of both starter and finisher basal rations were analyzed for zinc and copper by modification of the procedure outlined by the Association of Official Analytical Chemists (1975) using a Jarrell Ash flame spectrophotometer. A four- and a seven-week water sample from Experiment 4 were analyzed for zinc using the same flame spectrophotometer.

RESULTS AND DISCUSSION

Experiment 1

The four-week data for Experiment 1 are presented in Table 4. Male broiler chicks fed the control ration supplemented with either 40 ppm zinc alone or in combination with 4 ppm copper were significantly heavier thanbroilers fed the control ration or the control ration supplemented with 20 ppm zinc. However, male chicks fed the control ration supplemented with either 4 ppm copper alone or in combination with 20 ppm zinc were not significantly different from the control or the control with 20 ppm zinc.

In the mean female and combined sex body weights, broiler chicks fed the control ration supplemented with either 40 ppm zinc or 4 ppm copper or the combination of these two mineral levels had significantly better growth than broiler chicks fed either the control ration with or without 20 ppm supplemental zinc. The mean female and combined sex body weights for the birds on the control ration with 20 ppm zinc and 4 ppm copper were significantly smaller than the body weights of the birds fed the control ration with either 40 ppm zinc or 4 ppm copper or the combination of these two mineral levels. There were no significant differences in either the feed conversion or mortality.

The birds used in this experiment were from a commercial source where the composition of the breeder hen diet was unknown. The possibility exists that the growth responses seen here can be partially

TABLE 4. Mean broiler male, female and combined sex body weights, feed conversions and mortality for Experiment 1 (4 weeks of age)[1]

Treat No.	Dietary Treat.	Mean Body Weights Male	Female	M&F	Feed[3] Conv.	Mort.
		(g)	(g)	(g)		(%)
1	Corn-Soybean[2] Meal (Control)	770[a]	675[a]	722[a]	1.55[a]	10.7[a]
2	As #1 + 20 ppm Zn	790[a]	684[a]	737[a]	1.55[a]	0.0[a]
3	As #1 + 40 ppm Zn	854[b,c]	770[c]	812[c]	1.48[a]	0.0[a]
4	As #1 + 4 ppm Cu	817[a,b]	778[c]	798[c]	1.50[a]	0.0[a]
5	As #1 + 20 ppm Zn and 4 ppm Cu	819[a,b]	706[a,b]	762[b]	1.56[a]	3.6[a]
6	As #1 + 40 ppm Zn and 4 ppm Cu	875[c]	756[b,c]	816[c]	1.52[a]	10.7[a]

[1]Values in each column with different superscripts are significantly different at $P < .05$.

[2]Trace mineral premix in the basal ration contributed per kg of ration the following: zinc, 27.5 mg; copper, 2.0 mg; iron, 20.0 mg; manganese, 60.0 mg; iodine, 1.2 mg; and cobalt, 0.2 mg.

[3]Calculated as kg feed consumed per kg body weight gain.

attributed to a low level of zinc or copper in the maternal diet. Chicks that have a low level of zinc or copper at hatching may respond more dramatically to the addition of these minerals in their diets. The addition of 4 ppm copper, as copper sulfate, may be adequate to alter the gastrointestinal flora with a resulting growth response. Also, the rearing of chicks in batteries largely reduces the possibility of coprophagy, thus the diet becomes more important for providing the trace elements and vitamins required for optimal growth.

Experiment 2

The seven-week mean body weight, feed conversion, mortality, feather score and incidence of perosis and crooked toes data for Experiment 2 are presented in Table 5. Edwards *et al.* (1958) reported variable zinc-deficiency symptoms in birds reared in galvanized batteries. The birds used in this experiment were reared on litter to eliminate the effect galvanized battery rearing may have had in Experiment 1. No significant differences were observed in the seven-week mean body weights, feed conversions or mortality among treatments. The mean feather scores, incidences of perosis and crooked toes were not significantly different among dietary treatments.

The feeding of broilers under practical floor rearing conditions is different than feeding broilers in galvanized batteries. Since floor rearing gives the birds access to manure rich in certain minerals and vitamins, the additional supplementation of zinc and copper

TABLE 5. Mean broiler male, female and combined sex body weights, feed conversions, mortality, feather score, and incidence of perosis and crooked toes for Experiment 2 (7 weeks of age)[1]

Treat No.	Dietary Treat.	Mean Body Weights Male	Mean Body Weights Female	Mean Body Weights M&F	Feed Conv.[3]	Mort.	Mean Feath. Score[4]	Perosis	Crkd. Toes
		(g)	(g)	(g)		(%)		(%)	(%)
1	Corn-soybean Meal[2] (Control)	2027[a]	1686[a]	1857[a]	2.07[a]	7.7[a]	1.19[a]	4.0[a]	11.1[a]
2	+ 20 ppm Zn	1926[a]	1680[a]	1803[a]	2.06[a]	4.8[a]	1.25[a]	2.9[a]	6.8[a]
3	+ 40 ppm Zn	2003[a]	1671[a]	1837[a]	2.06[a]	6.7[a]	1.13[a]	3.0[a]	8.0[a]
4	+ 60 ppm Zn	1969[a]	1674[a]	1822[a]	2.06[a]	5.8[a]	1.06[a]	2.0[a]	14.0[a]
5	+ 4 ppm Cu	2022[a]	1724[a]	1873[a]	2.04[a]	3.8[a]	1.19[a]	2.0[a]	10.0[a]
6	+ 20 ppm Zn + 4 ppm Cu	2019[a]	1721[a]	1870[a]	2.04[a]	3.8[a]	1.19[a]	2.0[a]	8.9[a]
7	+ 40 ppm Zn + 4 ppm Cu	1983[a]	1638[a]	1810[a]	2.08[a]	2.9[a]	1.31[a]	1.9[a]	7.8[a]
8	+ 60 ppm Zn + 4 ppm Cu	2042[a]	1633[a]	1838[a]	1.98[a]	10.6[a]	1.25[a]	4.1[a]	11.2[a]

[1]Values in each column with different superscripts are significantly different at $P < .05$.

[2]Trace mineral premix in the basal ration contributed per kg of ration the following: zinc, 27.5 mg; copper, 2.0 mg; iron, 20.0 mg; manganese, 60.0 mg; iodine, 1.2 mg; and cobalt, 0.2 mg.

[3]Calculated as kg feed consumed per kg body weight gain.

[4]Scored subjectively based on the following scale: 1 = Normal; 2 = Slightly Abnormal; 3 = Abnormal.

in the ration may be less beneficial. In addition, the chicks used in this experiment were hatched from eggs laid by broiler breeder hens kept at Oregon State University and fed a diet containing levels of zinc and copper considered to be sufficient.

The statistical analysis revealed significant differences between replicates within treatments. Some possible explanations for this large experimental error were: (1) drafty conditions created by the ventilation system that was directed toward certain pens which had more mortality; (2) one pen in Treatment two had a faulty feeder which resulted in no feed being available to that group of birds unless the feeder was shaken; and (3) the height of the water cups was too high for day-old chicks in some of the pens and in those groups the birds appeared to have been somewhat stunted. Although it is difficult to be sure that the above factors account for the unusually high variation between replicates, the conditions mentioned were corrected for all subsequent experiments.

Experiment 3

The level of zinc or copper supplementation may be influenced by the level of the other trace minerals normally supplemented. The ratios of zinc to copper varied in Experiment 3, and they were tested with two different levels of iron, iodine and cobalt. The zinc-to-copper ratios ranged from 9 to 28 (Table 6). The mean body weight, feed conversion and mortality data are present in Table 6.

TABLE 6. Mean broiler male, female and combined sex body weights, feed conversions, mortality[1] and zinc-to-copper ratios for Experiment 3 (7 weeks of age)[1]

Treat. No.	Dietary Treat.	Zn/Cu Ratio	Mean Body Weights			Feed Conv.[4]	Mort.
			Male	Female	M&F		
			(g)	(g)	(g)		(%)
1	Corn-soybean Meal[2]	13	2179[a]	1763[a]	1971[a]	2.11[a]	1.52[a]
2	As #1 + 30 ppm Zinc	21	2142[a]	1776[a]	1959[a]	2.09[a]	6.10[a]
3	As #1 + 60 ppm Zinc	28	2076[a]	1760[a]	1918[a]	2.14[a]	4.55[a]
4	Corn-soybean Meal[3]	9	2141[a]	1767[a]	1954[a]	2.09[a]	2.27[a]
5	As #4 + 30 ppm Zinc	14	2120[a]	1780[a]	1950[a]	2.10[a]	3.79[a]

[1]Values in each column with different superscripts are significantly different at $P < .05$.

[2]Ration contained a trace mineral premix A which contributed per kg of ration the following: zinc, 27.5 mg; copper, 2.0 mg; iron, 20.0 mg; manganese, 60.0 mg; iodine, 1.2 mg; and cobalt, 0.2 mg.

[3]Ration contained a trace mineral premix B which contributed per kg of ration the following: zinc, 30.0 mg; copper, 6.0 mg; iron, 60.0 mg; manganese, 60.0 mg; iodine, 1.0 mg; and cobalt, 0.4 mg.

[4]Calculated as kg feed consumed per kg body weight gain.

None of the seven-week data were significantly different among the dietary treatments.

At seven weeks of age, the birds which received the ration with the widest zinc-to-copper ratio (Treatment three) had a numerically smaller mean body weight than the other dietary treatments (Table 7). A possible explanation for this is that at higher levels of dietary zinc supplementation, where the zinc-to-copper ratios are wider, the availability of both zinc and copper is reduced. This would agree with the conclusion of Magee and Matrone (1960). Possibly a further widening of the zinc-to-copper ratio would have produced a significant reduction in growth or performance.

Experiment 4

The seven-week mean squares for the analysis of variance for Experiment 4 are shown in Table 7. The strain source of variation showed significant differences, but there were no significant differences in treatment or treatment x strain interaction.

The mean body weights for all three broiler strains at seven weeks of age are shown in Table 8. No significant differences among treatments were observed at seven weeks of age, even though the control group had no zinc or copper supplementation. However, there were significant differences in growth characteristics among strains. The Hubbard x Hubbard and Peterson x Hubbard males were significantly heavier than the Peterson x H & N males when all three strains were fed the basal ration

TABLE 7. Mean square for the analysis of variance of Experiment 4 (7 weeks of age)

Source of Variation	df	Mean Squares			
		Male Body Wt.	Female Body Wt.	Sex Body Weight	Feed Conv.
Treatment (T)	2	6.7×10^{-2}	1.8×10^{-2}	2.1×10^{-2}	1×10^{-4}
Strain (S)	2	3.9×10^{-1}**	1.0×10^{-1}**	1.2×10^{-1}**	5×10^{-3}*
T X S	4	6.0×10^{-3}	1.8×10^{-2}	1.3×10^{-2}	1×10^{-3}
Error	18	4.0×10^{-2}	7.0×10^{-3}	1.4×10^{-2}	1×10^{-3}

*P = 0.05

**P = 0.01

TABLE 8. Mean male, female and combined sex body weights of Hubbard x Hubbard, Peterson x H & N and Peterson x Hubbard strains of broilers for Experiment 4 (7 weeks of age)[1,2]

Treat No.	Dietary Treat.	Hubbard x Hubbard Male (g)	Hubbard x Hubbard Female (g)	Hubbard x Hubbard M&F[4] (g)	Peterson x H & N Male (g)	Peterson x H & N Female (g)	Peterson x H & N M&F[4] (g)	Peterson x Hubbard Male (g)	Peterson x Hubbard Female (g)	Peterson x Hubbard M&F[4] (g)
1	Corn-Soy without Zn or Cu[3]	$2144^{a,A}$	$1788^{a,B}$	$1961^{a,B}$	$1976^{a,A}$	$1656^{a,A}$	$1824^{a,A}$	$2118^{a,A}$	$1749^{a,B}$	$1893^{a,A,B}$
2	As #1 + 60 ppm Zn & 6 ppm Cu	$2194^{a,A}$	$1796^{a,B}$	$1980^{a,A}$	$1999^{a,A}$	$1719^{a,A,B}$	$1878^{a,A}$	$2095^{a,A}$	$1700^{a,A}$	$1874^{a,A}$
3	As #1 + 90 ppm Zn & 9 ppm Cu	$2231^{a,B}$	$1794^{a,A}$	$1964^{a,B}$	$2041^{a,A}$	$1713^{a,A}$	$1888^{a,A}$	$2189^{a,B}$	$1800^{a,A}$	$1954^{a,B}$

[1]Values in each column with different lower case superscripts are significantly different at $P < .05$ (Treatment Effect).

[2]Values in each row for either male, female or combined sex body weights with different upper case superscripts are significantly different at $P < .05$ (Strain Effect).

[3]Trace mineral premix in the basal ration contributed per kg of ration the following: iron, 60.0; manganese, 60.0 mg; iodine, 1.0 mg; and cobalt, 0.4 mg.

[4]Combined body weight is a weighted average to account for unequal numbers of males and females.

supplemented with 90 ppm zinc and 9 ppm copper. There was no significant difference in mean male body weights among strains when the different strains were fed the basal ration alone or supplemented with 60 ppm zinc and 6 ppm copper. The mean body weights of the female Hubbard x Hubbard and Peterson x Hubbard strains of birds were significantly heavier than the Peterson x H & N female broilers when all three strains were fed the basal ration. The Peterson x Hubbard strain females were significantly lighter than the Hubbard x Hubbard female birds when both strains were fed the basal ration supplemented with 60 ppm zinc and 6 ppm copper. No significant mean body weight differences existed between any of the three strains of female broilers when they were fed the basal ration supplemented with 90 ppm zinc and 9 ppm copper. The mean combined sex body weights of the Hubbard x Hubbard and Peterson x Hubbard strains were significantly heavier than the Peterson x H & N strain when all three strains were fed the basal ration supplemented with 90 ppm zinc and 9 ppm copper. No significant differences in combined sex mean body weights were observed among strains fed 60 ppm zinc and 6 ppm copper in the basal ration. Even though the body weight data are not significant among treatments for a given strain, there was a fairly consistent tendency for body weight to increase as the zinc and copper supplementation increased.

Mean feed conversion, mortality and feather score data for all three strains are presented in Table 9. No significant differences between treatments or strains were observed at seven weeks of age.

TABLE 9. Mean feed conversion, mortality and feather score of Hubbard x Hubbard, Peterson x H x N Peterson x Hobbard strains of broilers for Experiment 4 (7 weeks of age)[1,2]

		STRAIN								
		Hobbard x Hubbard			Peterson x H & N			Peterson x Hubbard		
Treat No.	Dietary Treat.	Feed Conv.[3]	Mort. (%)	Feath. Score[5]	Feed Conv.[3]	Mort. (%)	Feath. Score[5]	Feed Conv.[3]	Mort. (%)	Feath. Score[5]
1	Corn-soy without Zn or Cu[4]	$2.10^{a,A}$	$6.1^{a,A}$	$1.40^{a,A}$	$2.03^{a,A}$	$1.5^{a,A}$	$1.33^{a,A}$	$2.06^{a,A}$	$3.0^{a,A}$	$1.22^{a,A}$
2	As #1 + 60 ppm Zn 6 ppm Cu	$2.10^{a,A}$	$1.5^{a,A}$	$1.11^{a,A}$	$2.06^{a,A}$	$1.5^{a,A}$	$1.28^{a,A}$	$2.05^{a,A}$	$4.5^{a,A}$	$1.45^{a,A}$
3	As #1 + 90 ppm Zn 9 ppm Cu	$2.08^{a,A}$	$1.5^{a,A}$	$1.50^{a,A}$	$2.08^{a,A}$	$4.5^{a,A}$	$1.33^{a,A}$	$2.04^{a,A}$	$4.5^{a,A}$	$1.17^{a,A}$

[1]Values in each column with different lower case superscripts are significantly different at $P < .05$ (Treatment Effect).

[2]Values in each row for the same measurement with different upper case superscripts are significantly different at $P < .05$ (Strain Effect).

[3]Calculated as kg feed consumed/kg body weight gain.

[4]Basal ration supplemented with the following levels of trace minerals/kg of ration: (mg) iron, 60.0; manganese, 60.0; iodine, 1.0; and cobalt, 0.4.

[5]Mean of the observations made subjectively based on the following scale: 1 = Normal; 2 = Slightly Abnormal; 3 = Abnormal.

During the course of this study, a period of several years, the type of broilers used changed considerably. The birds observed in 1976 with characteristic marginal zinc deficiency symptoms grew to market size in seven and one-half to eight weeks. The birds used in Experiment 4 could easily have been marketed at six and one-half weeks of age. Tremendous strides in the growth characteristics of commercial broilers have been made in a relatively short time. The nutritionists have the job of making sure that feeding programs keep pace with these changes wherever necessary.

The chicks or eggs used in these experiments were obtained from numerous commercial sources. The levels of zinc or copper supplementations which the various breeder hen flocks received are important. The amount of zinc or copper in hatching eggs influences the strength and viability of newly hatched chicks (Turk et al., 1959). Since the source of birds varied, the difference in maternal influence must be recognized as a possible factor in explaining why additional zinc and copper supplementation did not significantly affect the growth of floor-reared broilers.

The response seen in Experiment 1 was obtained with galvanized battery rearing and may have been different or absent at seven weeks of age. The possible effect of coprophagy was discussed previously.

Since soybean meal protein is known to contain phytic acid which complexes zinc (O'Dell, 1961), the amount of soybean meal in the ration may influence the response seen from additional zinc supplementation. The heat of the oil extraction process for soybeans may destroy this phytate complexing ability, but this destruction may also vary. The starter ration fed exclusively in Experiment 1 contained five percent more soybean meal than the finisher ration fed for approximately the last five weeks of the other experiments. If the availability of zinc is altered by this difference in soybean meal levels in the two types of basal rations, then supplementation of the starter ration would be more beneficial. This may help explain the results seen in Experiment 1, but does not account for the lack of a growth response from the addition of only 20 ppm zinc.

The amount of zinc in the feed ingredients used in these experiments may have varied considerably over the course of the study. Different shipments of different crop years may yield feed grains with widely varied levels of trace minerals, including zinc and copper. The data in Table 1 show the variability of different feed ingredients, but the values for a particular ingredient are only an average about which individual samples may vary quite a bit. No determinations of individual feed ingredients for zinc and copper levels over time were made, but recognition of this factor is necessary.

The analyzed and calculated levels of zinc and copper in the basal diets of Experiments 3 and 4 are presented in Table 10. The differences between actual and calculated levels of zinc and copper give credence to the normal contamination and variation evident in feed mixing. The levels of zinc and copper in the basal rations of

TABLE 10. The calculated and actual levels of zinc and copper in the basal starter and finisher rations of Experiments 3 and 4

Ration	Zinc		Copper	
	Actual	Calc.	Actual	Calc.
	(ppm)	(ppm)	(ppm)	(ppm)
Experiment 3				
Starter	60.3	53.0	8.2	4.0
Finisher	55.6	51.3	8.1	4.2
Experiment 4				
Starter	34.8	25.5	7.0	2.0
Finisher	35.9	23.8	6.8	2.2

Experiment 4, which contained no supplemental zinc or copper, are very close to the NRC (1977) required levels of 40 ppm and 4 ppm for zinc and copper, respectively. Depending upon the availability of these trace minerals from the basal ration, and the contribution of tap water and other environmental contact, the zinc and copper found in the feed may have adequately met the birds' requirements. The analysis of water samples from Experiment 4 showed .50 ppm and .71 ppm zinc at four and seven weeks, respectively.

Mehring et al. (1956) reported no growth response in birds fed graded levels of zinc in a basal ration containing 36 ppm zinc. The results in Experiments 2, 3, and 4 appear to agree with the results of Mehring and coworkers. Although Experiment 1 did show a significant response to the addition of 40 ppm zinc and to 4 ppm copper, alone or in combination, this may be related to the possibility that the chicks used in this experiment may have been more severely marginal in zinc or copper at hatching.

CONCLUSIONS

Under the conditions of these experiments, the following points can be mentioned:

1. The additional supplementation with 40 ppm zinc, 4 ppm copper or the combination of these two in a practical corn-soybean meal ration fed to galvanized battery-reared broiler chicks significantly improved growth, but not feed conversion or mortality.

2. The additional supplementation of zinc or copper in a practical corn-soybean meal ration fed to floor-reared broilers did not significantly affect growth, feed conversion or mortality.

3. The ratio of zinc to copper may influence the availability of the zinc, copper, or both. Broilers fed a ration with a zinc-to-copper ratio of 28 were numerically smaller than broilers fed similar rations with zinc-to-copper ratios ranging from 9 to 21.

4. Different strains of broilers do not appear to have different requirements for zinc or copper. Broilers with Hubbard breeding in their genetic makeup appear to have a superior growth rate regardless of dietary treatment.

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