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To the Graduate Council:

I am submitting herewith a thesis written by Emily Ann Davis entitled "Supplementation of Chick Diets Containing High Levels of Hydrolyzed Feather Meal." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Poultry.

Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Dean of the Graduate School

SUPPLEMENTATION OF CHICK DIETS CONTAINING HIGH LEVELS OF HYDROLYZED FEATHER MEAL

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Emily Ann Davis

August 1965

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INTRODUCTION

Jensen (1965) predicted that the efficient utilization of raw and by-product materials for poultry diets will increase in importance as humans compete directly with animals for today's feeds. Feather meal or hydrolyzed poultry feathers is such a product. According to Davis et al. (1961) the Association of American Feed Control Officials in 1958 adopted the following definition for Hydrolyzed Poultry Feathers:

> Hydrolyzed Poultry Feathers is the product resulting from the treatment under pressure of clean, undecomposed feathers from slaughtered poultry, free of additives, and/or accelerators. Not less than 70 percent of its crude protein content shall consist of "digestible protein."

The protein in feathers is beta keratin (Crick and Kendrew, 1957). Because of the unique physiocochemical characteristics of keratins, they are insoluble in dilute acids and alkalies, in water, in organic solvents, and resistant to digestion by proteolytic enzymes. These characteristics are well described by Gortner and Gortner, 1950; Hawk et al., 1954; Fruton and Simmonds, 1958; West and Tood, 1963; and others.

Binkley and Vasak (1950) found that by steam pressure cooking, drying, and grinding feathers could be used as a feedstuff. Early work with hydrolyzed feather meal indicated that the amount that could be used in a poultry diet was limited due to a growth depressing effect. The high incidence of perosis in birds fed diets containing high levels of feather meal presented another problem.

To date, the author is unaware of any researchers who have been able to supplement a diet containing a high level of feather meal in such a manner as to obtain chick growth equivalent to that obtained by chicks fed a corn-soybean oil meal-fish meal diet, or to eliminate perosis. Since most researchers have used only one level of supplementation for each amino acid studied, the questions of availability and the optimum level of supplementation in feather meal diets have not been answered. In addition the availability of folic acid, manganese, and phosphorus in feather meal and the optimum level of supplementation of these nutrients is not known; therefore, a series of experiments were designed (1) to determine the effect of graded levels of supplemental amino acids on the growth response and feed efficiency of chicks fed a diet containing 14.5 percent hydrolyzed feather meal and (2) to determine the effect of graded levels of antiperotic nutrients in preventing perosis and in enhancing growth and feed efficiency of chicks fed a diet containing 14.5 percent hydrolyzed feather meal.

LITERATURE REVIEW

Properties of Feathers and Feather Meal

Commercially processed feather meals vary from a light gray to a dark gray or brown in color. Samples used in experiments have been very finely ground and light and soft in texture. Feather meal has its own odor, but unlike fish meal's odor it is pleasant.

The protein in feathers is a keratin, specifically a beta keratin (Crick and Kendrew, 1957). The digestibility and the availability of the amino acids in keratins are low because of the protein's unique physiocochemical structure. Goddard and Michaelis (1934) showed that the digestibility of keratin by proteolytic enzymes could be increased by reducing the disulfide linkage to the sulfhydryl group. The disulfide bonds could be reduced by thioglycolic acid, potassium cyanide, sodium sulfide, and sodium sulfite. These reductants reacted very quickly and without bringing about other major chemical alterations than those concerned with the sulfide. The reaction took place readily in alkaline solutions (pH 10 to 13).

The keratin in feathers was considered by Block (1939) to be a eukeratin or true keratin based on its relatively constant proportion of histidine, lysine, and arginine present in the molecular ratio of 1:4:12 or 1:5:12. He hypothesized that the basic amino acids might be of some importance in tissue protein and have a direct influence on pro-

tein synthesis in organisms. The general characteristics of a group of proteins might be due to their proportions of histidine, lysine, and arginine, and the variations due to the kind and number of other amino acids.

Routh (1942 a, b) found that the amino acids trytophan, methionine, histidine, and lysine were in suboptimal concentrations in powdered keratins (wool and hen's feathers).

Studies by Wagner and Elvehjem (1942, 1943) and Newell and Elvehjem (1947) indicated that the nutritive value of feather and other type of keratin proteins was enhanced as the size of the particle decreased. The finer the subdivision, the more reactive the keratin protein was due to the increased surface area which apparently improved enzymatic action.

Block (1939), Graham et al. (1949), Block and Bolling (1951), Gregory et al. (1956) and others have determined the amino acid composition of raw and processed feathers (Table XXI, Appendix). The analysis of Gregory et al. (1956) showed that the amino acids in feather protein were relatively stable during steam pressure processing except for arginine, phenylalanine, isoleucine, and cystine. Cystine was the only amino acid to show considerable loss.

Hubbell (1964) listed the average analysis and certain nutrients of feather meal as follows: protein, 85 percent; fat, 2.5 percent; fiber, 1.5 percent; calcium, .20 percent; phosphorus, .75 percent; ash, 3.9 percent; productive energy, 600 Calories per pound; riboflavin,

.8 mg. per pound; niacin, 8.0 mg. per pound; pantothenic acid, 3.5 mg. per pound; choline, 400 mg. per pound; arginine, 5.6 percent; lysine, 1.5 percent; methionine, .52 percent; cystine, 2.3 percent; tryptophan, .57 percent; and glycine, 6.7 percent.

There have been reports of an unidentified growth factor in feather meal. Lillie et al. (1956) found that the growth stimulation obtained from diets containing 2.5 and 5 percent feather meal could not be attributed to the feather meal's protein, but to the presence of an unidentified growth factor. This work was confirmed by Menge et al. (1956) who reported that 4 percent feather meal and ash equivalent to 4 percent feather meal exhibited a growth stimulation that was significant at the 1 percent level. The results indicated that the unidentified growth factor present in feather meal was inorganic in nature. Fuller (1956 b, c) also reported that feather meal exhibited unidentified growth factor activity on a corn-soy type diet with adequate methionine levels. However, he believed that the unidentified growth factor activity in feather meal was not attributed to its inorganic fraction or to the amino acid cystine. The feather meal growth factor may have been responsible for the heavier four week body weights of chicks fed a diet containing 2 percent feather meal than chicks fed a diet containing only soybean oil meal as reported by Stephens et al. (1961).

Feathers as a Feedstuff for Chicks

Early work. Scott and Payne (1928) studied the use of hydrolyzed feathers as a feed for chicks. Their results indicated that hydrolyzed feathers added nothing of importance to diets of layers, chicks, or fattening broilers of that day. They believed that the cost of hydrolyzation was too great to expect such a feed to compete commercially with other protein supplements on an equal feeding basis.

Draper (1944) found that sodium-sulfide treated feathers could be assimilated by the chick; however, unsatisfactory growth occurred when chicks were fed a diet in which all the supplementary protein was from treated feathers. The nutritive value of raw feathers was not enhanced by autoclaving, and the cost of treating feathers with chemicals was considered to prohibit their use as a protein feed.

Processing methods. Binkley and Vasak (1950) developed a feather meal processing method at the Western Regional Research Laboratory. Results from tests indicated that best results occurred when wet feathers, as received from poultry processors, were treated with saturated steam in a cooker for 30 to 60 minutes at a pressure of 40 to 60 p.s.i. and 287 to 370°F. Uniform heating was achieved by agitating the feathers. After the steam was exhausted, the treated feathers were transferred to drying equipment, dried to a moisture content of 8 to 12 percent, and ground to a satisfactory bulk density.

Western Regional Laboratory workers found that the *in vitro* digestion of feather meal with pepsin-hydrochloric acid under standard conditions could be used as an indicator of the degree of processing. A meal with a 70 percent pepsin-hydrochloric acid digestibility value was desirable. A relationship was obtained showing that as the pressure was increased over 30 p.s.i. there was a rapid decrease in the time to reach 70 percent digestibility. In commercial processing the primary point was to provide sufficient heat and moisture to break down the physical structure of the feather (Davis *et al.*, 1961).

Sullivan and Stephenson (1957) tested hydrolyzed feather meals from seven processing methods. The authors found that the various steam pressure cooking methods tested had similar effects on the nutritive value of feather meal when fed to growing chicks. It appeared that digestibility of feather protein was greatly increased by treating with steam. A mild treatment of 15 pounds steam pressure for 20 minutes was satisfactory. The greatest chick growth was obtained with diets containing feathers that were dried, cooked with 35 pounds of steam pressure for one hour, and then dried and ground.

In 1959, Naber and Touchburn found that when experimentally processed feather meals were compared in diets where one-third of the protein was contributed by the feather meal, all samples that yielded a pepsin digestibility of 60 percent or more appeared to produce satisfactory growth rates. When feather meal supplied two-thirds of the protein, it was possible to distinguish between meals of 60, 70,

and 80 percent pepsin digestibility, based on chick growth.

Stephens et al. (1961) studied two samples of hydrolyzed feather meal from different processing plants and one sample of lime-cooked feathers. These authors found that lime-cooked feather meal was less satisfactory than either of the two hydrolyzed feather meals when fed as 14.5 percent of the total chick diet.

Naber et al. (1961) concluded that contamination with blood and offal and/or fermentation of feathers prior to processing improved the growth promoting properties of the feather meals. The procedures used in processing the feathers affected the nutritive value of the feather meals. Feathers from poultry processors are usually held for a time before processing; thus, feathers have the opportunity to undergo fermentation and the chance to become contaminated.

Amino acid supplementation of feather meal. The amino acid requirements for growing chicks have been suggested by Almquist (1957), National Research Council (NRC) (1960), Klain et al. (1960), and Dean and Scott (1965). Naber (1961) compared the chick requirement for amino acids to the percentage of amino acid requirement provided by feather meal protein (see Table XXII, Appendix). He showed that feather meal was low in histidine, lysine, tyrosine, tryptohan, and methionine.

A number of studies have been conducted to determine the amino acid deficiencies of feather meal in poultry diets. Harms and Douglas

(1958) showed that lysine was the first limiting amino acid in feather meal. This was confirmed by Naber and Touchburn (1959).

Fuller (1956, a, b, c) found that 5 percent feather meal could be used to furnish part of the protein in broiler diets when the diets were supplemented with methionine and unidentified growth factors.

Naber and Morgan (1956) demonstrated that feather meal had a high supplementary value in a corn-soybean oil meal diet when supplemented with methionine.

In the first trials conducted by Combs et al. (1957, a, b) feather meal diets did not require additional methionine for best results. In the second group of trials chicks fed the methionine supplemented feather meal diets had heavier body weights and better feed efficiency. These workers suggested that the methionine sparing effect exhibited by the feather meal in the first trials was due to the particular feather meal sample.

Harms and Douglas (1958) conducted studies to determine the relationship between feather meal and the response from supplemental DL-methionine and methionine hydroxy analogue. The growth depression caused by the feather meal was not overcome, but growth was improved with each level of either source of methionine.

Romoser (1955) indicated that at least 2.5 percent feather meal could be satisfactorily added to broiler diets to supply part of the protein if supplemented with methionine and lysine and other amino acid levels were adequate.

Methionine was found by Harms and Douglas (1958) to be the second limiting amino acid in feather meal. The addition of methionine by itself had no effect on body weight.

Naber and Touchburn (1959) verified that methionine was the second limiting amino acid in feather meal. In a diet where feather meal, soybean oil meal, and corn each supplied one-third of the protein, lysine and methionine supplementation produced maximum growth.

Growth rate of chicks was better on a corn-feather meal diet containing 0.7 percent lysine and 0.4 percent methionine than when only 0.7 percent lysine was added to the diet as reported by Naber et al. (1961).

Bletner and Stephens (1962) indicated that the optimum level of added L-lysine and DL-methionine in a 14.5 percent feather meal diet was close to 0.46 and 0.065 percent, respectively, for these amino acids.

Other amino acids have been reported to be limiting in feather meal. Supplementation of feather meal with methionine, lysine, and tryptophan was found to be of value by Gerry (1956). Naber and Morgan (1956) and Harms and Douglas (1958) recognized that histidine and tryptophan were low in feather meal, and the latter workers supplemented their diets with them. Naber and Touchburn (1959) showed tryptophan, histidine, and arginine to be the third, fourth, and fifth limiting amino acids, respectively, in feather meal.

Naber et al. (1961) found further improvement in growth of chicks fed corn-feather meal diets when supplemented with 0.1 percent tryptophan and histidine in addition to lysine and methionine.

Stephens et al. (1961) supplemented 6 percent feather meal diets with methionine and lysine and those containing 14.5 percent feather meal with histidine and tryptophan in addition to the methionine and lysine.

Graded levels of tryptophan added to a 14.5 percent feather meal diet had no effect on chick growth as reported by Bletner and Stephens (1962).

Level of feather meal for practical useage. Harms and Douglas (1958) found that supplementation of 17.5 percent feather meal diets with lysine and methionine did not support growth equal to the soybean oil meal basal. They suggested that perhaps sufficient amounts of amino acids had not been added to the feather meal for maximum growth or that there were other limiting factors. Naber and Touchburn (1959) and Naber et al. (1961) found that when chicks were fed a simplified corn-feather meal diet supplemented with the amino acids lysine, methionine, tryptophan, and histidine growth and nitrogen retention were markedly improved; but that the growth rate was poorer than for the chicks fed a corn-soybean oil meal diet.

Stephens et al. (1959, 1961) tested 14.5 percent feather meal diets and soybean oil meal diets calculated to contain approximately

equal amounts of essential amino acids at a level to meet the National Research Council (NRC) recommendations. They confirmed the reports of Harms and Douglas (1958), Naber and Touchburn (1959), and Naber et al. (1961) that more rapid weight gains were made by chicks fed the soybean oil meal diets than fed the feather meal diets. Stephens and co-workers (1961) were unable to improve feather meal as a source of protein for broiler diets (1) when the levels of vitamins and minerals were increased, (2) when massive amounts of essential amino acids were supplied by a casein-gelatin mixture, or (3) when a combination of the above two were used.

Wilder (1953), Gerry and Smyth (1954), Stephenson et al. (1957), Stephens et al. (1961), and Tsang et al. (1963) found that 7, 10, 6.5, 6, and 8 percent feather meal, respectively, could be used in a broiler diet without depressing growth. Harms and Goff (1956) and Sullivan and Stephenson (1957) found that diets containing 7.5 percent feather meal caused a growth depression, while Harms and Douglas (1958) and Sibbald et al. (1962) found that 6 percent feather meal depressed growth. Stephens et al. (1961) reported that 14.5 percent feather meal significantly depressed growth. Other workers, Wilder et al. (1955), Naber and Morgan (1955, 1956) Harms and Goff (1956), Lillie et al. (1956), McKerns and Rittersporn (1958), and Wisman et al. (1958) have stated that up to 5 percent feather meal might be used in broiler diets without depressing growth.

Perosis

Chicks fed diets containing high levels of feather meal have exhibited a high incidence of perosis (Stephens et al., 1961, and unpublished work of Bletner, 1962). If perosis is severe, it will adversely affect the growth rate of the chicks. This in turn will cause the growth pattern to be skewed and a true picture of chick growth on high levels of feather meal is not obtained.

Perosis is a malformation of chick bones. The hock is swollen and the condyles flattened, which allows the Achilles' tendon to slip to one side. The tibia and tarsometatarsus may exhibit bending near the hock joint and lateral rotation (NRC, 1960). Perosis is also known as slipped tendon and hock disease (Ewing, 1963).

Ewing (1951, 1963) has extensively reviewed the literature concerning perosis. A number of factors can initiate and/or aggravate the condition of perosis or slipped tendon. They are as follows:

1. A deficiency of manganese with a species variation in requirements
2. A deficiency of choline
3. A deficiency of folic acid
4. A deficiency of biotin
5. Excess dietary calcium, phosphorus, or total mineral content of the diet
6. Inheritance, heavy breeds of chickens generally more susceptible than Leghorns.

7. Confinement rearing, especially on wire.

Suggested requirements for manganese, choline, folic acid, biotin, calcium, and phosphorus are set forth by the NRC (1960).

Mohamed and Greenberg (1943) produced perosis in chicks fed a synthetic diet deficient in manganese and adequate in calcium and phosphorus. Using labeled manganese the authors showed that the major portion of manganese, whether administered orally or by injection, was excreted by the control and deficient chicks. The liver was the most active organ in the metabolism of manganese. The uptake of the labeled manganese by the bone was not measurable when the dose was administered orally.

In 1955, Parker et al. using radioactive isotopes of calcium, phosphorus, and manganese determined the effects of manganese levels in the diet on the location and amount of deposition of these elements in the bones of the growing chick. Bone sections from manganese deficient chicks accumulated more manganese-52-54 than those which the authors indicated as normal chicks. The radioautographs indicated that manganese-52-54 was deposited in all parts of the tibiae with the highest concentration being found at the site of active calcification. The manganese level in the diet did not significantly effect the amount or location of the calcium-45 or phosphorus-32 deposition in the tibiae.

In recent work by Norris and Klein (1961) it was shown that the erythrocytes of duck blood took up manganese-54 reversibly in vitro;

however, no evidence was obtained for the association of the metal with porphyrin. After X-irradiation of the animal, *in vitro* uptake decreased to a low level, which suggested that the uptake was mainly a function of the reticulocytes. *In vivo*, intravenously administered manganese appeared to be taken up by erythrocytes during formation or maturation in the bone marrow and after the cells entered the circulation. The manganese taken up *in vivo* was recovered in association with the heme, lending support to the hypothesis that the metal, manganese, was present in the cells as a porphyrin complex.

Creek and Vasaitis (1963) studied the effect of excess dietary protein on the need for folic acid by the chick. They found that choline had a sparing effect on the folic acid requirement, and that B_{12} also influenced the chick's need for folic acid. Using a purified diet they found that a high protein level increased the need for folic acid and amplified the severity of perosis.

PROCEDURES

Vantress x Arbor Acre chicks obtained from a Tennessee hatchery were used in seven experiments. Parmenter Red chicks were used in an eighth experiment. At one day of age, the chicks were sexed, wing banded, weighed, vaccinated for Newcastle disease and infectious bronchitis by the intraoccular method, and placed on experiment for four weeks. The all-mash diets and water were available to the chicks at all times. Birds that died during the first week were replaced with ones of the same sex that had been fed a control diet. A daily log of mortality, room and battery temperature, and chick conditions was maintained in the Poultry Nutrition Laboratory.

Chicks were housed in electrically-heated, raised wire-floored battery brooders. Prior to placing chicks on experiment, the heating elements in the batteries were adjusted to the same level, and the thermostats were adjusted to operate in the range of 95 to 100°F. The battery temperatures were lowered five degrees a week until equal to the room temperature when weather conditions permitted. Room temperatures were maintained between 70 and 85°F.

Birds were individually weighed in grams when placed on experiment, and thereafter were weighed and observed for perosis at weekly intervals for four weeks. Feed consumption was determined at the end of each experiment.

The basic 14.5 percent feather meal diet employed in the following experiments was developed at the Tennessee Agricultural Experiment Station and has been studied for several years (Stephens et al., 1959, 1961 and Bletner and Stephens, 1962). The diet was composed of corn, alfalfa meal, fish meal, feather meal, vitamins, minerals, and non-nutritive additives. The diet contained somewhat higher calculated levels of most supplemental vitamins and minerals than did the soybean oil meal basal used as a control diet.

Data obtained from incomplete Latin square designed experiments were analyzed according to an analysis of variance procedure suggested by Cochran and Cox (1957). Data obtained from randomized split block and randomized block designed experiments were analyzed according to an analysis of variance procedure suggested by Snedecor (1956). Significant treatment, replication and other differences were determined by the use of Duncan's Multiple Range Test (1955).

Amino Acid Supplementation Experiments

Experiment 1. Experiment 1 was designed to study the effects of graded levels of DL-methionine and 0.5 percent added L-lysine in a 14.5 percent hydrolyzed feather meal diet for broiler chicks. A 5 x 4 incomplete Latin square experimental design was used. Five male and five female chicks were randomly assigned to each pen. Diets 62-51, 62-52, 62-53, 62-54, and 62-55 were supplemented with DL-methionine at levels of 0.0325, 0.0488, 0.065, 0.13, and 0.39 percent, respectively.

The composition and calculated analyses of the five diets are given in Tables I and II.

Experiment 2. Experiment 2, conducted at the same time as experiment 1, was designed to investigate the effects upon chick growth of graded levels of DL-methionine and 0.7 percent added L-lysine in a 14.5 percent hydrolyzed feather meal diet. Diets 62-56, 62-57, 62-58, 62-59, and 62-60 were supplemented with DL-methionine at levels of 0.065, 0.13, 0.195, 0.26, and 0.39 percent, respectively. Diet 62-53 containing 0.5 percent added L-lysine and 0.065 percent added DL-methionine was used as a control diet. The composition and calculated analyses of the six diets are given in Table III. A 6 x 5 incomplete Latin square experimental design was used. Five male and five female chicks were randomly assigned to each pen.

Experiment 3. Experiment 3 was conducted to determine the effect of graded levels of L-histidine in the 14.5 percent feather meal diet on growth, incidence of perosis, and feed efficiency in broiler-type chicks. The basal feather meal diet contained 0.5 percent and 0.065 percent added L-lysine and DL-methionine, respectively. According to calculations the diet met the NRC (1960) requirements of 0.3 percent histidine. Diets 65-12, 65-13, 65-14, and 65-15 were supplemented with 0.0, 0.1, 0.2, and 0.3 percent L-histidine, respectively. An isonitrogenous, isocaloric soybean oil meal-fish meal diet was used as a control in the experiment. The composition and calculated analyses of the five

TABLE I

COMPOSITION AND CALCULATED ANALYSES OF DIETS--
EXPERIMENT 1

Ingredients	Diet number 62-51	62-52	62-53	62-54	62-55
	percentage				
Yellow corn	68.273	68.256	68.240	68.175	67.915
Alfalfa meal (17% protein)	2.500	2.500	2.500	2.500	2.500
Fish meal (65% protein)	5.700	5.700	5.700	5.700	5.700
Feather meal (85% protein)	14.500	14.500	14.500	14.500	14.500
Defluorinated rock phosphate	1.200	1.200	1.200	1.200	1.200
Limestone	1.000	1.000	1.000	1.000	1.000
Salt	0.500	0.500	0.500	0.500	0.500
$MnSO_4$ supplement (75%)	0.025	0.025	0.025	0.025	0.025
Vitamin mix[a]	4.000	4.000	4.000	4.000	4.000
DL-methionine	0.033	0.049	0.065	0.130	0.390
L-lysine supplement (200 g./kg.)	2.270	2.270	2.270	2.270	2.270
	100.000	100.000	100.000	100.000	100.000
Calculated analyses[b]					
Productive energy, Cal./kg.	2182	2182	2182	2180	2174
Crude protein, %	23.38	23.40	23.41	23.47	23.71
Methionine, %	0.346	0.363	0.379	0.444	0.703
Cystine, %	0.512	0.512	0.512	0.512	0.512
Lysine, %	1.197	1.197	1.197	1.197	1.196

[a]Composition of vitamin mix used is given in Table II.

[b]Calculations based on average analyses of feedstuffs according to Hubbell (1962).

TABLE II

COMPOSITION OF THE VITAMIN MIX USED IN HYDROLYZED FEATHER MEAL DIETS[a]

Ingredients	grams
Vitamin D_3 supplement (30,000 ICU/g.)	1.20
Vitamin A supplement (10,000 IU/g.)	20.00
Riboflavin supplement (52.8 g./kg.)	7.55
Vitamin B_{12} supplement (44.0 mg./kg.)	11.70
Aureomycin supplement (22.0 g./kg.)	25.00
Choline chloride supplement (25%)	281.00
Niacin supplement (50%)	8.00
D-calcium pantothenate	0.40
Arsanilic acid supplement (20%)	19.00
Yellow corn (carrier)	1442.15
Total	1816.00

Calculated vitamin and nonnutritive additive content per 1,816 grams

Vitamin D_3	36,000 ICU
Vitamin A	200,000 IU
Riboflavin	400.00 mg.
Vitamin B_{12}	515.00 mcg.
Choline chloride	70.25 g.
Niacin	4.00 g.
D-calcium pantothenate	400.00 mg.
Aureomycin	550.00 mg.
Arsanilic acid	3.80 g.

[a]Potencies of ingredients varied from mix to mix, but the content was calculated to be constant.

TABLE III

COMPOSITION AND CALCULATED ANALYSES OF DIETS--
EXPERIMENT 2

Ingredients	Diet number					
	62-53	62-56	62-57	62-58	62-59	62-60
	percentage					
Yellow corn	68.240	67.340	67.275	67.210	67.145	67.015
Alfalfa meal (17% protein)	2.500	2.500	2.500	2.500	2.500	2.500
Fish meal (65% protein)	5.700	5.700	5.700	5.700	5.700	5.700
Feather meal (85% protein)	14.500	14.500	14.500	14.500	14.500	14.500
Defluorinated rock phosphate	1.200	1.200	1.200	1.200	1.200	1.200
Limestone	1.000	1.000	1.000	1.000	1.000	1.000
Salt	0.500	0.500	0.500	0.500	0.500	0.500
$MnSO_4$ supplement (75%)	0.025	0.025	0.025	0.025	0.025	0.025
Vitamin mix[a]	4.000	4.000	4.000	4.000	4.000	4.000
DL-methionine	0.065	0.065	0.130	0.195	0.260	0.390
L-lysine supplement (220 g./kg.)	2.270	3.170	3.170	3.170	3.170	3.170
Total	100.000	100.000	100.000	100.000	100.000	100.000
Calculated analyses[b]						
Productive energy, Cal./kg.	2182	2158	2158	2156	2154	2152
Crude protein, %	23.41	23.69	23.75	23.81	23.87	23.99
Methionine, %	0.379	0.377	0.442	0.507	0.572	0.702
Cystine, %	0.512	0.511	0.510	0.510	0.510	0.510
Lysine, %	1.197	1.393	1.393	1.393	1.392	1.392

[a]Composition of vitamin mix used given in Table II on page 20.

[b]Calculations based on average analyses of feedstuffs according to Hubbell (1962).

diets used in the experiment are given in Table IV and V. A 5 x 4 incomplete Latin square experimental design was used in the study. Five male and five female chicks were randomly assigned to each pen.

Perosis Experiments

Experiment 4. A large number of perotic birds were observed in experiments 1 and 2 as well as in similar studies conducted earlier at this Station (Stephens et al., 1959, 1961). Since folic acid is one of many factors known to aid in the prevention of perosis, the effect of graded levels of folic acid in the 14.5 percent feather meal diet was studied in experiment 4. A deficiency of folic acid causes feather faults; thus Parmenter Reds were used in experiment 4 to determine if this vitamin might be involved. Five male and five female chicks were randomly assigned to each pen in the 6 x 5 incomplete Latin square experimental design. All diets contained 0.5 percent added L-lysine. Diets 63-11 through 63-14 contained 0.065 percent added DL-methionine, and diets 63-15 and 63-16 contained 0.26 percent added DL-methionine. A commercial folic acid supplement (guaranteed to contain not less than 3 percent folic acid) was added in sufficient quantity to diets 63-11, 63-12, 63-13, and 63-14 to supply 0.00, 0.55, 1.10, and 1.65 mg. folic acid per kilo, respectively. Diets 63-15 and 63-16 were supplemented with quantities to supply 0.0 and 1.10 mg. folic acid per kilo. The composition and calculated analyses of the two basal diets used are given in Table VI.

TABLE IV

COMPOSITION AND CALCULATED ANALYSES OF DIETS--EXPERIMENT 3

Ingredients	Diet number 65-12	65-13	65-14	65-15	65-16
	percentage				
Yellow corn	69.510	69.410	69.310	69.210	60.935
Alfalfa meal (17% protein)	2.500	2.500	2.500	2.500	2.500
Fish meal (65% protein)	5.700	5.700	5.700	5.700	5.700
Feather meal (85% protein)	14.500	14.500	14.500	14.500	---
Soybean oil meal (50% protein)	---	---	---	---	27.690
Defluorinated rock phosphate	1.200	1.200	1.200	1.200	1.000
Limestone	1.000	1.000	1.000	1.000	1.000
Salt	0.500	0.500	0.500	0.500	0.500
$MnSO_4$ supplement (75%)	0.025	0.025	0.025	0.025	0.025
DL-methionine	0.065	0.065	0.065	0.065	0.050
L-lysine supplement (50%)	1.000	1.000	1.000	1.000	---
L-histidine	0.000	0.100	0.200	0.300	---
Vitamin mix[a,b]	4.000	4.000	4.000	4.000	0.600
Total	100.000	100.000	100.000	100.000	100.000
Calculated analyses[c]					
Productive energy Cal./kg.	2138	2136	2134	2132	2141
Crude Protein, %	23.41	23.41	23.40	23.39	23.41
Methionine, %	.39	.39	.39	.39	.52
Cystine, %	.49	.49	.49	.49	.33
Lysine, %	1.23	1.23	1.23	1.23	1.38
Histidine, %	0.31	0.42	0.52	0.61	0.23

[a]Composition of vitamin mix used in feather meal diets given in Table II on page 20.

[b]Composition of vitamin mix used in soybean oil meal-fish meal diets given in Table V.

[c]Calculations based on average analyses of feedstuffs according to Hubbell (1964) except for histidine values which were taken from National Research Council (1956), Almquist (1957), and Davis et al. (1961).

TABLE V

COMPOSITION OF THE VITAMIN MIX USED IN SOYBEAN OIL MEAL-FISH MEAL DIETS[a]

Ingredients	grams
Vitamin D_3 supplement (30,000 ICU/g.)	1.13
Vitamin A supplement (10,000 IU/g.)	18.92
Riboflavin supplement (44.0 g./kg.)	4.89
Vitamin B_{12} supplement (44.0 mg./kg.)	11.32
Aureomycin supplement (22.0 g./kg.)	24.55
Choline chloride supplement (25%)	85.16
Niacin supplement (50%)	3.66
D-calcium pantothenate supplement (70.4 g./kg.)	4.54
Arsanilic acid supplement (20%)	18.93
Yellow corn (carrier)	177.09
Total	272.40

Calculated vitamin and nonnutritive additive content per 272.4 grams:

Vitamin D_3	34,000 ICU
Vitamin A	189,167 IU
Riboflavin	215.000 mg.
Vitamin B_{12}	498.000 mcg.
Choline chloride	21.290 g.
Niacin	1.828 g.
D-calcium pantothenate	318.000 mg.
Aureomycin	540.000 mg.
Arsanilic acid	3.786 g.

[a]Potencies of ingredients varied from mix to mix, but the content was calculated to be constant.

TABLE VI

COMPOSITION AND CALCULATED ANALYSES OF BASAL DIETS--
EXPERIMENT 4 AND 5

Ingredients	Feather meal basals	
	percentage	
Yellow corn	68.240	68.045
Alfalfa meal (17% protein)	2.500	2.500
Fish meal (65% protein)	5.700	5.700
Feather meal (85% protein)	14.500	14.500
Defluorinated rock phosphate	1.200	1.200
Limestone	1.000	1.000
Salt	0.500	0.500
$MnSO_4$ supplement (75%)	0.025	0.025
DL-methionine	0.065	0.260
L-lysine supplement (220 g./kg.)	2.270	2.270
Vitamin mix[a]	4.000	4.000
Total	100.000	100.000
Calculated analyses[b]		
Productive energy, Cal./kg.	2119	2112
Crude protein, %	23.70	23.88
Methionine, %	0.379	0.573
Cystine, %	0.481	0.481
Lysine, %	1.146	1.145
Folic acid mg./kg.	0.265	0.265

[a]Composition of vitamin mix used is given in Table II on page 20.

[b]Calculations based on average analyses of feedstuffs according to Hubbell (1963) except folic acid values which were from Hubbell (1964).

Experiment 5. Only five cases of perosis occurred in experiment 4 when Rhode Island Red chicks were used. This Rhode Island Red is a slow developing bird, and its growth rate may not have been sufficient to test the requirement of folic acid in the diet. Experiment 5 was a repetition of experiment 4 using a fast growing, white feathered, broiler-type chick which was considered capable of placing greater importance on the folic acid requirement in the diet. The diets used were designated as 63-17 through 63-22. The composition and the calculated analyses of the two basal diets are shown in Table VI on page 25.

Experiment 6. Manganese is another factor that aids in the prevention of perosis. It was thought that feather meal might contain some factor which hindered or inhibited the bird's ability to utilize the manganese present in a diet containing large amounts of feather meal.

Experiment 6 was conducted to determine the effect of graded levels of manganese in the 14.5 percent feather meal diet and in an isocaloric, isonitrogenous soybean oil meal diet on growth, the incidence of perosis, and feed efficiency.

Manganese was added to each diet at the expense of the entire diet in amounts calculated to bring the total manganese content of the diets to about 27.5, 55.0, 110.0, 220.0, and 330.0 mg. per kilo of diet. In addition both diets were fed without added manganese. A randomized split block experimental design was used which included twelve treatments and four replications per treatment. Six male and six female

chicks were randomly assigned to each pen. The composition and calculated analyses of the feather meal basal and soybean oil meal basal are given in Table VII. The level of choline chloride in the feather meal vitamin mix was reduced from 70.25 g. per 1.816 kg. to 35.00 g. per 1.816 kg.

Two purified diets, one containing no added manganese and the other containing 55.0 mg. added manganese per kilo were included in the experiment. Each diet was fed to one pen of six male and six female chicks. Due to an error in mixing of the purified diet, this part of the experiment was repeated at a later date. The composition of the purified basal is given in Table VIII. This is essentially the same diet which was used by Leach and Muenster (1962).

The second part of experiment 6 was to determine the in vitro uptake of manganese-54 (Mn-54) by erythrocytes secured from chicks fed the feather meal and soybean oil meal diets containing graded levels of manganese and from chicks fed the purified diets. The effect of the diets on the absorption and tissue deposition of Mn-54 was studied using birds fed the feather meal and soybean oil meal diets containing 0 and 110.0 mg. manganese per kilo and the purified diets.

Blood samples from three male and three female nonperotic chicks per treatment and from a like sample of perotic birds, when available, were obtained when the chicks were about four weeks old. The in vitro uptake of Mn-54 by erythrocytes was studied using the method of Wright and Bell (1963).

TABLE VII

COMPOSITION AND CALCULATED ANALYSES OF BASAL DIETS--
EXPERIMENT 6 AND 7

Ingredients	Feather meal basal	Soybean oil meal basal
	percentage	
Yellow corn	68.265	58.440
Alfalfa meal (17% protein)	2.500	2.500
Fish meal (65% protein)	5.700	5.700
Feather meal (85% protein)	14.500	-----
Soybean oil meal (50% protein)	-----	28.210
Fat, stabilized, fancy bleachable	-----	1.800
Defluorinated rock phosphate	1.200	1.200
Limestone	1.000	1.000
Salt	0.500	0.500
Vitamin mix[ab]	4.000	0.600
DL-methionine	0.065	0.050
L-lysine supplement (220 g./kg.)	2.270	-----
Total	100.000	100.000
Calculated analyses[c]		
Productive energy, Cal./kg.	2123	2130
Crude protein, %	23.71	23.66
Calcium, %	1.14	1.17
Total phosphorus, %	0.68	0.72
Inorganic phosphorus, %	0.55	0.54
Manganese mg. per kg.	7.81	14.48

[a]Composition of vitamin mix used in feather meal diets is given in Table II on page 20.

[b]Composition of vitamin mix used in soybean oil meal diets is given in Table V on page 24.

[c]Calculations based on average analysis of feedstuffs according to Hubbell (1963) except for manganese calculations which were based on figures from Heuser (1955) and unpublished data of Stephens (1960).

TABLE VIII

COMPOSITION OF PURIFIED DIET--
EXPERIMENT 6 AND 7

Ingredients	1 Kilo grams
Glucose	598.8
Isolated soybean protein	270.0
Corn oil	30.0
Celulose	30.0
Vitamin mix[a]	12.2
Mineral mix[b]	58.0
Glycine	3.0
Methionine hydroxy analogue	7.0
Total	1000.0

[a]Supplies the following per kilogram of diet: inositol, 250.0 mg.; niacin, 50.0 mg.; calcium pantothenate, 20.0 mg.; pyridoxine·HCl, 4.5 mg.; folic acid, 4.0 mg.; menadione sodium bisulfite, 1.52 mg.; biotin, 0.20 mg.; bitamin B_{12}, 54 µg. diluted to 16.0 g.; a-tocopheryl acetate, 66.0 mg.; vitamin A, 5400 IU; vitamin D_3, 980 ICU; thiamine·HCl, 11.0 mg.; riboflavin, 11.0 mg.; choline chloride 1540.0 mg.; santoquin, 0.25 g.

[b]Supplies the following per kilogram of diet: $CaHPO_4$, 17.0 g.; $CaCO_3$, 18.3 g.; KH_2PO_4, 13.8 g.; NaCl, 6.0 g.; $MgSO_4$, 2.5 g.; $FeSO_4 \cdot 7H_2O$, 333.0 mg.; KI, 2.6 mg.; $CuSO_4 \cdot 5H_2O$, 16.7 mg.; $CoCl_2 \cdot 6H_2O$, 1.7 mg.; $Na_2MoO_4 \cdot 2H_2O$, 8.3 mg.; ZnO, 74.7 mg.

At four weeks, five representative cockerels from each feather meal and soybean oil meal diet containing 0 and 110 mg. manganese per kg. and the purified diets were orally dosed with 25 µc of Mn-54. The excreta samples were collected daily for ninety-six hours at which time the birds were sacrificed. Tissue samples (liver, kidney, spleen, blood, and tibia) were collected and radioactivity determinations made. The excreta samples were dried, ashed, dissolved in concentrated hydrochloric acid, made to volume (the volume depended on the amount of radioactivity in sample), and aliquot samples taken to determine the radioactivity. The entire tibia was dried, ashed, and counted to determine the radioactivity.

Experiment 7. Experiment 7 was a continuation and extension of experiment 6. The effect of graded levels of manganese in the 14.5 percent feather meal diet, in an isocaloric, isonitrogenous soybean oil meal diet, and in a purified diet on growth, incidence and severity of perosis, and feed efficiency was studied.

Manganese was added to each diet at the expense of the entire diet in amounts calculated to bring the total manganese content of the diets to about 55, 110, 220, and 440 mg. manganese per kilo of feed. In addition, the three diets were fed without added manganese. A randomized block experimental design was used which included fifteen treatments and three replications per treatment. Eight male and seven female chicks were randomly assigned to each pen. In addition to the

Newcastle disease and infectious bronchitis vaccination, the chicks were vaccinated for Avian nephritis-nephrosis, (Gumboro) by the intra-occular method. The composition and calculated analyses of the feather meal basal and soybean oil meal basal are given in Table VII page 28. Because the potency of L-lysine supplement was changed from 220 g. per kg. to 50 percent, the level of corn used for the feather meal basal was changed from 68.265 to 69.535 percent. The composition of the purified basal was the same as that given in Table VIII on page 29. with the exception that the inositol was reduced from 250 mg. per kg. to 166 mg. per kg. of diet.

A severity index for the incidence of perosis was set up with the following code being used: 1 - slightly slipped tendon, 2 - slipped tendon, and 3 - slipped tendon and twisted leg.

The in vitro uptake of the Mn-54 by erythrocytes secured from chicks fed the feather meal, soybean oil meal, and purified diets containing graded levels of manganese, and the absorption and tissue deposition of Mn-54 were determined.

Blood samples from three male and three female nonperotic chicks per treatment when available and from a like sample of perotic birds when available were obtained at about four weeks. The study was conducted according to the method of Wright and Bell (1963).

Five representative cockerels from each treatment were dosed intramuscularly with 10 μc. of Mn-54. Excreta samples were collected for forty-eight hours at which time the birds were sacrificed and

tissue samples (liver, kidney, spleen, muscle, blood, and tibia) were collected and radioactivity determinations made. The excreta and tibiae samples were dried, ashed, dissolved in concentrated hydrochloric acid, made to volume (the volume depended on the amount of radioactivity in sample), and aliquot samples taken to determine the radioactivity.

Experiment 8. Perosis can be caused by too much calcium, phosphorus, an imbalance in the Ca/P ratio, or too much total mineral content in the diet. Experiment 8 was conducted to determine the effect of graded levels of phosphorous in the 14.5 percent feather meal diet on growth, incidence of perosis, and feed efficiency. A soybean oil meal-fish meal control diet was fed. An unusually high incidence of perosis occurred in the birds fed the soybean oil meal-fish meal diets in the manganese study, experiment 6. Because of this fact, the level of defluorinated rock phosphate used in the soybean oil meal-fish meal diet (65-10) in experiment 8 was reduced from 1.20 to 1.00 percent of the diet. The soybean oil meal-fish meal diet contained 0.69 percent calculated total phosphorus and 1.10 percent calculated calcium. In the 14.5 percent feather meal diets (65-1 through 65-6), the limestone level was held constant and the defluorinated rock phosphate level was increased which increased both calcium and phosphorus levels in the diets. Both limestone and defluorinated rock phosphate were varied in diets 65-7, 65-8, and 65-9. The composition and calculated analyses of the ten diets are shown in Table IX. A randomized split block

TABLE IX

COMPOSITION AND CALCULATED ANALYSES OF DIETS--EXPERIMENT 8

Ingredients	Diet numbers									
	65-1	65-2	65-3	65-4	65-5	65-6	65-7	65-8	65-9	65-10
	percentage									
Yellow corn	70.710	70.410	70.110	69.810	69.510	69.210	70.590	70.650	70.350	59.405
Alfalfa meal (17% protein)	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
Fish meal (65% protein)	5.700	5.700	5.700	5.700	5.700	5.700	5.700	5.700	5.700	5.700
Feather meal (85% protein)	14.500	14.500	14.500	14.500	14.500	14.500	14.500	14.500	14.500	---
Soybean oil meal (50% protein)	---	---	---	---	---	---	---	---	---	28.220
Fat, stabilized, fancy bleachable	---	---	---	---	---	---	---	---	---	1.000
Defluorinated rock phosphate	0.000	0.300	0.600	0.900	1.200	1.500	1.120	0.560	0.860	1.000
Limestone	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.500	0.500	1.000
Salt	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
$MnSO_4$ supplement (75%)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Vitamin mix[a,b]	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	.600
DL-methionine	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	.050
L-lysine supplement (50%)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	---
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.00

TABLE IX (Continued)

Ingredients	Diet numbers									
	65-1	65-2	65-3	65-4	65-5	65-6	65-7	65-8	65-9	65-10
Calculated analyses[c]										
Productive energy, Cal./kg.	2178	2169	2163	2154	2147	2138	2174	2176	2167	2174
Crude protein, %	23.55	23.52	23.50	23.47	23.44	23.42	23.54	23.54	23.52	23.54
Calcium, %	0.74	0.84	0.94	1.04	1.14	1.25	0.74	0.74	0.84	1.10
Total P, %	0.46	0.52	0.57	0.63	0.68	0.73	0.66	0.55	0.62	0.69
Inorganic P, %	0.33	0.39	0.44	0.50	0.55	0.60	0.54	0.44	0.49	0.45
Ca/P Ratio	1:0.62	1:0.62	1:0.61	1:0.61	1:0.60	1:0.58	1:0.89	1:0.74	1:0.74	1:0.61

[a]Composition of vitamin mix used in feather meal diets given in Table II on page 20.

[b]Composition of vitamin mix used in soybean oil meal-fish meal diets given in Table V on page 24.

[c]Calculations based on average analyses of feedstuffs according to Hubbell (1964).

experimental design was used which included ten treatments and four replications per treatment. Six male and six female chicks were randomly assigned to each pen.

RESULTS AND DISCUSSION

Amino Acid Supplementation Experiments

Experiment 1. The results of this study are presented in Table X. At the 5 percent level of probability chicks fed the diet containing 0.5 percent added L-lysine and 0.0325 percent added DL-methionine were significantly lighter in average four week body weights than chicks fed diets with either 0.0488 or 0.39 percent added DL-methionine, but not significantly different from chicks fed diets containing 0.065 or 0.13 percent added DL-methionine. Chicks fed diets containing 0.0488, 0.065, 0.13, and 0.39 percent added DL-methionine were not significantly different in average body weights. There were no significant differences in average body weights of chicks fed any of the diets at the 1 percent level of probability.

No significant differences were found in four week feed efficiency at the 5 percent level of probability due to treatments or replications. Feed efficiency tended to vary with growth.

The incidence of perosis was found to be high at all levels of added methionine with 30 to 45 percent of the chicks in the five treatments exhibiting perosis.

Experiment 2. The results of this experiment are presented in Table XI. Chicks fed the diet containing 0.7 percent added L-lysine and 0.195 percent added DL-methionine had significantly ($P < 0.05$)

TABLE X

RESULTS OF EXPERIMENT 1

Diet No.	Percent added lysine	Percent added methionine	Adjusted* avg. 4-week body weights** grams	Adjusted* grams feed per gram chicken**	Percent perosis
62-51	0.5	0.0325	425[b]	1.62	35
62-52	0.5	0.0488	462[a]	1.61	32
62-53	0.5	0.0650	437[ab]	1.64	45
62-54	0.5	0.1300	443[ab]	1.64	30
62-55	0.5	0.3900	462[a]	1.59	35

*Treatment means were adjusted for block differences according to procedures for incomplete Latin square designs as indicated by Cochran and Cox (1957). Averages are of 4 replicate pens each containing 5 male and 5 female broiler-type chicks.

**Means bearing the same small letter superscripts do not differ significantly at the 5 percent level of probability.

TABLE XI

RESULTS OF EXPERIMENT 2

Diet No.	Percent added lysine	Percent added methionine	Adjusted* avg. 4-week body weights** grams	Adjusted* grams feed per gram chicken**	Percent perosis
62-53	0.5	0.065	477[a]	1.57	28
62-56	0.7	0.065	461[ab]	1.58	44
62-57	0.7	0.130	448[ab]	1.65	38
62-58	0.7	0.195	438[b]	1.58	40
62-59	0.7	0.260	451[ab]	1.60	26
62-60	0.7	0.390	452[ab]	1.56	26

*Treatment means were adjusted for block differences according to procedures for incomplete Latin square designs as indicated by Cochran and Cox (1957). Averages are of 5 replicate pens each containing 5 male and 5 female broiler-type chicks.

**Means bearing the same small letter superscripts do not differ significantly at the 5 percent level of probability.

lighter average four week body weights than did chicks fed the diet containing 0.5 percent added L-lysine and 0.065 percent added DL-methionine, but did not differ from chicks fed diets containing 0.7 percent added lysine and the other levels of added DL-methionine. The average body weights of chicks fed diets containing 0.5 percent added L-lysine and 0.065 percent added DL-methionine, 0.7 percent added L-lysine and 0.065, 0.13, 0.26, and 0.39 percent added DL-methionine were not different at the 5 percent level of probability. No significant differences in average body weights of chicks fed any of the diets were found at the 1 percent level of probability.

No significant differences were found in four week feed efficiency at the 5 percent level of probability in this trial; although, the feed efficiency tended to be related to growth.

As in experiment 1 the incidence of perosis was observed to be high with 26 to 44 percent of the chicks exhibiting slipped tendon on the various treatments.

Graded levels of amino acids were used in these experiments to determine the optimum levels of supplementation. The levels of added lysine used in experiments 1 and 2 appeared not to influence the response of chicks fed the 14.5 percent feather meal diet to graded levels of methionine. The additions of 0.5 percent L-lysine to the feather meal diet resulted in a calculated lysine level of 1.197 percent which approximated that suggested by NRC (1960) as adjusted for total protein and that of Klain et al. (1960). The addition of 0.7 percent L-lysine

resulted in a 1.393 percent calculated lysine level equal to that suggested by Anderson (1961).

The chick's response to added DL-methionine was erratic and not in relationship to the levels of DL-methionine used. Apparently, supplemental levels of 0.0488 to 0.39 percent of DL-methionine to the feather meal diet may be expected to yield about the same results. On the basis of these data, there appeared to be no detrimental effect on growth with the high levels of methionine supplementation.

From the results of Bletner and Stephens (1962), unpublished work of Bletner (1962), and from experiment 1 and 2 described above, it would appear that satisfactory levels of added L-lysine and added DL-methionine for the 14.5 percent feather meal diet studied were 0.5 percent and 0.065 percent, respectively. The levels of L-lysine and methionine used by Harms and Douglas (1958) and Naber et al. (1961) were higher; however, they were within a suitable range, and their results probably were not affected by the higher levels of lysine and methiosine.

It appears that the level of supplementation of an amino acid in a diet per se is not as critical as the level and balance of the amino acids in a diet.

Experiment 3. The results of the study are summarized in Tables XII and XIII. There was a trend suggesting that added levels of L-histidine might be beneficial in improving four week body weights of chicks

TABLE XII

RESULTS OF EXPERIMENT 3

Diet No.	Percent added histidine	Adjusted** avg. 4-week body weights grams	Adjusted** grams feed per gram chicken	Percent perosis
65-12	0.0	519	1.62	12
65-13	0.1	523	1.60	12
65-14	0.2	533	1.64	15
65-15	0.3	537	1.62	20
65-16	SBOM-FM*	558	1.62	12

*SBOM-FM - soybean oil meal-fish meal diet used as a control.

**Treatment means were adjusted for block differences according to procedures for incomplete Latin square designs as indicated by Cochran and Cox (1957). Averages are of 4 replicate pens each containing 5 male and 5 female broiler-type chicks.

TABLE XIII

AVERAGE BODY WEIGHTS OF CHICKS BY REPLICATIONS IN EXPERIMENT 3

Diet No.	Percent added histidine	Replication numbers	Average body weight by pens
			grams
65-12	0.0	1	536.00
		2	499.60
		3	520.80
		4	507.10
			515.88
65-13	0.1	1	531.00
		2	540.10
		3	535.10
		4	505.70
			527.98
65-14	0.2	1	499.00
		2	552.70
		3	538.90
		4	541.90
			533.12
65-15	0.3	1	548.10
		2	562.10
		3	529.90
		4	505.80
			536.48
65-16	SBOM-FM*	1	559.90
		2	549.50
		3	562.70
		4	558.10
			557.55

*SBOM-FM - soybean oil meal-fish meal diet used as a control diet.

fed the 14.5 percent feather meal diet (0.5 percent added L-lysine and 0.065 percent added DL-methionine). However, no significant differences in average four week body weights were found between treatments or replications due to the large variability between pens within a treatment. The chicks fed the soybean oil meal-fish meal control diet were not significantly heavier than chicks fed the feather meal diets. There were no significant differences in four week feed efficiency among any of the diets.

Of the 160 chicks fed the 14.5 percent feather meal diets, 12.5 to 20.0 percent exhibited perosis which was not as high as observed in preceeding experiments. Moreover, the incidence of perosis in the forty chicks fed the soybean oil meal-fish meal diet was as high (12.5 percent) as two groups of chicks fed the feather meal diets. The calculated L-histidine content of the feather meal basal was 0.3 percent which was the level recommended by Almquist (1957), Rosenberg et al. (1957), NRC (1960), and Dean and Scott (1965), but was lower than the level suggested by Klain et al. (1960) for growing chicks. Supplementing with up to 0.3 percent L-histidine in graded levels did not upset the amino acid balance of the feather meal diet as occurred when high levels of lysine had been added to the 14.5 percent feather meal diet (Bletner and Stephens, 1962).

Perosis Experiments

Experiment 4. The results of this study are summarized in Table XIV. There were no significant differences in the average four week

TABLE XIV

RESULTS OF EXPERIMENT 4

Diet No.	Percent added methionine	Mg. added folic acid per kg.	Ajusted* avg. 4-week body weights grams	Adjusted* grams feed per gram chicken	Percent perosis
63-11	0.065	0.00	312	1.79	0
63-12	0.065	0.55	322	1.69	4
63-13	0.065	1.10	319	1.77	0
63-14	0.065	1.65	319	1.72	4
63-15	0.260	0.00	306	1.74	0
63-16	0.260	1.10	311	1.85	4

*Treatment means were adjusted for block differences according to procedures for incomplete Latin square designs as indicated by Cochran and Cox (1957). Averages are of 5 replicate pens each containing 5 male and 5 female Parmenter Red chicks.

body weights of Parmenter Red chicks due to treatments. At the 5 percent level of probability there was a significant difference in average body weights between chicks in replication 1 and 2. No significant differences were found in four week feed efficiency between treatments and replications on any diet. The incidence of perosis was low ranging from 0 to 4 percent for chicks on the various treatments. Although feather faults were observed on three chicks fed diet 63-11 (0.065 percent added DL-methionine and 0.0 mg. added folic acid per kilo) this did not clearly indicate that a folic acid deficiency was present since there were fifty chicks per treatment.

Experiment 5. The results of this experiment are presented in Table XV. Broiler-type white feathered chicks fed the feather meal diet containing 0.065 percent added DL-methionine and 0.0 mg. added folic acid per kilo and the feather meal diet containing 0.26 percent added DL-methionine and 0.0 mg. added folic acid per kilo had significantly lighter average four week body weights at the 5 percent level of probability than did chicks fed the other diets. At the 1 percent level of probability, chicks fed the diet containing 0.065 percent added DL-methionine and 0.0 mg. added folic acid per kilo and the diet containing 0.26 percent added DL-methionine and 0.0 mg. added folic acid per kilo had significantly lighter average body weights than chicks fed diets with 0.065 percent added DL-methionine and 0.55, 1.10, and 1.65 mg. added folic acid per kilo, but did not differ from chicks fed

TABLE XV

RESULTS OF EXPERIMENT 5

Diet No.	Percent added methionine	Mg. added folic acid per kg.	Adjusted* avg. 4-week body weights**	Adjusted * grams feed per gram chicken**	Percent perosis
			grams		
63-17	0.065	0.00	417^{A}	1.62	24
63-18	0.065	0.55	458^{B}	1.56	16
63-19	0.065	1.10	454^{B}	1.59	28
63-20	0.065	1.65	463^{B}	1.61	10
63-21	0.260	0.00	414^{A}	1.65	24
63-22	0.260	1.10	440^{AB}	1.64	12

*Treatment means were adjusted for block differences according to procedures for incomplete Latin square designs as indicated by Cochran and Cox (1957). Averages are of 5 replicate pens each containing 5 male and 5 female broiler-type chicks.

**Means bearing the same capital letter superscripts do not differ significantly at the 1 percent level of probability.

the diet containing 0.26 percent added DL-methionine and 1.10 mg. added folic acid per kilo. There were no differences in average body weights due to replications. No significant differences were found in four week feed efficiency between treatments and replications.

The addition of folic acid to the 14.5 percent feather meal diet appeared to stimulate growth but did not eliminate the incidence of perosis. The percent of the birds in the experiment exhibiting perosis ranged from 10 to 28 percent for the six treatments.

The results of experiments 4 and 5 suggest that the breed of chicken may influence the requirement for a nutrient. Chicks fed the diets containing no added folic acid had the lowest average four week body weights in both experiments, although not significantly different in experiment 4. The diet containing 55 mg. added folic acid per kilo met the NRC (1960) suggested requirements. Four week body weights of chicks fed diet 63-20 (0.065 percent added DL-methionine and 1.65 mg. added folic acid per kilo, were the heaviest, but not significantly heavier from the other levels of supplementation in experiment 5.

Because of the relatively few cases of perosis in experiment 4, it was impossible to evaluate the value of folic acid in preventing perosis. In experiment 5, evaluation of the results was different. The addition of folic acid to the 14.5 percent feather meal diet reduced the number of slipped tendons in all diets except 63-19 (0.065 percent added DL-methionine and 1.10 mg. added folic acid per kilo).

The level of methionine apparently made no difference in the growth rate of the chicks or the incidence of perosis.

Experiment 6, growth data. The results of this experiment are presented in Table XVI. The average four week body weights of chicks fed the feather meal diets (64-6 through 64-11) were lighter than those of chicks fed the soybean oil meal diets (64-12 through 64-17). These results are in agreement with Harms and Douglas (1958), Naber et al. (1961), and Stephens et al. (1959, 1961).

The best growth of chicks fed the 14.5 percent feather meal diet was obtained when chicks were fed a diet containing 55.0 mg. manganese per kilo of diet (64-8) although only significantly different from diet 64-6 which contained no added manganese. The average four week body weights of chicks fed diet 64-8 (55.0 mg. manganese per kilo) did not differ significantly from the weight of those chicks fed the soybean oil meal diets 64-15 (110 mg. manganese per kilo) and 64-17 (330.0 mg. manganese per kilo). Average four week body weights of chicks fed the soybean oil meal diets with graded levels of manganese were not significantly different; however, the average four week body weights of chicks receiving 330 mg. of manganese per kilo of diet were the lightest.

When the purified diet containing no added manganese (64-18) was fed to chicks the growth rate was significantly depressed as compared to the growth rate of chicks fed the same diet but supplemented to contain 55 mg. manganese per kilo (64-19). However, it was impossible to

TABLE XVI

RESULTS OF EXPERIMENT 6 GROWTH, FEED EFFICIENCY, AND PEROSIS

Diet	Calculated mg. Mn per kg.	Average* 4-week body weights** grams	Grams feed* per gram chicken**	Percent perosis
Feather meal				
64-6	7.9	464^{A}	1.60^{ABCD}	54
64-7	27.5	468^{AB}	1.64^{A}	29
64-8	55.0	492^{BCD}	1.56^{ABCD}	12
64-9	110.0	482^{ABC}	1.59^{ABCD}	27
64-10	220.0	483^{ABC}	1.61^{ABC}	31
64-11	330.0	484^{ABC}	1.63^{AB}	15
Soybean oil meal				
64-12	14.5	536^{E}	1.55^{BD}	29
64-13	27.5	536^{E}	1.52^{D}	27
64-14	55.0	528^{E}	1.58^{ABCD}	12
64-15	110.0	516^{DE}	1.53^{CD}	29
64-16	220.0	532^{E}	1.53^{CD}	25
65-17	330.0	509^{CDE}	1.60^{ABCD}	21
Purified***				
64-18	0.00	349^{A}	1.05^{A}	100
64-19	55.00	552^{B}	1.30^{B}	8

*Averages for the feather meal and soybean oil meal diets are of 4 replicate pens each containing 6 male and 6 female broiler-type chicks. Averages for the purified diets are based on 1 pen of 6 male and 6 female broiler-type chicks.

**Means bearing the same superscripts do not differ significantly at the 1 percent level of probability. Data from the purified diets should not be compared with that from the feather meal and soybean oil meal diets.

***Experiment with purified diets was conducted at a later date due to an error in mixing in the diets.

conclude if the growth rate was depressed due to the high percentage of perosis per se (100 percent) or if manganese was needed for growth of the chickens. Chicks fed the purified diet with 55 mg. manganese per kilo had good growth rate and a low incidence of perosis.

The incidence of perosis was high on both the 14.5 percent feather meal diets and the soybean oil meal diets. When manganese was added to the 14.5 percent feather meal diets, the incidence of perosis was decreased in the birds but not eliminated. The lowest incidence of perosis on both basal diets occurred when the basal diets contained 55 mg. manganese per kilo of diet. This was the level of manganese recommended by the NRC (1960).

The four week feed efficiency data failed to indicate any trends.

Experiment 7, growth data. The results of this study are summarized in Table XVII. Chicks fed the feather meal diets (65-17 through 65-21) and the purified diets (65-27 through 65-31) had significantly ($P<0.01$) lighter average four week body weights than chicks fed the soybean oil meal diets (65-22 through 65-26). Chicks fed the purified diet containing no added manganese (65-27) had the lowest average body weights of the entire experiment which differed significantly at the 1 percent level of probability from all other weights. No significant differences were found in the average body weights of chicks fed the feather meal diets and the purified diets containing added manganese. There were no significant differences in body weights among replications.

TABLE XVII

RESULTS OF EXPERIMENT 7 GROWTH, FEED EFFICIENCY, AND PEROSIS

Diet	Calculated mg. Mn per kg.	Average* 4-week body weights**	Perosis Severity index*** 1	2	3	Percent
		grams	number			
Feather meal						
65-17	7.9	488^{B}	2	6	6	31
65-18	55.0	486^{B}	4	1	2	16
65-19	110.0	505^{B}	4	2	0	13
65-20	220.0	504^{B}	5	2	1	18
65-21	440.0	486^{B}	7	1	2	22
Soybean oil meal						
65-22	14.5	568^{A}	5	4	1	22
65-23	55.0	562^{A}	2	1	1	9
65-24	110.0	582^{A}	4	2	2	18
65-25	220.0	567^{A}	4	2	3	20
65-26	440.0	563^{A}	5	1	2	18
Purified						
65-27	0.0	341^{C}	3	7	35	100
65-28	55.0	507^{B}	3	2	0	11
65-29	110.0	507^{B}	3	0	1	9
65-30	220.0	489^{B}	3	2	2	13
65-31	440.0	502^{B}	3	4	0	16

*Averages are of 3 replicate pens each containing 8 male and 7 female broiler-type chicks.

**Means bearing the same superscripts do not differ significantly at the 1 percent level of probability.

***Code for Severity Index: 1 - slightly slipped tendon, 2- slipped tendon, 3 - slipped tendon and twisted leg.

As in experiment 6 when manganese was added to the 14.5 percent feather meal diets the incidence of perosis was decreased but not eliminated. The incidence of perosis was reduced by half when 55 mg. manganese per kilo of diet was fed. The lowest incidence of perosis on the feather meal basal, soybean oil meal basal, and purified basal was at 110, 55, and 110 mg. manganese per kilo, respectively.

Due to an uncorrectable error in weighing of the feed, the four week feed efficiency data were not reported in this study.

Experiment 6 and 7, isotope work. The results of the Mn-54 studies are presented in Tables XVIII and XIX. Although the data obtained from orally and intramuscularly administered Mn-54 differed in magnitude of the percent uptake of Mn-54, the results were in agreement with the exception of the tibia data of the birds fed the feather meal diets and soybean oil meal diets.

In experiment 6 there was a reduction in the percent of Mn-54 recovered from the tissues as the dietary manganese was increased except for the tibiae of the birds fed the purified diets. In terms of the percent dose per tibia, there was a reduction in both experiments of Mn-54 uptake on the purified diets containing no added manganese. The growth rate of chicks receiving the purified diet containing no added manganese was slower. The increase in percent dose per tibiae on the purified diets containing manganese may have occurred because a slow growing chick deposits less total bone and, therefore, less total manganese in the bone.

TABLE XVIII

PERCENT OF ORALLY ADMINISTERED Mn-54 DOSAGE RECOVERED IN CERTAIN TISSUES AND EXCRETA. EXPERIMENT 6

Diet	Tibia	Liver	Kidney	Spleen	96 hr. Excretion
	10^{-2}%/Tibia	10^{-2}%/g.**			%
Feather meal					
7.9 mg. Mn*	1.46[a]	0.97[a]	1.28[a]	0.28[a]	90
110.0	1.16[a]	0.20[b]	0.28[b]	0.05[b]	100
Soybean oil meal					
14.5 mg. Mn*	3.12[a]	0.98[a]	0.98[a]	0.23[a]	99
110.0	0.90[b]	0.16[b]	0.20[b]	0.05[b]	98
Purified					
0.0 mg. Mn*	1.72[a]	2.30[a]	1.87[a]	0.40[a]	66
55.0	3.28[b]	0.54[b]	0.60[b]	0.12[b]	88

*Calculated mg. manganese per kilo. of diet.

**For various manganese levels within a diet type, means bearing the same superscripts are not significantly different at the 5 percent level of probability.

TABLE XIX

PERCENT OF INTRAMUSCULARLY ADMINISTERED Mn-54 DOSAGE RECOVERED IN CERTAIN TISSUES AND EXCRETA. EXPERIMENT 7.

Diet	Tibia %/tibia**	Liver %/g.**	Kidney %/g.**	Spleen %/g.**	Muscle 10^{-1}%/g.**	48 hr. Excretion %
Feather meal						
7.9 mg. Mn.*	0.96[a]	0.45[a]	0.61[a]	0.20[a]	0.32[a]	21
55.0	1.04[b]	0.30[b]	0.41[b]	0.12[b]	0.25[b]	39
110.0	1.06[b]	0.26[c]	0.38[c]	0.09[c]	0.22[c]	41
220.0	1.08[c]	0.18[d]	0.35[d]	0.08[d]	0.19[d]	48
440.0	1.01[b]	0.16[e]	0.33[e]	0.07[e]	0.18[d]	52
Soybean oil meal						
14.5 mg. Mn.*	0.94[a]	0.48[a]	0.60[a]	0.18[a]	0.31[a]	27
55.0	0.91[a]	0.33[b]	0.44[b]	0.13[b]	0.25[b]	37
110.0	0.90[a]	0.20[c]	0.34[c]	0.10[c]	0.18[c]	45
220.0	0.96[a]	0.17[d]	0.25[d]	0.07[d]	0.16[d]	49
440.0	0.87[a]	0.12[e]	0.22[e]	0.05[e]	0.13[e]	52
Purified						
0.0 mg. Mn.*	0.68[a]	0.90[a]	1.84[a]	0.51[a]	0.79a	12
55.0	0.99[c]	0.28[b]	0.38[bc]	0.12[b]	0.22[b]	32
110.0	0.98[c]	0.24[c]	0.36[cd]	0.10[c]	0.22[b]	36
220.0	0.86[b]	0.16[e]	0.33[d]	0.09[d]	0.21[b]	44
440.0	0.98[c]	0.19[d]	0.40[b]	0.08[e]	0.18[c]	46

*Calculated mg. manganese per kilo of diet.

**For various manganese levels within a diet type, means bearing the same superscripts are not significantly different at the 5 percent level of probability.

In experiment 7 the tibia values on a percent dose per gram basis ranged from 0.3 to 0.2. When the tibiae were compared on a percent dose per gram tissue basis there were no significant differences ($P<0.05$) attributed to the level of manganese in the feather meal and purified diets. However, chicks fed the soybean oil meal diets showed a significant reduction in Mn-54 uptake per gram of tibia as the level of manganese increased in the diet.

Tibiae of intramuscularly dosed birds fed diets containing 14.5 percent feather meal had consistently higher uptake values of Mn-54 than tibiae of birds fed the soybean oil meal diets. Dietary manganese may be in a complex which the chick cannot utilize for bone formation, but may deposit as a complex in the soft tissues. Tibiae from chicks fed the soybean oil meal diets had improved tibia weights as the manganese level in the diet increased.

In all soft tissues, the first added increment of manganese in the diet had the greatest effect in reducing the intramuscular dose of Mn-54 taken up. The uptake of the soft tissues showed a significant trend towards decreased manganese uptake by the tissues as the manganese level in the diet increased.

At the two highest levels of manganese in the diets (220 and 440 mg. manganese per kilo), the dietary manganese had a greater effect in reducing the Mn-54 uptake on the soybean oil meal diets than on the feather meal diets.

The total excretion picture followed more closely the calculated values of manganese in the diet than did the tissues. It appeared from the data of the two experiments that no appreciable amount of manganese was being tied up by the feather meal diets as shown by the excretion and tissue uptake data.

Since there was no activity in the blood or plasma of the Mn-54 dosed birds the results were not calculated.

Erythrocytes incubated with Mn-54 took up some of the isotope, but the amount taken up failed to reflect the manganese content of the diet.

Experiment 8. The results of this experiment are presented in Table XX. The calculated total calcium and phosphorus content of the diets has been shown in Table IX on page 33. It will be noted that feather meal diet 65-3 (0.57 percent total phosphorus with 0.94 percent total calcium) was slightly below NRC (1960) suggested levels of calcium and phosphorus, while feather meal diet 65-4 (1.04 percent total phosphorus with 1.14 percent total calcium) was slightly above the suggested level. Feather meal diets containing less than 0.56 percent added defluorinated rock phosphate had less inorganic phosphorus than suggested by NRC (1960), and feather meal diets containing more than 0.9 percent added defluorinated rock phosphate were considerably over the amount suggested by NRC (1960).

At the percent level of probability, chicks fed the 14.5 percent feather meal diets with graded levels of phosphorus had significantly

TABLE XX

RESULTS OF EXPERIMENT 8

Diet	Percent added defluorinated rock phosphate	Percent added limestone	Average* 4-week body weights** grams	Grams feed per gram chicken**	Percent perosis
Feather meal					
65-1	0.00	1.0	513^{A}	1.60^{A}	10
65-2	0.30	1.0	521^{A}	1.63^{B}	15
65-3	0.60	1.0	521^{A}	1.58^{A}	6
65-4	0.90	1.0	536^{A}	1.56^{A}	8
65-5	1.20	1.0	540^{A}	1.56^{A}	8
65-6	1.50	1.0	532^{A}	1.56^{A}	15
65-7	1.12	0.0	538^{A}	1.54^{A}	12
65-8	0.56	0.5	529^{A}	1.61^{A}	10
65-9	0.86	0.5	515^{A}	1.61^{A}	8
Soybean oil meal-fish-meal					
65-10	1.00	1.0	581^{B}	1.54^{A}	19

*Averages are of 4 replicate pens each containing 6 male and 6 female broiler-type chicks.

**Means bearing the same capital letter superscripts do not differ significantly at the 1 percent level of probability.

($P<0.01$) lighter average four week body weights than chicks fed the control, soybean oil meal-fish meal diet (65-10). No significant differences were found in the body weights of chicks fed the 14.5 percent feather meal diets. There were no significant differences found in body weights among replications.

Chicks fed feather meal diet 65-2 (0.3 percent added defluorinated rock phosphate with 1.00 percent added limestone) had the poorest four week feed conversion ratio ($P<0.01$) in this experiment.

A total of 480 birds were used in the experiment with 6.26 to 18.75 percent exhibiting perosis on the ten diets. In the range of phosphorus levels the lowest incidence of perosis was exhibited by chicks fed feather meal diet 65-3 (0.6 percent added defluorinated rock phosphate with 1.00 percent added limestone). No significant differences were found among the diets in the percentages of perosis.

SUMMARY AND CONCLUSIONS

A total of eight experiments were conducted to determine the effect of supplementing chick diets containing 14.5 percent feather meal on growth, feed efficiency, and incidence of perosis. The basic 14.5 percent feather meal diet consisted of corn, alfalfa meal, fish meal, vitamins, minerals, and feather meal. The diet contained approximately 23.5 percent crude protein and 2150 Calories of productive energy per kilogram. In some of the experiments, an isocaloric, isonitrogenous soybean oil meal-fish meal diet was used as a control.

Broiler-type chicks were used in seven experiments and Parmenter Red chicks in one. Day-old chicks were placed in electrically-heated battery brooders for four week growth trials. When studies with Mn-54 were undertaken, they were conducted during the week following the termination of the growth studies.

It was found that satisfactory levels of supplementary DL-methionine and L-lysine were 0.065 and 0.5 percent, respectively, in the 14.5 percent feather meal diet. The total calculated methionine and lysine in the supplemented diet was 0.379 and 1.197 percent, respectively. As the level of supplemental L-histidine in the 14.5 percent feather meal diet was increased to 0.3 percent, there was a trend towards improved four week body weights, although not significant.

The addition of folic acid to the 14.5 percent feather meal diet improved growth of broiler-type chicks, but had inconsistent effect on the incidence of perosis.

The incidence of perosis was higher in chicks fed the feather meal basal than in chicks fed the soybean oil meal basal. The addition of manganese to the 14.5 percent feather meal diet decreased the incidence and severity of perosis, but did not eliminate the condition.

The addition of graded levels of defluorinated rock phosphate to the 14.5 percent feather meal diet had no significant effect on growth of chicks or the incidence of perosis.

In three of four experiments the growth rate of chicks fed the 14.5 percent feather meal diet was less than the growth rate of chicks fed the soybean oil meal-fish meal diet.

Chicks fed the 14.5 percent feather meal diets, soybean oil meal diets, and purified diets containing graded levels of manganese were dosed orally or injected intramuscularly with Mn-54. The percent of Mn-54 recovered from the liver, kidney, spleen, and muscle samples showed a significant trend towards an inverse relationship between dietary manganese and the percent of Mn-54 taken up. In all soft tissues the first added increment of manganese in the diet had the greatest effect in reducing the intramuscular dose of Mn-54 taken up. The tibiae were inconsistent in taking up Mn-54.

It appeared that no appreciable amount of manganese was being tied up by the feather meal diets. Erythrocytes incubated with Mn-54 took up some of the isotope, but the amount taken up failed to reflect the manganese content of the diet.

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APPENDIX

TABLE XXI

AMINO ACID COMPOSITION OF FEATHERS AND FEATHER MEAL

Amino Acids	Raw Feathers			Feather Meal
	Block 1939[a]	Block and Bolling 1951[a]	Graham et al. 1949	Gregory et al. 1956
			Percent protein	Percent protein
Arginine	6.0	8.0	7.5	6.41
Histidine	0.3	0.6	0.4	0.46
Lysine	1.6	1.8	1.3	1.76
Tryptophan	0.7	0.7		0.66
Tyrosine	2.2	2.3	2.2	2.75
Phenylalanine	5.3	5.5	5.2	4.31
Cystine	6.8	8.7	8.2	3.55
Methionine		0.5	0.5	0.58
Threonine		4.6	4.4	4.51
Serine		10.2		
Leucine		8.5	8.0	8.48
Isoleucine		6.4	6.0	4.33
Valine		8.9	8.3	7.45
Glutamic acid		10.0	9.7	9.19
Aspartic acid		7.7	7.0	
Glycine	9.5			
Proline		4.0	8.8	

[a]Amino acids in amount of feathers required to supply 16 gm. of nitrogen.

TABLE XXII

COMPARISON OF AMINO ACID REQUIREMENTS OF GROWING CHICK AND AMINO ACIDS SUPPLIED BY FEATHER MEAL[a]

Amino acids	Chick requirement as percentage of total protein intake	Percentage of amino acid requirement provided by feather meal protein
	percent	percent
Arginine	6.0	110.0
Histidine	1.5	25.0
Lysine	5.0	35.0
Tryosine	3.5	75.0
Tryptophan	1.0	50.0
Phenylalanine	4.0	110.0
Cystine	1.8	280.0
Methionine	2.3	15.0
Threonine	3.0	160.0
Leucine	7.0	115.0
Isoleucine	3.0	155.0
Valine	4.0	200.0
Glycine	5.0	160.0

[a]Information taken from Naber (1961).