COMPARISON OF FEEDING BROILER-STRAIN CHICKS A BASAL DIET SUPPLEMENTED WITH ZINC PROTEINATE, ZINC, METHIONINE, CHROMIUM AND A COMBINATION OF ZINC, METHIONINE AND CHROMIUM

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INTRODUCTION

The great importance of protein in nutrition is indicated by their many functions in the animal organism. They are indispensable constituents of blood, muscles, organs, skin, tendons, bone, nails, and feathers--in fact, of all animal tissues. The amino acids are often referred to as the "building stones" from which the proteins are made. Synthetic amino acids are being used in increasing quantities to supplement natural protein. Methionine can be added economically to many practical diets. Typical poultry feeds, in which much of the protein is furnished by soybean meal, may contain less than the desired quantities of methionine. In such cases, the first limiting amino acid is methionine, and it is preferable to add methionine rather than to raise the total protein content. Methionine may be added either as synthetic DL-methionine or as the hydroxy analogue which is converted in the body to the amino acid.

The term "minerals," as it is now used in animal nutrition, refers simply to the inorganic chemical elements. The functions of the mineral elements in the animal body are numerous. Compounds of these elements are found in all tissues. Zinc is found to be essential for reproduction, normal bone development, normal feather development and enzyme systems. Zinc must ordinarily be added to practical poultry feeds. A number of zinc compounds are suitable ingredients to supply this mineral element. Among those suggested for feed use are: zinc acetate, zinc ammonium sulfate, zinc carbonate, zinc chloride, zinc citrate, zinc lactate, zinc oxide, zinc phosphate, zinc propionate, and zinc sulfate. Zinc oxide is probably the most generally used.

Chromium has been found in the tissue of chickens, but the significance of the element in the nutrition of chickens has not been established.

However, some research has been reported that trivalent chromium was found to be necessary for normal glucose tolerance in mammals.

Two experiments were conducted in order to test the effects of Zinpro$^{(R)}$ (zinc-methionine-chromium complex), zinc oxide, DL-methionine, chromium and a combination of zinc oxide, DL-methionine and chromium in a practical basal diet on weight gain and feed utilization of chickens 0 to 8 weeks of age.

REVIEW OF LITERATURE

The use of supplemental DL-methionine and its beneficial effects on growth and efficiency of feed utilization obtained with practical chick starter and broiler diets are well known from the work of Bird and Mattingly (1945), Gerry et al. (1948), Slinger et al. (1952a), Matterson et al. (1953), and Featherston and Stephenson (1960).

[illegible]ber et al. (1971) reported a constant methionine requirement for maximal gain of growing chick from two to eight weeks of age. Peterson et al. (1944) and Bolin et al. (1946) have shown that addition of DL-methionine and protein supplements to a basal ration containing ground peas and meat meal, as the chief sources of protein, increased growth response and protein efficiency. Bolin et al. (1951) concluded that methionine added to a pea-meat meal ration increased the utilization of other amino acids.

Saxena and McGinnis (1952) found methionine increased the feed efficiency on an all-vegetable protein diet but that the increase was most marked when fish meal was in the diet.

Hayward and Hafner (1941) experimented with a chick diet of 20 to 21 percent protein. When raw soybeans were used as a main source of protein, the diet was effectively supplemented with DL-methionine. Cooking the soybeans resulted in greater growth response than the addition of the amino acid, but the diet containing the cooked soybeans was still further improved by addition of methionine.

Almquist et al. (1942) fed choline to chicks receiving raw soybeans as the sole source of protein, but no increased growth resulted. An addition of methionine to the diet produced a growth response similar to that of heating the soybeans. Clandinin et al. (1946) and Gerry et al. (1948) concluded that soybean oil meal rations are improved by methionine supplementation.

Mishler et al. (1949) found that a three percent level of semi-solid fish product plus riboflavin in a corn and soybean oil meal ration was significantly improved when calcium pantothenate, nicotinic acid, choline and methionine were added.

Reed et al. (1954) reported that methionine at the .05 percent level produced an increase in growth and an improvement in feed efficiency. Best results were obtained when the amino acid was added to the ration containing fish meal or fish soluble.

Bolin et al. (1952) found indications that other factors are present in cereal grain which affect the utilization and methionine requirement of the chick, and that the methionine requirement of the chick may depend on the type of composition of the ration.

Bird and Mattingly (1945) showed a significant improvement in growth of chicks when 0.2 percent DL-methionine was added to a starting diet whose only protein supplement was soybean oil meal.

Milligan et al. (1951) reported the methionine requirement of Rhode Island Red chicks fed soybean meal, as the only protein supplement, was no higher than 0.42 percent to six weeks of age. They required a combined total of only 0.7 percent of methionine and cystine. To reach these levels 0.1 percent of synthetic DL-methionine was added to the diet.

Almquist (1952) stated the requirement for methionine and other essential amino acids increased as the protein content of the diet increased, but not to the same extent. He also noted that approximately 0.1 percent more methionine is required in the diet for maximum efficiency of feed utilization than is required for maximum growth. Hill (1953) reviewed the methionine and cystine requirements of the chick and was in agreement with Almquist (1952) that total requirement for sulfur amino acid did not exceed 0.8 percent of a diet containing 20 percent protein.

Pisano (1959) observed that methionine-deficient chicks are able to digest and absorb protein in the limited amount of diet consumed. Carew and Hill (1961) reported that chicks fed the methionine deficient diet had greater gains in tissue fat but lower gains of protein. As a consequence, the higher caloric intake of chicks fed the methionine deficient diet did not produce additional weight gain.

Slinger et al. (1953) and Nelson et al. (1960) observed that a higher level of dietary methionine was required to produce maximal gross efficiency than was necessary to promote maximum growth.

Tipton et al. (1965) produced a growth depression in chicks with 0.80 percent DL-methionine added to a basal diet containing 0.24 percent methionine. Boorman and Fisher (1966) reported the addition of 2.42 percent L-methionine to an otherwise adequately balanced purified diet had been shown to produce a severe growth depression in young chicks. Moderate growth depression was observed by Tamimie (1967) by supplementation of a conventional diet with 1.2 percent L-methionine.

Griminger and Fisher (1968) reported the supplementation of a conventional starter ration with 1 percent or more of DL-methionine depressed growth in young chicks. Hebert et al. (1970) observed that performance of chicks fed diets differing in methionine levels was best with a 0.90 percent dietary methionine level as measured by weight gain and feed conversion. Levels of

1.20 and 1.50 percent total methionine gave lower weight gain than did the 0.90 percent level.

Todd (1952) reported methionine content of three test rations was in an apparent progressive series. More and larger worms developed in birds fed the 0.9 percent methionine supplemented diet than developed in birds fed only the basal ration. Menge et al. (1953) indicated response of broilers to methionine supplementation may perhaps be related to factors other than dietary ones, such as "disease levels," temperature or other environmental stress.

Methionine was shown by Jukes (1941) to have no growth promoting or perosis preventing properties when added to a basal ration containing 30 percent casein, and suggested that methionine does not act as a precursor of choline for the chick. On the other hand, choline has been reported by Klose and Almquist (1941) to act as a precursor of methionine for the chicks if homocystine is added to the diet.

Almquist and Grau (1944) described experiments with a practical diet in which soybean oil meal furnished at most slightly more than half of total protein. Their findings showed that methionine could be replaced by a combination of homocystine and choline, and that methionine could partially but not completely replace choline.

Marvel et al. (1944) observed choline and methionine exerted an interchangeable supplementary action in a chick ration consisting largely of corn and soybean oil meal.

Almquist and Grau (1945) found levels of choline in chick diets as high as 0.6 percent gave only a 4 percent per day increase in chick growth; whereas, a level of 0.55 percent methionine gave optimal gains of 6 percent per day.

They also observed that cystine cannot compensate for a methionine deficiency regardless of the level of choline fed.

McKittrick (1947) observed the methionine and choline requirement for chick growth consist of essential and replaceable parts. For optimal growth it was found that 0.5 percent methionine and 0.1 percent choline constitute the essential parts, and that 0.25 percent methionine or 0.45 percent choline or any equivalent mixture may comprise the replaceable parts.

Quillin et al. (1961) reported that addition of methionine produced a significant growth response only with low choline ration; similarly, the improvement in growth which accompanied the addition of choline approached statistical significance only with the methionine low ration.

Almquist (1947) stated the growing chicken requires 0.9 percent sulfur amino acids, 0.5 percent of which must be methionine and 0.4 percent of which may be provided by cystine or methionine. Grau and Kamei (1950) concluded when the diet contained approximately 20 percent total protein the sulfur amino acid requirement appears to be met with approximately 0.5 percent methionine and 0.3 percent cystine or with 0.8 percent methionine alone.

March et al. (1950) reported the nutritive value of meat meals, supplemented with lysine plus methionine gave better results than that with lysine alone. Gardiner and Aqudu (1968) found that methionine improved growth when added to diets containing lysine or lysine and glycine.

Sanford et al. (1967) compared the performance of chickens fed a 20 percent protein basal diet and a basal diet with the addition of 0.18 percent methionine, and with 0.18 percent methionine and 0.14 percent glycine. Feeding the 20 percent basal, without amino acid supplementation, resulted in significantly less growth than supplemented diets while other diets produced similar weight gain.

Kazemi and Daghir (1971) observed improvement of growth and feed efficiency could be increased by adding levels of vitamin B_6 above 3 mg per kg of diet and methionine in purified chick diets.

Briggs et al. (1950) found methionine had a strong sparing action on vitamin B_{12}, and could completely replace the vitamin B_{12} requirement of chicks fed a corn-soybean oil meal diet. Sunde et al. (1951), in agreement with Fox et al. (1957), reported that vitamin B_{12} exerted a sparing action on methionine. Jukes et al. (1950) reported that vitamin B_{12} may be needed in the transformation of homocystine to methionine in chicks.

Patrick (1950) found methionine and vitamin B_{12} increased chick weight gains; however, the weight gains of birds fed both supplements were no greater than those of birds receiving a single supplement. Patrick (1952) reported also that aureomycin or penicillin plus methionine gave better performance than either of these antibiotics plus vitamin B_{12}.

Both vitamin B_{12} and methionine supplements were found to be necessary by Machlin et al. (1952) for maximum growth response of chicks fed a corn-soybean meal diet.

Ringrose and Potter (1952) reported that methionine, when added to a basal ration supplemented with vitamin B_{12} and fish meal, failed to improve growth, but improved feed efficiency to a point closely approaching statistical significance. Slinger et al. (1952b) also failed to obtain a significant growth response from DL-methionine at the 1.5 percent level in a soy-cereal grain broiler diet adequate in vitamin B_{12}, but their data showed an increase in feed efficiency in every instance when DL-methionine was added.

Harbaugh and Sanford (1970) reported that supplementation with zinc-methionine complex in laying diets produced more eggs, greater egg weight, increased specific gravity and improved feed conversion when compared to the non-supplemented diet.

Matterson et al. (1953), Menge et al. (1953), and Reed et al. (1954) have shown quite clearly that supplementary DL-methionine markedly improved feed efficiency and in some instances growth and feathering of broilers fed high energy type rations.

Baldini and Rosenberg (1955) observed that methionine requirement, expressed as percent of diet, increased as the energy content of the diet increased. Rosenberg and Baldini (1957) further reported that when sufficient energy is available from non-protein sources to permit full utilization of protein for tissue synthesis and repair, the methionine requirement, expressed as percent of diet, increased as protein level increased. Baldini (1961) observed the ability of a bird to utilize for productive purposes the metabolized calories of a diet was impaired by a dietary deficiency of methionine.

Rosenberg et al. (1955b) found an interaction between DL-methionine and a high energy fish meal diet. Rosenberg et al. (1955a) found also a significant interaction between DL-methionine and fat. Greater improvements in performance due to DL-methionine were noted when supplemental fat was added to the diet than when it was absent. This was in agreement with Featherston and Stephenson (1960).

West et al. (1951) stated that chickens could utilize both optical isomers of methionine. The isomers also were effective in promoting growth according to Fell et al. (1959).

Marrett and Sunde (1965) found full utilization of the isomer of methionine by the chick was dependent on the amino acid composition of the diets, especially the D-amino acids.

Leveille et al. (1960) and Featherston et al. (1962) indicated equal utilization of D- and L-isomers of methionine by chickens. Bauriedel (1963), using peanut meal in the balanced ration, indicated that chicks were capable of utilizing D-methionine as effectively and efficiently as L-methionine.

Tipton et al. (1966) reported a diet containing D-methionine produced significantly heavier chicks with improved feed utilization as compared to a diet containing L-methionine. Grau and Almquist (1943) reported DL-methionine is equivalent to L-methionine for growth, whether in the presence or absence of choline in the chick diet.

Gordon and Sizer (1955) found chickens did not utilize D-methionine as completely as L-methionine, and it was postulated this was because D-methionine was metabolized primarily in the kidney tissue, and was partially lost by excretion. Marrett et al. (1964) also observed that L-form of methionine was utilized better than D-form.

Smith (1966) found that L-methionine was more efficiently utilized than the DL-form when added to a crystalline amino acid diet, and that DL-methionine was superior to equimolar amounts of methionine hydroxy analogue. When a semi-purified basal diet was used, methionine hydroxy analogue again appeared to be inferior to the other forms of methionine tested. Gordon et al. (1954) reported that feed conversion by broiler chickens was significantly improved by the addition of methionine hydroxy analogue to corn-soybean oil meal diets containing 20 percent protein.

Sullivan and Bird (1957) compared methionine hydroxy analogue and DL-methionine on an equimolar basis in 12 and 14 percent protein chick diets and found the analogue failed by a wide margin to support performance equivalent to DL-methionine. Tipton et al. (1965) reported that DL-methionine consistently supported better chick growth performance than did methionine hydroxy analogue when used on an equimolar basis.

Bird (1952) reported chick growth obtained from methionine hydroxy analogue paralled that obtained from DL-methionine when both were supplemented at molecular equivalent levels to a 20 percent protein diet low in methionine. Gordon and Sizer (1955) observed L-methionine, D-methionine, and the hydroxy analogue were equal on the equimolar basis as supplements to chick diet. Machlin and Gordon (1959) concluded that addition of methionine hydroxy analogue and DL-methionine to diets containing 12 or 14 percent isolated soybean protein resulted in equivalent growth response in young chickens.

Gordon and Sizer (1965) using S-35 labelled methionine hydroxy analogue calcium (MHA-Ca), L-methionine and DL-methionine, reported greater incorporation of MHA-Ca and L-methionine into chick liver protein than that found for DL-methionine.

The study of Kienholz et al. (1959) indicated that zinc in un-autoclaved field peas was not available to chicks, or the pea contained a heat-labile factor which increased the requirement for zinc. Kratzer et al. (1959) and Lease et al. (1960) reported that autoclaving reduced the chick's or poult's need for added zinc with isolated soybean protein or sesame diets.

Titus (1932) added 0.001 percent zinc as zinc acetate to a diet on which a high level of perosis occurred and found the zinc supplement did not prevent the occurrence of the abnormality. Wilgus et al. (1937) observed that zinc supplements reduced the incidence of perosis in their experiments, but the zinc supplement was less effective than manganese. In contrast, Insko et al. (1938) concluded that 30 mg per kg of aluminum and zinc added to a ration low in calcium and phosphorous appeared to increase the incidence of perosis rather than to decrease its occurrence. Mehring et al. (1956) added graded levels of zinc, 15 to 77.8 mg per kg to a corn-soy broiler diet that contained about 40 mg per kg of zinc and observed no effects on growth and feed efficiency. Studies on the zinc requirement of chicks by Young et al. (1958), using a purified diet, have shown that more than 55 p.p.m. of zinc was required for maximum rate of growth. Zeigler et al. (1961) found that zinc requirement of chicks fed a casein diet was 12 to 14 mg per kg of diet while the requirement of chicks fed an isolated soybean protein diet was 27 to 29 mg per kg of diet.

O'Dell et al. (1958) described the zinc deficiency symptom as slow growth, shortening and thickening of the long bones, keratosis, development of frizzled feathers, an abnormal respiration and an unsteady gait. Morrison and Sarett (1958) also reported that a zinc deficiency in chicks resulted in enlarged hocks as well as poor growth.

Raman et al. (1961) reported that addition of 20 p.p.m. of zinc provided either as zinc oxide dissolved in acetic acid or as zinc-bacitracin to a basal diet, which contained 14 p.p.m. of zinc, prevented all the symptoms of the deficiency. Forty p.p.m. of added zinc was no more effective in preventing the symptoms of a deficiency than 20 p.p.m. of zinc, and was not found to be harmful to the chicks.

Roberson and Schaible (1960c) demonstrated that 1,000 p.p.m. of zinc was tolerated by growing chickens, but that 1,500 p.p.m. or more depressed growth and adversely affected feed conversion. They compared the effects of the carbonate, sulfate and oxide of zinc and concluded that, at the higher levels of zinc supplementation, the carbonate depressed growth more than sulfate, and sulfate, more than the oxide. Johnson et al. (1962) indicated that chickens tolerated at least 1,000 p.p.m. of zinc added to a practical, corn-soybean oil meal diet. In the first experiment, growth was not markedly depressed on the diet containing less than 2,391 p.p.m. of added zinc. In the second experiment there was a slight reduction in growth on the diet containing 2,000 p.p.m. of added zinc, and on the diets containing 3,000, 4,000, and 5,000 p.p.m., there were significant reductions in growth. The addition to the diet of less than 4,000 p.p.m. of zinc, as zinc oxide, did not affect efficiency of feed utilization.

Turk and Stephens (1970b) studied an induced coccidial infection in birds. Zinc and oleic acid absorption were both decreased during the period 7 to 10 days after the initial *E. acervulina* inoculation and were slightly enhanced later. Zinc absorption was more severely impaired than oleic acid absorption during the *E. necatrix* infection. The period of most severe absorptive impairment after the series of *E. necatrix* inoculations was delayed until the 10th day following inoculation in comparison with the 6th day after a single inoculation. Turk and Stephens (1970a) also studied the effects of sulfaquinoxaline treatment upon an induced coccidial infection. Sulfaquinoxaline therapy was most effective in preventing (1) impaired absorption of Zn-65, (2) weight gain reductions, and (3) intestinal damage when begun one day following inoculation.

Lease et al. (1960) described an experiment where chicks fed purified rations containing sesame meal, made from decorticated K-10 seed as the sole source of protein, showed gross signs of zinc deficiency although the ration contained about 52 p.p.m. of zinc. The chicks were raised in galvanized batteries and given tap water. Growth was significantly improved and leg deformities were greatly reduced when 60 or 120 p.p.m. of zinc were added to the ration. Addition of the EDTA solution to the sesame meal, or of dry

EDTA to the ration, greatly reduced leg deformities and resulted in growth as good as 120 p.p.m. of added zinc. Suso and Edwards (1968) reported that Zn-65 absorption was significantly increased as the levels of EDTA were increased from 0 to 0.165 percent of the diet attaining maximal absorption at 0.125 percent EDTA. The 0.19 percent EDTA level did increase absorption, but not to an extent that was statistically significant. Nielsen et al. (1966) also found the availability of zinc was increased as the stability constants of the chelating agents increased.

Edwards (1966) observed that chicks receiving the casein-gelatin diet absorbed a much greater amount of the orally administered Zn-65 than those receiving the isolated soybean protein diet. Lease (1966) showed that chicks fed untreated sesame meal showed poor growth, leg deformities, feather abnormality and low zinc per gram in tibia. Addition of 60 p.p.m. of zinc prevented these symptoms.

Turk (1968) observed the growth response, when antibiotics were fed, was not due to improved absorption of zinc and oleic acid. The interaction between zinc and phytic acid has been reported by O'Dell et al. (1964) and Likuski and Forbes (1964). Addition of phytic acid to casein diets increased the chicken's dietary requirement of zinc. Savage et al. (1964) presented evidence that fecal zinc excretion was increased by adding phytic acid to a casein-gelatin type diet.

Edwards et al. (1959) experimenting with chicks using corn-soybean meal diets of two calorie and protein levels, under practical conditions, showed that zinc supplementation would increase the growth rate.

Roberson and Schaible (1958) reported that both chloride and sulfate of zinc at 100 p.p.m. in a glucose-soybean protein diet prevented zinc deficiency symptoms and permitted normal growth and feed conversion in the growing chick.

Roberson and Schaible (1960a) conducted an experiment to determine the availability to the chick of zinc as the sulfate, oxide or carbonate when added to a semi-purified diet at levels of 10 and 20 p.p.m. The availability of zinc from the three compounds was approximately the same at the two levels tested, as indicated by growth and prevention of deficiency symptoms. Pensack et al. (1958) stated that carbonate, oxide, chloride and proteinate of zinc were equally available to the chick when added to a cerelose-casein-gelatin diet with variable calcium:phosphorous ratios.

Morrison and Sarett (1958) found that addition of 0.5 and 1.0 percent calcium to an isolated soybean protein diet reduced weight gains and increased incidence and severity of hock disorder normally associated with a zinc deficiency. The addition of 25 p.p.m. of zinc completely overcame the growth depression and alleviated the symptoms. O'Dell et al. (1958) and Norris and Ziegler (1958) reported that an excess of calcium aggravated zinc deficiency in the chick, and that this adverse effect of calcium was overcome with supplemental zinc. Conversely, Pensack et al. (1958), using a casein-gelatin diet, found that growth was not depressed with calcium:phosphorous ratio of 1.0:0.6, 2.0:0.6, and 1.0:1.2 in the presence of 6, 20 and 40 p.p.m. of supplemental zinc.

Roberson and Schaible (1960b) conducted three experiments under relatively zinc-free conditions to determine the effect of high levels of calcium and phosphorous on the zinc requirement of the chick. Addition of 0.5 and 1.0 percent calcium to a slightly zinc-deficient ration containing a normal level (1.23 percent) of calcium depressed growth and feed efficiency and made zinc deficiency symptoms more than severe. Twenty p.p.m. of supplemental zinc did not overcome the effects of 1.0 percent additional calcium. In the presence of 80 p.p.m. of zinc and 2.23 percent of calcium, growth of chicks was normal and no deficiency symptoms were observed. The addition of 0.5 percent of phosphorous to the diet containing 0.6 percent phosphorous and a total of 36 p.p.m. of zinc, exerted no measurable effect on the growth rate of chicks.

Lease and Williams (1967) reported that addition of 450 p.p.m. of magnesium did not affect the zinc requirement of chicks fed a soybean meal ration with 0, 30, or 60 p.p.m. of added zinc. Increasing the added magnesium to a ration total of 3,000 p.p.m. had no effect until 60 p.p.m. of zinc were added.

O'Dell and Savage (1957) obtained an increase in growth with chicks when adding 0.5 percent KCl and 0.01 percent $ZnCO_3$ to a Drackett protein-cerelose diet containing 0.116 percent added potassium and 6.6 p.p.m. added zinc.

An interaction between zinc and cadmium or mercury was shown by Suso and Edwards (1969) as evidenced by the decrease of Zn-65 absorption and the increase of zero-day retention value. Iron, also, depressed the absorption and increased the retention at zero-day of Zn-65, and zinc increased Fe-59 absorption, indicating some type of relationship between these elements.

Edwards (1959) has conducted a detailed study of the availability to chicks of zinc in various compounds. Two levels, 10 and 20 p.p.m., of zinc from each material were fed in purified diets of low zinc in the form of sulfate, willemite, zinc carbonate, zinc metal, zinc oxide (technical grade), smithsonite, hemirophite, zinc oxide (A. R. grade), and zincite. Each form was relatively available to the young growing chicken. The zinc in sterling black and brown crude ore was of lower availability and that from sphalerite and franklinite was relatively unavailable.

Mertz et al. (1965) reported orally administered trivalent chromium was poorly absorbed to the extent of only about 1 percent or less, regardless of dose and dietary chromium status. Conn et al. (1932) observed that soluble chromates were poorly absorbed and appeared mainly in feces in insoluble complex form. Chromic oxide is so insoluble that it has found wide application as a "marker" for determining the digestibility of components of the diet and of feed intake by grazing stock, according to Kane et al. (1950).

Studies with Cr-51 indicated that hexavalent chromium is better absorbed than trivalent chromium. Mackenzie et al. (1959) observed a three to fivefold greater blood radioactivity following intestinal administration of hexavalent Cr-51 than after trivalent Cr-51. Donaldson and Barreras (1966) similarly obtained a consistently greater intestinal uptake of chromium from Na_2CrO_4 than $CrCl_3$ in man and in rats.

Schwartz and Mertz (1959) showed that trivalent chromium was effective in very low concentrations in bringing about glucose removal from the blood of rats on a deficient diet and that chromium appeared to be a principal glucose tolerance factor. Romosor (1960) found as much as 100 p.p.m. chromium fed as Na_2CrO_4 had no effect on growth, feed conversion, or mortality. The addition of chromium as Na_2CrO_4 also failed to exert any effect on the performance of chicks used in his experiment (1961).

Kunishisa et al. (1966) reported White Leghorn chicks were fed the diet supplemented with 0, 100, 300, and 900 p.p.m. of Cr as K_2CrO_4 which was used as a typical hexavalent Cr source. Feed intake and body weight gain for chicks six weeks of age, fed a diet supplemented with 100 p.p.m. Cr, were almost equal to those of the nonsupplemented control chicks. Feed intake and weight gain of chicks on 300 p.p.m. Cr were 84.7 and 81.4 percent of the controls, respectively. Those of chicks on 900 p.p.m. Cr were only 59.9 and 50.8 percent of those of the controls, respectively.

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MATERIALS AND METHODS

Two separate experiments were conducted at the Kansas State University poultry nutrition laboratory. A total of 576 birds were used in the two experiments. Experiment I, consisting of 192 birds, was initiated on September 28, 1971, and ran until November 23, 1971. The second experiment was conducted from November 30, 1971, to January 25, 1972, and utilized 384 birds. Male meat-strain White Rock Strain-Cross broiler chicks were used in both experiments.

The chicks were randomized into 12 lots of 16 chicks each in Experiment I and into 24 lots of 16 chicks in Experiment II, and were individually wing-banded. Electrically heated battery brooders were used to rear the birds to four weeks of age, at which time they were transferred to unheated batteries until the end of the experimental period. Feed and water were provided *ad libitum*.

Grain was ground and all ingredients were mixed at the university poultry farm. The Kansas State University basal broiler diets of 24 and 20 percent protein were used as the control diets at 0 to 4 and 5 to 8 weeks of age, respectively. Various supplements were added to the basal diets. The composition of these diets are given in Tables 1 and 2. A large platform balance was used to weigh macroingredients in pounds; whereas, gram levels of microingredients were weighed on a double pan computagram balance. The microingredients were added to approximately 10 pounds of ground yellow corn and mixed for five minutes in a small electrically operated Hobart mixer. This premix was then blended into the remaining amount of the 100 pounds of macroingredients and mixed for an additional five minutes in the 100-pound horizontal paddle mixer. The above procedure was repeated for adding a supplement or a combination of supplements to each 100 pounds of basal. The lists of supplements and levels used are listed in Tables 3 and 4.

All feed was put into paper bags, labeled, and stored in the poultry nutrition laboratory. Feed was added to the diet storage cans, the amounts were recorded, and at the end of each two-week period the feed remaining in the storage can was weighed back. This amount was then subtracted from the total weighed out to give the kilograms consumed per lot. Feed utilization or kilograms of feed required per kilogram of gain was calculated for each lot of chicks at the end of each eight-week experiment. The feed utilization summaries appear in Tables 5 and 6. Individual body weights were recorded for each two-week period.

Analysis of variance was run on 0-2, 2-4, 4-6, 6-8, 0-4, 0-6, and 0-8 week weight gains and feed utilization. A pooled analysis of variance, including both experiments, was obtained also for each of the above criteria.

RESULTS

Experiment I

An analysis of variance was run on the 0-2, 2-4; 4-6, 6-8, 0-4, 0-6, and 0-8 week body weight gains and feed utilization. This analysis indicated that diets were not significantly different in either average body weight gains or feed utilization for the various experimental periods.

Under the conditions of this experiment, no supplement gave better weight gains or feed utilization than Diet 1 (basal) for chickens 0-8 weeks of age. A summary of body weight gains and feed utilization appears in Table 5.

Experiment II

An analysis of variance was run on the 0-2, 2-4, 4-6, 6-8, 0-4, 0-6, and 0-8 week body weight gains and feed utilization using the same basis as for Experiment I. This analysis indicated that Diet 5 resulted in significantly greater weight gains than Diet 1 at the 0.05 level of probability at 0-2, 2-4, 0-4, and 0-6 week period, but no significant difference in feed utilization among the diets for the various experimental periods.

However, a comparison of the gains and the feed utilization for 0-8 weeks of age indicated that Diets 3, 6, and 5 gave better weight gain and 2, 6, and 3 required less feed per unit of gain than Diet 1 (basal). A summary of weight gains and feed utilization is shown in Table 6.

Pooled Analysis

A pooled analysis of variance of Experiments I and II was run on the two-week periods as for both previous experiments. This analysis indicated that diets were not significantly different among treatments in weight gain or feed utilization for the various experimental periods. The pooled analysis of variance of weight gain and feed utilization is given in Tables 8 and 9.

There was no supplemented diet which gave better gain or feed utilization than Diet 1 (basal). The data for weight gain and feed utilization are shown in Table 7.

DISCUSSION

Results of two experiments, using Zinpro(R) (zinc-methionine-chromium complex), zinc oxide, DL-methionine, chromium, and a combination of zinc oxide, DL-methionine, and chromium in the practical basal diet indicated no significant difference among the diets in weight gain or feed utilization; however, the basal diet gave better growth and feed utilization for chicks 0-8 weeks of age.

The pooled weight gain and feed utilization data are presented as means in Table 7. It is apparent the basal diet made a slightly greater gain than did those receiving the basal diet supplemented with 45.5 gm of Zinpro(R), 5.1 gm of zinc oxide, 4.5 gm of DL-methionine, 1 gm of chromium, and the combination of 5.1 gm of zinc oxide, 4.5 gm of DL-methionine, and 1 gm of chromium per 100 lb of diet. These results are in contrast to Harbaugh and Sanford (1970) who worked with laying hens, and had better performance with the addition of zinc-methionine complex at the levels of 1, 2, 3 and 4 lb per ton of diet as compared to the nonsupplemented practical basal diet.

The basal diet supplemented with zinc oxide at the level of 5.1 gm per 100 lb was not significantly different from the practical basal diet, and it produced slightly less weight gain and efficiency of feed utilization than the basal diet. These results are in agreement with Supplee et al. (1958), who reported the addition of 48 mg of zinc per kg of diet did not improve the growth and feed conversion of chick, and Roberson and Schaible (1960c) who added 1,000 p.p.m. of zinc as zinc oxide to the practical-type, corn-soybean oil meal diet. This level of zinc did not affect chick growth as compared with the lower levels. Mehring et al. (1956) reported the quantity of zinc, as zinc oxide, added to the practical-type, corn-soybean meal, all mash diet, ranged from 15 to 778 p.p.m. Growth and efficiency of feed utilization were equally good on all diets, and were not affected by the added zinc. The results also are in agreement with Johnson et al. (1962) who showed growth was not markedly effected on a practical-type, corn-soybean oil meal diet containing 2,391 p.p.m. of added zinc, as zinc oxide; however, a diet containing 3,000, 4,000 and 5,000 p.p.m. of supplemental zinc resulted in a significant reduction in growth. The efficiency of feed utilization was not affected by the addition of zinc to the diet up to a level of 2,391 p.p.m., but there was a reduction when 4,000 and 5,000 p.p.m. of zinc were added to the diet. These results are in contrast to the work reported by Edwards et al. (1959) who found that chicks, receiving 20 p.p.m. of supplemental zinc in a corn-soybean oil meal diet, were significantly heavier than the control group.

There was no significant difference between the basal diet and 4.5 gm DL-methionine supplemented diet in growth or feed utilization under the conditions of these experiments. These results are in agreement with the work of Ringrose and Potter (1952), Slinger et al. (1952b) and Titus et al. (1955) who reported DL-methionine had no effect on the gain and feed utilization, and also are in agreement with Griminger and Fisher (1968) who concluded that addition of DL-methionine at the level 0-0.8 percent had no effect on growth, but 1 percent or more caused depression of growth in young chicks. The results are in contrast to Bird et al. (1945), Gerry et al. (1948), Saxena and McGinnis (1952), Reed et al. (1954), Rosenberg and Baldini (1957), Featherston and Stephenson (1960), Dean et al. (1960), Gardiner and Aqudu (1968), and many others who reported that methionine improved growth and feed efficiency when added to corn-soybean basal diet.

Chromium was not effective on the performance of chicks when added to the basal diet. Zinpro$^{(R)}$ (zinc-methionine-chromium complex) was not different from the combination of zinc oxide, DL-methionine and chromium.

There appears to be a possible explanation of these experiments as to why zinc oxide, DL-methionine and chromium did not have a beneficial effect on weight gain and feed utilization. The practical basal diet was calculated to contain the amount of these supplements which would be adequate to meet the chick requirements. The supplements used at the levels of 5.1 gm zinc oxide, 4.5 gm DL-methionine, and 1 gm chromium per 100 lb of diet were probably too small a quantity to effect weight gain or feed utilization of broiler-strain chicks 0-8 weeks of age.

SUMMARY AND CONCLUSIONS

Two experiments were conducted in order to study the weight gain and the feed utilization of broiler-strain chicks fed 45.5 gm of Zinpro(R), 5.1 gm of zinc oxide, 4.5 gm of DL-methionine, and 1 gm of chromium per 100 lb of diet. A total of 576 Cobbs Strain-Cross White Rock male chicks were used in the two experiments. The chicks were kept in electrically heated battery brooders to four weeks of age. At four weeks they were transferred to unheated batteries. Body weights and feed consumption data were taken at two-week intervals during the eight-week period of the experiments.

The Kansas State University basal broiler ration was used as the control diet. The level of each supplement per hundered pounds of feed was added to the basal ration to provide five supplemented diets.

There was no significant difference in weight gain or feed utilization of birds fed each supplement as compared to the control or any other supplement.

The following conclusions were drawn from the results of these experiments.

1) There was no significant difference in weight gain by feeding 45.5 gm of Zinpro(R), 5.1 gm of zinc oxide, 4.5 gm of DL-methionine, 1 gm of chromium or the combination of 5.1 gm of zinc oxide, 4.5 gm of DL-methionine and 1 gm of chromium per 100 lb of basal diet as compared to the nonsupplemented basal diet.

2) There was no significant difference in feed utilization by feeding the above supplements as compared to the nonsupplemented basal diet.

3) Zinpro(R) (zinc-methionine-chromium complex) was not superior to the combination of zinc oxide, DL-methionine and chromium in weight gain or feed utilization when added to the nonsupplemented basal diet.

4) Chromium at the level 1 gm per 100 lb of diet did not improve chick growth or feed utilization.

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APPENDIX

Table 1. Composition of the K. S. U. 24 percent protein broiler chick starter basal ration (complete feed to be fed 0-4 weeks of age) used in both experiments.

Ingredients	Quantity Used per 100 Pounds
Corn, yellow, ground	26.0 pounds
Sorghum grain, ground	26.0 pounds
Alfalfa meal, dehy., 17% protein	2.0 pounds
Soybean meal, solv. extr., 44% protein	42.0 pounds
Distiller dried solubles	1.5 pounds
Calcium carbonate	1.0 pounds
Dicalcium phosphate	1.0 pounds
Sodium chloride	0.5 pounds
Total	100.0 pounds
Added per 100 Pounds of Diet	
Trace mineral mix[1]	23 grams
Vitamin A (10,000 USP units/gm)	20 grams
Vitamin D_3 (15,000 ICU/gm)	8 grams
B-complex vitamin mix[2]	46 grams
DL-Methionine	23 grams
Vitamin B_{12} (20 mg/lb)	10 grams
Choline chloride, 25% mix	40 grams
Coccidiostat (Amprol Plus, 25%(R))	23 grams

[1]Contained 10% manganese, 10% iron, 12-14% calcium, 1% copper, 5% zinc, 0.3% iodine, and 0.1% cobalt.

[2]Contained mg/lb: riboflavin 8,000; pantothenic acid 14,720; niacin 24,000; choline chloride 80,000.

Table 2. Composition of the K. S. U. 20 percent protein broiler finisher basal ration (complete feed 4-8 weeks of age) used in both experiments.

Ingredients	Quantity Used per 100 Pounds
Corn, yellow, ground	32.0 pounds
Sorghum grain, ground	31.0 pounds
Alfalfa meal, dehy., 17% protein	2.0 pounds
Soybean meal, solv. extr., 44% protein	31.0 pounds
Fermentation residue	1.5 pounds
Calcium carbonate	1.0 pounds
Dicalcium phosphate	1.0 pounds
Sodium chloride	0.5 pounds
Total	100.0 pounds
Added per 100 Pounds of Diet	
Trace mineral mix[1]	23 grams
Vitamin A (10,000 USP units/gm)	20 grams
Vitamin D_3 (15,000 ICU/gm)	8 grams
B-complex vitamin mix[2]	46 grams
DL-Methionine	23 grams
Vitamin B_{12} mix (20 mg/lb)	10 grams
Choline chloride, 25% mix	40 grams
Coccidiostat (Amprol Plus, 25%(R))	23 grams

[1]Contained 10% manganese, 10% iron, 12-14% calcium, 1% copper, 5% zinc, 0.3% iodine, and 0.1% cobalt.

[2]Contained mg/lb: riboflavin 8,000; pantothenic acid 14,720; niacin 24,000; choline chloride 80,000.

Table 3. The levels and kinds of supplements used in Experiment I.

Diet No.	Lot No.	Supplements	Levels (gm/100 lb.)
1	1 & 2 Basal	None	None
2	3 & 4 Basal	Zinpro[(R)]	45.5
3	5 & 6 Basal	Zinc Oxide	5.1
4	7 & 8 Basal	DL-Methionine	4.5
5	9 & 10 Basal	Chromium[1]	1.0
6	11 & 12 Basal	Zinc Oxide + DL-Methionine + Chromium	5.1 + 4.5 + 1.0

[(R)] Registered trademark for zinc-methionine-chromium complex (zinc 40 gm per pound, methionine 10%, and chromium 10 gm per pound) supplement manufactured by the Zinpro Corporation, Excelsior, Minnesota 55331.

[1] Organic chromium.

Table 4. The levels and kinds of supplements used in Experiment II.

Diet No.	Lot No.	Supplements	Levels (gm/100 lb.)
1	1, 2, 3, 4 Basal	None	None
2	5, 6, 7, 8 Basal	Zinpro[(R)]	45.5
3	9, 10, 11, 12 Basal	Zinc Oxide	5.1
4	13, 14, 15, 16 Basal	DL-Methionine	4.5
5	17, 18, 19, 20 Basal	Chromium[1]	1.0
6	21, 22, 23, 24 Basal	Zinc Oxide + DL-Methionine + Chromium	5.1 + 4.5 + 1.0

[(R)] Registered trademark for zinc-methionine-chromium complex (zinc 40 gm per pound, methionine 10%, and chromium 10 gm per pound) supplement manufactured by the Zinpro Corporation, Excelsior, Minnesota 55331.

[1] Organic chromium.

Table 5. Average eight week weight gains and feed utilization for all lots in Experiment I.

Diet No.	Lot No.	Gains in Grams	Kg. Feed per Kg. Gain
1	1	1883	2.34
	2	1884	2.15
2	3	1916	2.25
	4	1817	2.40
3	5	1810	2.36
	6	1805	2.34
4	7	1837	2.36
	8	1814	2.38
5	9	1807	2.32
	10	1840	2.29
6	11	1835	2.32
	12	1811	2.33

Table 6. Average eight week weight gains and feed utilization for all lots in Experiment II.

Diet No.	Lot No.	Gains in Grams	Kg. Feed per Kg. Gain
1	1	1784	2.31
	2	1785	2.34
	3	1823	2.51
	4	1772	2.35
2	5	1736	2.34
	6	1799	2.27
	7	1795	2.33
	8	1770	2.36
3	9	1871	2.43
	10	1818	2.39
	11	1855	2.31
	12	1732	2.31
4	13	1671	2.38
	14	1703	2.43
	15	1759	2.39
	16	1750	2.31
5	17	1882	2.34
	18	1714	2.45
	19	1805	2.39
	20	1824	2.37
6	21	1777	2.36
	22	1853	2.36
	23	1815	2.32
	24	1799	2.32

Table 7. Pooled means of eight week weight gain and feed utilization.

Diet No.	Gains in Grams	Kg. Feed per Kg. Gain
1	1837	2.31
2	1821	2.32
3	1813	2.36
4	1773	2.37
5	1815	2.35
6	1817	2.33

Table 8. Pooled analysis of variance of eight week weight gain.

Source of Variation	Degree of Freedom	Mean Square	F-Ratio
Diets	5	2,410	1.30^{ns}
Experiments	1	20,992	11.30
Diets × Experiments	5	3,403	1.83^{ns}
Residual	24	1,857	
Total	35		

^{ns}Nonsignificant

Table 9. Pooled analysis of variance of eight week feed utilization.

Source of Variation	Degree of Freedom	Mean Square	F-Ratio
Diets	5	.00292	$.9^{ns}$
Experiments	1	.01525	4.71
Diets × Experiments	5	.00355	1.10^{ns}
Residual	24	.00324	
Total	35		

^{ns}Nonsignificant

COMPARISON OF FEEDING BROILER-STRAIN CHICKS A BASAL DIET SUPPLEMENTED WITH ZINC PROTEINATE, ZINC, METHIONINE, CHROMIUM AND A COMBINATION OF ZINC, METHIONINE AND CHROMIUM

by

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B.S., Kasetsart University, 1967

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Two replicate experiments were conducted to study the effect of feeding various supplements and combination of supplements on weight gain and feed utilization of broiler-strain chicks.

A total of 576 chicks, of Cobbs Strain-Cross White Rock meat-strain birds were used in the two experiments. They were reared in batteries under normal poultry husbandry practices. The Kansas State University basal broiler ration was used as the control diet. All feed was mixed at the university poultry farm. The individual supplements and a combination of the supplements were added at the levels per 100 pounds of feed in the following manner: Zinpro(R), 45.5 gm; zinc oxide, 5.1 gm; DL-methionine, 4.5 gm; chromium, 1 gm; and the combination of zinc oxide, 5.1 gm; DL-methionine, 4.5 gm; and chromium, 1 gm. Body weights and feed consumption data were taken at two-week intervals. The experiments were conducted for a period of eight weeks each.

Conclusions based on pooled data indicated no significant difference among diets in weight gain or feed utilization.