

April 27, 1961

To the Graduate Council:

I am submitting herewith a thesis written by David B. Shoaf entitled "The Influence of Varying Calorie-Protein Ratios and Amino Acid Supplementation of Diets for Broilers". 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.

J. K. Beethner
Major Professor

We have read this thesis
and recommend its acceptance:

O. Glen Hall
O. E. Loff

Accepted for the Council:

H. E. Spivey
Acting Dean of the Graduate School

CRANES & CREST

THE INFLUENCE OF VARYING CALORIE-PROTEIN RATIOS
AND AMINO ACID SUPPLEMENTATION
OF DIETS FOR BROILERS

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
David B. Shoaf
June 1961

CRANES & CREST

2A
337

ACKNOWLEDGEMENT

The author would like to thank Drs. J. K. Bletner, O. E. Goff, and O. G. Hall for the guidance and assistance given him throughout his Master's program and especially in the preparation of this thesis.

Mr. R. P. Mitchell and the other assistants in the Poultry Department are acknowledged for their help in collection of the data used in the thesis. Acknowledgement is also given to Mr. and Mrs. Andy Sprinkle who typed and multilithed the thesis.



TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
REVIEW OF LITERATURE	3
Energy	3
Calorie-Protein Ratio	6
Protein and Energy Level	8
Protein Level and Amino Acids	9
Fish Meal and Whey in Broiler Diets	12
PROCEDURE	14
Experiment I	15
Experiment II	21
Experiment III	21
Experiment IV	23
Experiment V	23
Experiment VI	25
Experiment VII	25
Experiment VIII	25
Experiment IX	26
Experiment X	26
RESULTS	27
Experiment I	27
Experiment II	29
Experiment III	29
Experiment IV	32

PAGE

Experiment V.	32
Experiment VI	35
Experiment VII.	35
Experiments VIII, IX, and X	35
DISCUSSION.	42
SUMMARY	47
REFERENCES.	49



LIST OF TABLES

TABLE	PAGE
I. Composition and Calculated Analysis of Diets.	
Experiments I and II	17
II. Calculated Analysis of Mineral Mix	18
III. Calculated Analysis of Vitamin Mixes	19
IV. Composition of Coccidiostat Premixes	20
V. Composition and Calculated Analysis of Diets.	
Experiments III and IV	22
VI. Composition and Calculated Analysis of Diets.	
Experiment V	24
VII. Body Weights and Feed Conversions of Chicks at Nine	
Weeks of Age. Experiment I.	28
VIII. Body Weights and Feed Conversions of Chicks at Nine	
Weeks of Age. Experiment II.	30
IX. Adjusted Body Weights and Feed Conversions of Chicks	
at Four Weeks of Age. Experiment III.	31
X. Body Weights and Feed Conversions of Chicks at Nine	
Weeks of Age. Experiment IV	33
XI. Body Weights and Feed Conversions of Chicks at Eight	
Weeks of Age. Experiment V.	34
XII. Adjusted Body Weights and Feed Conversions of Chicks	
at Four Weeks of Age. Experiment VI	36
XIII. Adjusted Body Weights and Feed Conversions of Chicks	
at Four Weeks of Age. Experiment VII.	37

TABLE

PAGE

XIV. Adjusted Body Weights and Feed Conversions of Chicks at Four Weeks of Age. Experiment VIII	38
XV. Adjusted Body Weights and Feed Conversions of Chicks at Four Weeks of Age. Experiment IX	39
XVI. Body Weights and Feed Conversions of Chicks at Eight Weeks of Age. Experiment X.	40

INTRODUCTION

In the past twenty-five years, the production of broilers has moved from the small farmer with a few dual purpose birds to the integrated producer of thousands of cross-bred, meat-type birds. As the numbers and types of birds have changed, the nutritionist has been faced with the task of developing diets that will produce a bird possessing better market characteristics on less feed and in a shorter period of time.

In the quest for diets that would give superior results, the nutritionist has examined new feedstuffs and recombinations of old ones. To be considered for inclusion in a broiler diet, it is desirable that a feedstuff should be available in quantity the year around at a competitive price, perform its function efficiently, and contribute to the production of a desirable carcass. Synthetically produced amino acids and vitamins and industrial by-products such as stabilized animal fat and feather meal, are examples of materials that have been introduced into the practical broiler diet.

Before these new materials were placed in broiler diets, studies were conducted to determine the amounts and combinations of these materials that would give the best results. In an effort to establish the value of certain feedstuffs, many were included in semi-purified diets. Much of the published data disagree in regard to results that might be expected from these same feedstuffs when incorporated in "practical" diets. Some of the discrepancies between the calculated and actual response of chicks to a feedstuff may be attributed to

factors such as time of year, type of chick used, design of the study, or combinations of other feedstuffs included in the diet.

After considering the lack of agreement of reported work, a series of studies using varying amounts of stabilized yellow grease, soybean oil meal, and synthetic amino acids was initiated. These studies were designed to develop a high protein-high energy broiler diet using soybean oil meal as the principal source of protein and stabilized yellow grease and ground yellow corn as the principal sources of energy.



REVIEW OF LITERATURE

Energy

The problem of finding the optimum level of energy and crude protein in broiler diets has been considered from different viewpoints in the past several years. Most of the work has involved concentrated diets. In concentrating the diets, many high fiber feedstuffs such as oats were eliminated and animal fats and other high energy feeds included. Halnan, according to Robertson et al. (1948), reported in 1930 that fowls digested less than 10 percent of the fiber in a diet and that fiber caused lower digestability of the nitrogen-free extract. The digestion of fats and proteins were not affected by fiber. Halnan concluded that fiber could be ignored for its nutritive value and used only when bulk was needed in the diet.

Halnan's work was in agreement with that of Fraps (1928) who, after completing 63 digestion experiments with poultry, reported that poultry had little power to digest fiber and that feeds containing a high percentage of fiber were poorly digested by poultry. Mangold (1934) found that 30 to 40 percent of the fiber in grain was digested by poultry.

Productive energy values of feedstuffs (Fraps, 1946) gave the nutritionist a new tool to aid in the formulation of diets. In his report, Fraps defined the term productive energy as "the net energy measured by the energy stored up as fat and protein in growing or fattening animals." Productive energy differs from metabolizable energy in that metabolizable energy is the gross energy minus the energy

excreted in feces, urine and combustible gases.

In 1947, Scott, Matterson, and Singsen reported that when oats and wheat were substituted for corn in a basal ration poorer growth resulted. The basal diet used contained 68 percent grain and was the first successful low fiber, high energy diet. The ingredients other than corn used in this "Connecticut ration", as it was called, were: 8 percent fish meal, 8 percent soybean oil meal, 8 percent meat and bone meal, 3 percent liver meal, 2 percent riboflavin supplement, 1 percent alfalfa leaf meal, 1.5 percent bone meal, 0.5 percent salt, 0.3 percent Vitamin A and D feeding oil, 0.025 percent manganese sulfate, 108 grams nicotinic acid and 31.78 grams of choline-chloride per 100 pounds ration.

Biely and March (1954) reported that when 5 percent tallow was added to a diet containing 19 percent protein, chick growth was depressed, but, if the protein was increased to either 24 or 28 percent chick growth was accelerated and feed efficiency improved. When a diet containing 7 percent added tallow and 23 percent protein was compared to a control diet without added fat but with the same protein content, no difference in body weight of chicks resulted, but feed efficiency was greatly improved.

Mraz, Boucher, and McCartney (1956) used three levels of productive energy, 900, 670, and 450 Calories per pound, and fiber levels of 5, 10, and 20 percent. The diets were iso-nitrogenous, containing approximately 21 percent protein. The birds receiving the high energy, low fiber diets were larger at four and eight weeks of age than were

those fed any of the other diets in the study. With the exception of the chicks fed the diets containing 450 Calories per pound of feed, the feed efficiency was better for the lots fed the low fiber diets.

Donaldson et al. (1957) reported an increase in chick growth at four weeks of age when 10 percent fat was added to a basal diet. The addition of 10 percent fat did not improve feed efficiency or protein utilization of the chicks. The control ration contained 4 percent fat and 22 percent protein with a Calorie-protein ratio of 43:1. These researchers reported better feed efficiency of chicks when they added 15.0, 22.5, and 30.0 percent fat to a control diet. The higher levels of added fat resulted in the better feed efficiency, but no increase in chick growth was obtained by feeding a diet which contained more than 15 percent added fat. The protein level of these diets was altered so that a constant 43:1 Calorie-protein ratio was maintained.

Rand, Scott, and Kummerow (1958), on the assumption that protein level affected the utilization of added fat, fed diets containing 20 and 30 percent protein and 1 and 8 percent added fat. In this study the diet containing 8 percent added fat gave better chick growth and feed efficiency at both protein levels. When the fat was increased to 14.5 percent, the birds fed the 20 percent protein diet failed to increase in growth rate. The average body weight per chick and feed efficiency was improved when 14.5 percent fat was added to the 30 percent protein diet. This work is in agreement with that of Biely and March (1954) previously mentioned in this review but goes further by stating that added fat is beneficial at the higher protein levels. This also confirms the work of Aitken, Lindblad, and Hunsaker (1954), who received

only a slight improvement in feed efficiency when they added 10 percent beef tallow to a 22 percent protein chick diet; but, when the same amount of tallow was added to a 25 percent protein diet, a highly significant increase in chick growth and feed efficiency was obtained. The birds fed the 25 percent protein diet plus the tallow had a superior finish and were more desirable because of higher moisture content of the cooked flesh.

Calorie-Protein Ratio

The term Calorie-protein ratio, or the C/P ratio as it is generally called, was proposed in 1955 as a means of specifying the relationship of energy and protein in diets (Combs, 1959). It is derived by dividing the Calories of productive energy per pound of diet by the percent protein present in the diet (Combs, 1956). This is not to be confused with the metabolizable energy-protein ratio (ME/P) described by Hill and Renner (1957).

Donaldson, Combs, and Romoser (1956) fed rations with the protein content ranging from 15 to 27 percent and with the C/P ratios ranging from 35.7:1 to 70.5:1. As the C/P ratio of the diet became wider, the energy intake and fat deposition of the birds increased, and the water and protein content of the carcass decreased. They found that the productive energy level tended to influence the protein level required when measured by average body weights, carcass composition, and by feed utilization of chicks from one day to four weeks of age. On high, medium and low fat diets with C/P ratios of 53.7, 48.6, and 43.9, respectively, growth and feed efficiency of chicks were unimpaired. Chickens fed diets that contained added fat tolerated a wider C/P ratio

at any protein level than did chicks fed diets that derived energy from other sources. Furthermore, less protein was required per gram of gain.

In a similar study, Leong et al. (1955) fed chicks diets containing 15 to 42 percent protein and 700, 950, 1210, and 1450 calories per pound. They reported that diets with C/P ratios of 32, 35, and 38 containing 22, 27, and 32 percent protein, respectively, gave the best chick growth and feed efficiency through the first five weeks of the chicks' life. However, at nine weeks of age, best results were obtained from chicks fed diets with C/P ratios of 35, 45, and 42 and protein levels of 27, 27, and 32 percent, respectively. Poor feathering was reported in birds fed low protein, high energy diets. Potter et al. (1956) found that both chick growth and feed efficiency were more closely related to the productive energy level than the C/P ratio. Using diets that contained 20 or 30 percent protein with C/P ratios of 32 to 56, they obtained increased chick growth with a constant C/P ratio and increased protein and energy. These researchers also found that keeping the protein constant and increasing the energy level gave increased chick growth and improved feed efficiency. The increase in chick growth was constant until the energy reached 1150 Calories productive energy per pound of diet. Matterson and Potter (1958) reported similar results. In addition, they used iso-caloric diets in which the protein was varied. When the protein was increased, resulting in a lower C/P ratio, chick growth was increased.

The work of Mraz, Boucher, and McCartney (1958) is in agreement with that of Matterson and Potter (1958). Mraz et al. (1958) fed chicks

diets containing one of three energy levels, 900, 675, and 450 Calories productive energy per pound of feed, with protein levels at each energy level varying from 10 to 20 percent. A 30 percent protein diet was also used at the 900 Calorie level. They reported that the energy level had less influence on chick response than did the protein during the first four weeks. During this period, diets with a C/P ratio of 32:1 or less were superior to those with wider C/P ratios when measured by chick growth. However, at ten weeks, birds receiving diets with C/P ratios of 45:1 or less had heavier body weights. The C/P ratio of 32:1 for a broiler starter diet and 45:1 for a broiler finisher diet are lower than those suggested by Combs (1956). He reported that broiler starter diets with C/P ratios of 41:1 and 43:1 for summer and winter, respectively, and broiler finisher diets with a C/P ratio of 49.5:1 for both seasons were most economical.

Leong et al. (1959) conducted a series of studies on interrelationships of energy, protein, and amino acids in broiler diets. They reported that as the energy level was raised, higher levels of protein were required for maximum chick growth. The C/P ratio became wider at the higher energy and protein level. Birds fed the high energy diet (1450 Calories per pound) were characterized by poor feathering and feather picking. Further studies showed that as the productive energy level increased, the requirement of methionine and cystine increased, but at a slower rate than did the energy requirement.

Protein and Energy Level

Using 20 and 28 percent protein diets as controls, Sunde (1956)

studied the relationship of energy level to protein level by adding 5 or 10 percent animal fat to broiler diets. The addition of 10 percent fat to the 20 percent protein diet failed to improve the average body weight or feed efficiency of the chicks, but chicks fed the 28 percent protein diet with 5 or 10 percent added fat had heavier average body weights and improved feed efficiency. Chicks fed the 28 percent protein low energy diet did not perform as well as chicks fed the low energy 20 percent protein diet, however, Sunde stated that this indicated that the optimum Calorie-protein ratio would change as the protein level changes. These results confirm those of Scott, Sims, and Slakeli (1955) who found that 7 or 14 percent fat added to a 20 percent protein diet resulted in poor feathering and retarded growth of chicks. Best results from chicks were obtained by adding 7 percent fat to a diet containing 30 percent protein. However, some improvement in growth and feed efficiency of chicks resulted when 7 percent fat was added to a diet containing 25 percent protein. The addition of 14 percent added fat to a diet resulted in a slight retardation of chick growth. Both Scott et al. (1955) and Sunde (1956) reported improved feed efficiency of chicks at all protein levels when fat was added to the diet except in the case already noted.

Protein Level and Amino Acids

Most researchers studying energy levels in broiler diets either associate the energy level with the crude protein level or with the level of one or more amino acids.

Maddy (1958), in a partial review of literature concerning amino

acids, stated that all essential amino acids must be present in a specific amount for a particular tissue synthesis. If one of the essential acids is deficient, it will limit the utilization of the other amino acids. The amino acid requirement of an animal may be affected by the level of total protein and energy of the diet, the animal's plane of nutrition, the ratio of the amino acids to each other, and the age and strain of the animal.

Combs (1956) reported that the methionine requirement was affected by both the energy and protein level in the diet. In studying broiler starter diets, he reported that as the Calorie-protein ratio became wider the methionine requirement was greater when expressed as percent of total protein, and the methionine requirement per therm of energy was reduced. This work is in agreement with that of Baldini and Rosenberg (1955) who found the methionine requirement of the chick expressed as percent protein not to be a constant figure but to vary as a linear function of the productive energy content of the diet. Using the data presented by Baldini and Rosenberg (1955) a diet containing 800 Calories productive energy per pound would require 0.362 percent methionine, while a diet containing 1000 Calories productive energy would require 0.509 percent methionine. This relationship was true only if the diet was complete in all nutrients and the productive energy level of the diet was within a range of 800-1000 Calories per pound.

Rosenberg et al. (1955), reporting on a series of seven studies at three laboratories, found that the addition of 0.025 or 0.05 percent

methionine to a basal diet gave an increase in the average chick body weight and improved feed efficiency. When 3 or 6 percent fat was added to the diet, similar results were obtained. When both fat and methionine were added to the basal diet, the average body weight of the chicks and the feed efficiency further improved. These results were confirmed when a different basal diet was treated in the same manner.

Combs (1958) added methionine and glycine to practical broiler diets in which the Calorie-protein ratios were 42:1 and 50:1. The addition of 0.025 percent glycine alone failed to improve either diet when measured by average body weight and feed efficiency. The addition of methionine alone gave some improvement in chick growth, but not as much as when both amino acids were added. With the addition of glycine and methionine, the performance of chicks fed the 50:1 Calorie-protein ratio diets was equivalent to the performance of chicks fed the 42:1 Calorie-protein ratio diets.

Snetsinger and Scott (1957, 1958), using soybean oil meal as the only protein concentrate, found chick growth improved as the protein level was raised from 15 to 30 percent but declined at protein levels over 30 percent. When methionine was added to the diets, an increased chick growth was obtained with diets containing protein levels of 20 percent or less, but added methionine had no effect on chicks fed diets containing 30 percent protein. Glycine failed to improve the diets containing 20 percent protein, and glutamic acid plus methionine was no better than methionine used alone.

DL-methionine was found to be of little value in a corn-soybean oil meal type diet when added to a diet that contained 21 percent protein.

However, when DL-methionine and DL-lysine were added to a diet that contained 16 percent protein or a combination of soybean and cottonseed oil meal, chick growth was increased (Stephenson, 1954).

Maddy et al. (1958) obtained better growth and feed efficiency with broilers when they increased the energy level of the diet for the last 22 days of an eight week study rather than feeding a high energy diet throughout the study. Reduction of the protein level as the energy level increased gave poorer results than were obtained when the protein remained constant. Supplementary methionine and glycine were needed for maximum results at the higher energy level. Combs et al. (1959) reported improved chick growth when methionine was added to a corn-soybean oil meal type diet but received no benefit from glycine when it was added alone or in combination with methionine. This is slightly different from earlier work (Combs, 1958) where a slight increase in average body weight of chicks was obtained from additional glycine and methionine as compared to the addition of methionine alone.

Douglas et al. (1958) reported an increase in the average body weights of chicks fed a 21 percent protein-50:1 C/P ratio basal diet supplemented with glycine and methionine, compared to those of chicks fed either the basal diet or diets that contained either 24 or 25 percent protein. The energy level of all diets was equal.

Fish Meal and Whey in Broiler Diets

Combs and Nicholson (1958) and Combs et al. (1959) in a series of studies found that the addition of 2 percent fish meal to a broiler diet gave a slight increase in average body weight but feed efficiency was

unaffected. In the same series of studies, no difference in chick response was observed when a dried whey product was added at the 2 percent level.

Day (1960) added 4 and 8 percent fat to a corn-soybean oil meal diet and noted an increase in chick growth at each level. Two and one-half percent fish meal gave an additional increase in chick growth when either 4 or 8 percent fat was added to the basal diet, but feed efficiency was impaired in each case. Day attributed the poor feed efficiency to the heavy body weight of the birds on the diets that contained fish meal.



PROCEDURE

Vantress X Nichols 108 or Vantress X Arbor Acre chicks were used in all experiments. There were obtained from two local hatcheries. At one day of age, the chicks were sexed, vaccinated with a combination infectious bronchitis-Newcastle disease vaccine utilizing the intraocular method, wing banded, debeaked if they were to be used in a floor study, and housed. The all-mash diets and water were supplied ad libitum. Any bird that died during the first week of the study was replaced with one that had been fed the control diet. A daily log of mortality, room and chick conditions, and other observations was kept at the site of the study.

Fifty male and 50 female chicks were used in each replication of the floor trials with the exceptions of Experiment X, in which 49 chicks of each sex were used, and in Experiments II and IV, in which 48 females were used instead of 50. The chicks were randomly assorted into each of 12 pens in the first three floor experiments and into each of 18 pens in the fourth and fifth floor experiments. Wood shavings were used as litter and infra-red bulbs were used as a source of heat.

At the beginning of each experiment, the body weight of 50 male and 50 female day-old chicks was obtained and used as the average starting weight for all chicks in each of the replications. Group weights according to sex were taken weekly except when the rations were changed and at the conclusion of the study, at which times individual body weights were taken. Feed consumption was obtained weekly. The first three floor studies were terminated when the chicks were nine weeks of age, while

the others were concluded when the chicks were eight weeks of age. Data collected were analyzed by analysis of variance according to Snedecor (1956) with significant treatment differences determined by Duncan's multiple range test (1955). The randomized block design was used in all floor studies.

In the battery experiments, five male and five female chicks were assigned at random to each pen. In three of the experiments, a 5 x 4 incomplete Latin square design was used, and a 6 x 5 incomplete Latin square design was used in the other two battery studies. Prior to placing the chicks in the brooders, heating elements were adjusted to the same level, and the thermostats were adjusted to operate within a range of 95-100°F. The room temperature was maintained at approximately 75-85°F. The brooder temperature was lowered five degrees per week until room temperature was attained.

Individual body weights of all chicks were obtained when the chicks were placed in their respective pens and at weekly intervals for the duration of the study. Feed consumption was determined at the end of each experiment. All battery studies were terminated when the chicks were four weeks of age. The data were analyzed according to an analysis of variance procedure suggested by Cochran and Cox (1957) for this type of design in which inter-block differences are not recovered. Significant treatment differences were determined by the use of Duncan's multiple range test (1955).

Experiment I

This experiment was initiated to compare broiler-starter diets

containing 21 and 25 percent protein and broiler-finisher diets containing 20 and 23 percent protein.

The starter diets, ES¹ 1 and ES 2, shown in Table I, differed from each other in protein and energy² content. In addition, the 25 percent protein diet contained feather meal, a whey product, stabilized yellow grease, and added methionine. The 25 percent protein diet was calculated to contain one and one-fourth times the minimum vitamin and amino acid requirements for chicks recommended by the National Research Council (1954). Calculation of the protein content and productive energy level of feed ingredients was based upon data presented by Hubbell (1958). The finisher diets EF³ 1 and EF 2 (Table I) were produced by adding six pounds of stabilized yellow grease to 94 pounds of the corresponding starter. This lowered the protein content slightly, but increased the Calories per pound of finished feed. The treatments of this experiment were: (1) ES 1, (2) EF 1, (3) ES 2, (4) EF 2, (5) ES 1-EF 1, and (6) ES 2-EF 2. In treatments five and six, the starter diet was fed until the chicks were six weeks of age, and the finisher diet was fed from then until the chicks were nine weeks of age. The diets of the chicks receiving the other treatments were not changed during the nine weeks of the study. There were two replications of each treatment.

¹Experimental Starter.

²Energy refers to productive energy unless otherwise stated.

³Experimental Finisher

TABLE I
COMPOSITION AND CALCULATED ANALYSIS OF DIETS.
EXPERIMENTS I AND II

Ingredients	ES 1	ES 2	EF 1	EF 2	EF 3
	lbs.	lbs.	lbs.	lbs.	lbs.
Corn gluten meal		6.00			6.00
Yellow corn meal	63.70	47.60			66.00
Fish meal (60% protein)	2.50	5.00			2.50
Alfalfa meal (17% protein)	2.50	2.50			2.50
Soybean oil meal (50% protein)	25.50	22.50			11.50
Feather meal (hydrolyzed)		2.00			2.00
Flaydry ¹		2.00			2.00
DL-Methionine		0.10			0.10
Mineral mix ²	2.70	2.70			2.70
Vitamin mix A ³	0.60				
Vitamin mix B ³		0.60			0.60
Stabilized yellow grease		6.50	6.00	6.00	1.60
Coccidiostat mix ⁴	2.50	2.50			2.50
Diet ES 1			94.00		
Diet ES 2				94.00	
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Crude protein (percent)	21.67	25.49	20.31	23.17	20.09
Productive energy (Calories/lb.)	938.00	1020.00	1050.00	1125.00	1001.00
C/P Ratio	43:1	41:1	51:1	48:1	50:1

¹Whey product manufactured by Borden Co., New York, New York.

²See Table II.

³See Table III.

⁴See Table IV.

TABLE II

CALCULATED ANALYSIS OF MINERAL MIX

Minerals	Amount per pound of mix
Calcium (lb.)	0.291
Inorganic phosphorous (lb.)	0.063
Manganese (mg.)	727
Sodium chloride (lb.)	0.178

TABLE III
CALCULATED ANALYSIS OF VITAMIN MIXES

Nutrients	Mix A	Mix B	Mix C
	per lb.	per lb.	per lb.
Vitamin A (IU)	315,278	315,278	315,278
Vitamin D ₃ (ICU)	56,666	56,666	56,666
Riboflavin (mg.)	151	358	358
Vitamin B ₁₂ (mcg.)	830	830	830
Arsanilic Acid (mg.)	6,310	6,310	6,310
Aureomycin (mg.)			900
Procaine Penicillin (mg.)	550	550	
Choline (mg.)	30,700	30,700	30,700
Niacin (mg.)	890	3,047	3,047
Pantothenic Acid (mg.)	530	530	530

TABLE IV
COMPOSITION OF COCCIDIOSTAT PREMIXES

Ingredients	Premix A ¹	Premix B ²	Premix C ³
	lbs.	lbs.	lbs.
Nitrofurazone	4.00		
Sulfaquinoxaline (25%)		5.80	
Amprol (25%)			4.00
Soybean oil meal	200.00	200.00	200.00
Total	204.00	205.80	204.00

¹Used in Experiments I, II, III, and IV.

²Used in Experiments V, VI, VII, and X.

³Used in Experiments VIII and IX.



Experiment II

This study was designed to compare the response of chicks to diet EF 2, the 23 percent protein finisher diet used in Experiment I, with the response of chicks to diet EF 3, a 20 percent protein finisher diet (Table I). Diet EF 3 contained approximately the same Calorie-protein ratio and the same feed ingredients as EF 2. The 25 percent protein starter diet used in Experiment I was used as the control. All chicks were fed the control diet for the first five weeks. When the chicks were five weeks of age, they were randomized according to body weight into twelve pens. The control and the finisher diets were each fed to four replicate lots of chicks.

Experiment III

Some of the feed ingredients in the 25 percent protein starter, ES 2, used in Experiments I and II were expensive, and the contribution each might make to the gross value of the diet was questionable. This experiment was designed to study the effect of removing either the DL-methionine, feather meal, fish meal, or the whey product from the diet. The ground yellow corn, soybean oil meal, and/or the stabilized yellow grease were added to the diets in variable amounts in an attempt to keep the protein and energy levels approximately constant when an ingredient was removed from the basal diet. The composition of the diets (ES 3, ES 4, ES 5, and ES 6) is given in Table V. The design of the study, which was conducted in batteries, was a 5 x 4 incomplete Latin square.

TABLE V
COMPOSITION AND CALCULATED ANALYSIS OF DIETS.
EXPERIMENTS III AND IV

Ingredients	ES 3	ES 4	ES 5	ES 6	ES 7
	lbs.	lbs.	lbs.	lbs.	lbs.
Corn gluten meal	6.00	6.00	6.00	6.00	6.00
Yellow corn meal	47.70	45.60	42.00	48.00	48.00
Fish meal (60% protein)	5.00	5.00		5.00	5.00
Alfalfa meal (17% protein)	2.50	2.50	2.50	2.50	2.50
Soybean oil meal (50% protein)	22.50	25.80	29.50	24.20	24.20
Feather meal (hydrolyzed)	2.00		2.00	2.00	2.00
Flaydry ¹	2.00	2.00	2.00		
DL-Methionine		0.10	0.10	0.10	
Defluorinated rock phosphate ²			1.00		
Mineral mix ³	2.70	2.70	2.70	2.70	2.70
Vitamin mix B ³	0.60	0.60	0.60	0.60	0.60
Stabilized yellow grease	6.50	7.30	9.20	6.50	6.50
Coccidiostat mix ⁴	2.50	2.50	2.50	2.50	2.50
Total	100.00	100.10	100.10	100.10	100.00
Calculated Analysis					
Crude protein (percent)	25.44	25.31	25.55	25.53	25.43
Productive energy (Calories/lb.)	1022.00	1023.00	1033.00	1025.00	1025.00
C/P Ratio	40:1	40:1	40:1	40:1	40:1

¹Whey product manufactured by Borden Co., New York, New York.

²See Table II.

³See Table III.

⁴See Table IV.

Experiment IV

As no significant differences were found at the 5 percent level of probability among treatments in Experiment III, a study was designed to determine the response of chicks to similar diets under floor conditions. A 25 percent protein starter diet, ES 2, (Table I), was used as the control diet. The other diets (Table V) in the study were control minus DL-methionine and the whey product (ES-7), and control minus fish meal (ES 5).

After feeding the birds the starter diets for five weeks, they were given a corresponding finisher diet produced by mixing 94 pounds of each starter with six pounds of stabilized yellow grease. There were four replications of each of the three treatments. The study was terminated when the birds were nine weeks of age.

Experiment V

This experiment was designed to study the response of chicks to diets that contained 25 and 30 percent protein, and the effect of changing the C/P ratio of these diets.

The starter diets, ES 8, ES 9, and ES 10 (Table VI), contained 25, 30, and 30 percent protein with C/P ratios of 38:1, 30:1, and 38:1, respectively. The finisher (EF 4, Table VI) contained 25 percent protein with a C/P ratio of 48:1.

Each of the three starting diets was fed to six pens of chicks until the chicks were six weeks of age. At this time, three pens on each treatment were changed to the finisher diet, EF 4. The nine remaining pens were fed diet ES 8 for the duration of the study, which

TABLE VI
COMPOSITION AND CALCULATED ANALYSIS OF DIETS.
EXPERIMENT V

Ingredient	ES 8	ES 9	ES 10	EF 4
	lbs.	lbs.	lbs.	lbs.
Corn gluten meal	6.00	6.00	6.00	6.00
Yellow corn meal	52.80	40.20	21.50	33.70
Fish meal (60% protein)	5.00	5.00	5.00	5.00
Alfalfa meal (17% protein)	2.50	2.50	2.50	2.50
Soybean oil meal (50% protein)	21.00	33.00	36.00	24.10
Feather meal (hydrolyzed)	2.00	2.00	2.00	2.00
Flaydry ¹	2.00	2.00	2.00	2.00
DL-Methionine	0.10	0.10	0.10	0.10
Mineral mix ²	2.70	2.70	2.70	2.70
Vitamin mix C ³	0.60	0.60	0.60	0.60
Stabilized yellow grease	2.80	3.40	18.90	18.80
Coccidiostat mix ⁴	2.50	2.50	2.50	2.50
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Crude protein (percent)	25.00	30.00	30.00	25.00
Productive energy	950.00	900.00	1114.00	1200.00
C/P Ratio	38:1	30:1	38:1	48:1

¹Whey product manufactured by Borden Co., New York, New York.

²See Table II.

³See Table III.

⁴See Table IV.

was terminated when the chicks were eight weeks of age.

Experiment VI

This experiment was designed to study the effect of adding methionine or lysine to the 25 percent protein-38:1 C/P ratio diet (ES 8, Table VI) used in Experiment V. Two levels of added methionine⁴, 0.1 and 0.3 percent, and three levels of lysine, 0.05, 0.1, and 0.2 percent were used. The unsupplemented diet (ES 8) was used as the control. This study was conducted in batteries using a 6 x 5 incomplete Latin square design.

Experiment VII

This study was conducted simultaneously with Experiment VI, but because of difference in location of the batteries, the data could not be combined. Glycine was added to diet ES 8 at levels of 0.0, 0.1, 0.2, and 0.3 percent. Diet ES 2 (Table I) was included in this experiment since it was considered to be the control diet for the entire series of studies. A 5 x 4 incomplete Latin square design was used for the study.

Experiment VIII

In Experiments VI and VII, the diet containing 0.2 percent added glycine gave the largest average body weight per chick. Although no statistically significant differences in the body weights of chicks given the various treatments were found at the 5 percent level of

⁴Refers to methionine added in addition to that found in the formula of diet ES 8.

probability, it was decided to conduct a battery study supplementing diet ES 8 with 0.2 percent glycine and either 0.1 or 0.3 percent added methionine, or 0.1 or 0.2 percent added lysine. The unsupplemented diet was used as a control. A 6 x 5 incomplete Latin square experimental design was used.

Experiment IX

A 25 percent protein-38:1 C/P ratio diet (ES 8, Table VI) was used as a basal diet. The amino acids, glycine, methionine, and lysine, were added to the basal diet in the following combination: (1) 0.2 percent glycine, (2) 0.2 percent glycine, 0.2 percent lysine, and 0.1 percent methionine, and (3) 0.2 percent glycine, 0.1 percent lysine, and 0.1 percent methionine. Diet ES 2 (Table I) was used as an additional control diet. The study, conducted in batteries, was of a 5 x 4 incomplete Latin square design.

Experiment X

This experiment was based upon data secured in Experiments VIII and IX. Although in Experiments VIII and IX no statistical differences were found between treatments at the 5 percent level of probability, it was deemed desirable to study the response of chicks to these diets under floor management.

The control diets were the same as used in Experiment IX. The other diets were: (1) ES 8 plus 0.2 percent glycine, (2) ES 8 plus 0.2 percent glycine and 0.1 percent lysine, and (4) ES 8 plus 0.2 percent glycine, 0.2 percent lysine, and 0.1 methionine. Each of the six diets were fed to three replicate lots of chicks. The study was terminated when the chicks were eight weeks of age.

RESULTS

Experiment I

The results of this study are summarized in Table VII. When compared to chicks fed a 21 percent protein starter diet (ES 1), chicks fed a 25 percent protein starter diet (ES 2) for the entire nine weeks of the study had superior average body weights and feed conversions. However, chicks fed diet ES 2 for the first six weeks and diet EF 2 for the last three weeks of the experiment had the largest average body weights of any of the chicks, but they were not significantly larger than those fed diet ES 2 for the entire nine week period. Chicks fed either of the finisher diets (EF 1 or EF 2) for the entire study had smaller average body weights than chicks fed the corresponding starter diets.

All chicks fed diets ES 2 or EF 2 had significantly heavier average body weights ($P \leq 0.01$) and, with the exception of those in the treatment in which diet ES 2 was fed for the entire nine weeks, required significantly less feed per unit of body weight ($P \leq 0.01$) than did birds fed diets ES 1 or EF 1. However, at the 5 percent level of probability the feed required per unit of body weight by chicks fed diet ES 2 was significantly less than that required by chicks fed either diet ES 1 or EF 1.

The chicks fed diet EF 1, 20 percent protein finisher, were poorly feathered and contained yellow pigment to a lesser degree than did the other birds in the study. No differences in the feathering and degree of pigmentation of birds fed the other diets were found.

TABLE VII

BODY WEIGHTS AND FEED CONVERSIONS OF CHICKS
AT NINE WEEKS OF AGE. EXPERIMENT I

Diets ¹	Average Body Weights ²	Feed/Weight ²
	lbs.	
ES 2 - EF 2	3.23 ^a	2.0830 ^e
ES 2	3.17 ^a	2.2074 ^{ef}
EF 2	3.05 ^b	2.1042 ^e
ES 1	2.76 ^c	2.4822 ^f
ES 1 - EF 1	2.75 ^c	2.4320 ^f
EF 1	2.57 ^d	2.4442 ^f

¹Composition and calculated analysis given in Table I.

²Means with different superscripts are significantly different (P / 0.01).

From the results of this study, the 25 percent protein starter, ES 2, and the 23 percent protein finisher, EF 2, diets were selected as the control diets for the remainder of the studies in the series.

Experiment II

The birds fed the 20 percent protein finisher diet (EF 3) were significantly lighter in weight at the 1 percent level of probability (Table VIII) than were the birds fed the 23 percent protein finisher diet (EF 2) and were significantly lighter in weight at the 5 percent level of probability than were the chicks fed the control diet (ES 2). Birds fed the 20 percent protein finisher had significantly poorer feed conversion than did those fed the 23 percent protein finisher diet. No differences in feathering or pigmentation were observed among the birds receiving the different treatments.

Experiment III

As shown in Table IX, no significant differences in the average body weights of chicks were found between those fed the 25 percent protein starter (ES 2), and the average body weights of chicks fed diets in which either feather meal (ES 4), fish meal (ES 5), whey product (ES 6), or methionine (ES 3) was deleted. The feed required per unit of body weight by chicks fed the 25 percent protein diet less the fish meal (ES 5) was significantly less at the 5 percent level of probability than that required by other chicks in the experiment. The feed conversion of birds fed the 25 percent protein diet less methionine (ES 3) was significantly improved at the 5 percent level of probability

TABLE VIII
BODY WEIGHTS AND FEED CONVERSIONS OF CHICKS
AT NINE WEEKS OF AGE. EXPERIMENT II

Diets ¹	Average Body Weight ²	Feed/Weight ³
	lbs.	
ES 2 - EF 2	3.31	2.1516
ES 2	3.29	2.2492
ES 2 - EF 3	3.22	2.3370

¹Composition and calculated analysis of diets given in Table I.

²Any two means not connected by the same line are significantly different ($P \leq 0.01$).

³Any two means not connected by the same line are significantly different ($P \leq 0.05$).

TABLE IX

ADJUSTED¹ BODY WEIGHTS AND FEED CONVERSIONS OF CHICKS
AT FOUR WEEKS OF AGE. EXPERIMENT III

Diets	Average Body Weights ² (Adjusted)	Feed/Weight ² (Adjusted)
	gms.	
ES 4 (No feather meal)	464.1 ^a	1.5894 ^d
ES 5 (No fish meal)	462.9 ^a	1.5250 ^b
ES 2 (Control)	462.7 ^a	1.5796 ^d
ES 3 (No methionine)	458.8 ^a	1.5479 ^c
ES 6 (No whey product)	454.8 ^a	1.5661 ^{cd}

¹Average body weights and feed conversions adjusted according to procedure suggested by Cochran and Cox (1957).

²Means with different superscripts are significantly different (P / 0.05).

over that secured from birds fed diets ES 2 and ES 4.

Experiment IV

Chicks grown on litter and fed a diet from which either fish meal (diet ES 5) or both the whey product and methionine (diet ES 7) were omitted, were significantly smaller at the 1 percent level of probability (Table X) than were the chicks fed the control diet (ES 2). No significant difference was found at the 5 percent level of probability in the feed conversion of chicks fed diets ES 2 or ES 5. However, the feed required per unit of body weight by chicks fed the diet ES 7 was significantly greater at the 5 percent level of probability than that required by chicks fed diet ES 5.

Experiment V

As shown in Table XI, no significant differences at the 1 percent level of probability were found in the final average body weights of chicks fed the following diets: (1) ES 8-EF 4, (2) ES 9-ES 8, (3) ES 8-ES 8, or (4) ES 10-EF 4. However, chicks fed diets ES 8-EF 4, as a starter diet and finisher diet, respectively, were significantly heavier at the 5 percent level of probability than were the chicks fed the following combinations of diets: (1) ES 10-EF 4, (2) ES 9-EF 4, or (3) ES 10-ES 8.

Birds fed diets ES 10-EF 4 required significantly less feed per unit of body weight at the 1 percent level of probability than did the birds fed any of the other combinations of diets. Feed required per unit of body weight by birds fed diets ES 10-ES 8, was significantly

TABLE X
BODY WEIGHTS AND FEED CONVERSIONS OF CHICKS
AT NINE WEEKS OF AGE. EXPERIMENT IV

Diets	Average Body Weights ¹	Feed/Weight ²
	lbs.	
ES 2 (Control)	3.23	2.1335 ^{bc}
ES 7 (No whey product or methionine)	3.14 ^a	2.2193 ^c
ES 5 (No fish meal)	3.10 ^a	2.0946 ^b

¹Means having different superscripts are significantly different (P / 0.01).

²Means having different superscripts are significantly different (P / 0.05).

TABLE XI
BODY WEIGHTS AND FEED CONVERSIONS OF CHICKS
AT EIGHT WEEKS OF AGE. EXPERIMENT V

Diets	Average Body Weights ¹	Feed/Weight ¹
	lbs.	
ES 8 ² - EF 4 ³	3.11 ^a	2.1089 ^{de}
ES 9 ⁴ - ES 8	3.08 ^{ab}	2.2782 ^f
ES 8 - ES 8	3.06 ^{ab}	2.2521 ^f
ES 10 ⁵ - EF 4	3.04 ^{abc}	1.9130
ES 9 - EF 4	3.03 ^{bc}	2.1513 ^e
ES 10 - ES 8	2.99 ^c	2.0344 ^d

¹Means with different superscripts are significantly different (P / 0.01).

²Contains 25% protein with 38:1 C/P Ratio.

³Contains 25% protein with 48:1 C/P Ratio.

⁴Contains 30% protein with 30:1 C/P Ratio.

⁵Contains 30% protein with 38:1 C/P Ratio.

less at the 5 percent level of probability than that required by birds fed either of the other diet combinations except the combination of diets ES 10-EF 4, as previously mentioned. There were no differences in feathering or degree of pigmentation observed among birds fed different diets.

Experiment VI

With the addition of methionine to a basal diet (ES 8) at the 0.1 and 0.3 percent levels, or lysine at 0.05, 0.1 and 0.2 percent levels, chick responses were not significantly different at the 5 percent level of probability when measured in terms of average body weights or feed conversion of the chicks fed the diets (Table XII).

Experiment VII

As shown in Table XIII, the addition of 0.1, 0.2, or 0.3 percent glycine to a basal diet (ES 8) failed to give a significant difference in the average body weight of chicks fed the diets. The feed conversion of chicks fed the control diet, ES 2, (Table I) was significantly smaller at the 5 percent level of probability than that of chicks fed the basal diet plus 0.1 percent glycine. No significant differences were found between the feed conversions of chicks fed either of the remaining diets.

Experiments VIII, IX, and X

In Experiments VIII, IX, and X, as shown in Tables XIV, XV, and XVI, respectively, no significant differences at the 5 percent level of probability were found between the average body weights or feed conversion of chicks fed either of the control diets (ES 2 and ES 8)

TABLE XII

ADJUSTED¹ BODY WEIGHTS AND FEED CONVERSIONS OF CHICKS
AT FOUR WEEKS OF AGE. EXPERIMENT VI

Diets	Average Body Weights ² (Adjusted)	Feed/Weight ² (Adjusted)
	gms.	
ES 8 + 0.1% Lysine	539.2	1.5455
ES 8 + 0.3% Methionine	524.5	1.6557
ES 8 + 0.2% Lysine	517.7	1.7046
ES 8 + 0.05 Lysine	511.5	1.6752
ES 8 + 0.1% Methionine	510.3	1.6709
ES 8 (Basal)	510.2	1.6242

¹ Average body weights and feed conversions adjusted according to procedure suggested by Cochran and Cox (1957).

² Any two means not connected by the same line are significantly different ($P \leq 0.05$).

TABLE XIII

ADJUSTED¹ BODY WEIGHTS AND FEED CONVERSIONS OF CHICKS
AT FOUR WEEKS OF AGE. EXPERIMENT VII

Diets	Average Body Weights ² (Adjusted)	Feed/Weights ² (Adjusted)
	gms.	
ES 2 (Control)	532.4 ^a	1.4925 ^b
ES 8 + 0.2% Glycine	531.0 ^a	1.5737 ^{bc}
ES 8 + 0.3% Glycine	523.4 ^a	1.5647 ^{bc}
ES 8 + 0.1% Glycine	516.3 ^a	1.6339 ^c
ES 8 (Basal)	498.0 ^a	1.5578 ^{bc}

¹Average body weights and feed conversions adjusted according to procedure suggested by Cochran and Cox (1957).

²Means with same superscript are not significantly different (P / 0.05).

TABLE XIV

ADJUSTED¹ BODY WEIGHTS AND FEED CONVERSIONS OF CHICKS
AT FOUR WEEKS OF AGE. EXPERIMENT VIII

Diet	Average Body Weight ² (Adjusted)	Feed/Weight ² (Adjusted)
	gms.	
ES 8 + 0.2% Glycine + 0.1% Methionine	542.8	1.8072
ES 8 + 0.2% Glycine + 0.2% Lysine	541.3	1.7042
ES 8 (Basal)	534.1	1.8095
ES 8 + 0.2% Glycine + 0.1% Lysine	532.5	1.8634
ES 8 + 0.2% Glycine + 0.3% Methionine	530.8	1.7936
ES 8 + 0.2% Glycine	518.2	1.8829

¹Average body weights and feed conversions adjusted according to procedure suggested by Cochran and Cox (1957).

²Any two means not connected by the same line are significantly different ($P \leq 0.05$).

TABLE XV

ADJUSTED¹ BODY WEIGHTS AND FEED CONVERSIONS OF CHICKS
AT FOUR WEEKS OF AGE. EXPERIMENT IX

Diets	Average Body Weights ² (Adjusted)	Feed/Weight ² (Adjusted)
	gms.	
ES 8 + 0.2% Glycine + 0.2% Lysine + 0.1% Methionine	541.3	1.7143
ES 8 + 0.2% Glycine	529.3	1.7204
ES 8 + 0.2% Glycine + 0.1% Lysine + 0.1% Methionine	526.3	1.7013
ES 2 (Control)	526.1	1.6539
ES 8 (Basal)	525.1	1.6905

¹Average body weights and feed conversions adjusted according to procedure suggested by Cochran and Cox (1957).

²Any two means not connected by the same line are significantly different ($P \leq 0.05$).

TABLE XVI

BODY WEIGHTS AND FEED CONVERSIONS OF CHICKS
AT EIGHT WEEKS OF AGE. EXPERIMENT X

Diets	Average Body Weights ¹	Feed/Weight ¹
	lbs.	
ES 8 + 0.2% Glycine + 0.1% Methionine	2.92	2.2311
ES 8 (Basal)	2.91	2.2240
ES 2 (Control)	2.89	2.1703
ES 8 + 0.2% Glycine	2.88	2.2449
ES 8 + 0.2% Glycine + 0.2% Lysine - 0.1% Methionine	2.85	2.2371
ES 8 + 0.2% Glycine + 0.2% Lysine	2.84	2.2910

¹Any two means not connected by the same line are significantly different ($P \leq 0.05$).

or diet ES 8 plus supplementary amino acids.



DISCUSSION

A series of experiments were conducted in an attempt to develop practical high-protein, high energy broiler starter and finisher diets.

The results of Experiment I tended to verify the work of Combs (1956) and Sunde (1956), in that chicks fed either a 25 percent protein starter diet, a 23 percent protein finisher diet, or a combination of the above diets, had significantly heavier average body weights ($P \leq 0.01$) and required significantly less feed per unit of body weight ($P \leq 0.05$) than did chicks fed starter and finisher diets with a lower protein content. The C/P ratios of the starter and finisher diets were 41:1 and 48:1, respectively, which were the approximate ratios recommended by Combs (1956).

The results of this study differ from those of Mraz et al. (1958) who obtained best results, measured by body weight gain, with chicks fed diets of narrower C/P ratios than were used in this study. However, diets fed by these researchers contained lower levels of protein which may account for the difference in the results obtained in the two studies. This explanation is in accordance with the work of Sunde (1956) who concluded that a desirable C/P ratio varies with the protein level of the diet.

The work of Maddy et al. (1958) and Potter et al. (1956) was substantiated by the results of Experiment II. Chicks fed a 20 percent protein-50:1 C/P ratio finisher diet (EF 3) had significantly lighter average body weights ($P \leq 0.05$) and required significantly more feed per unit of body weight ($P \leq 0.05$) than did chicks fed a 23 percent

protein-48:1 C/P ratio finisher diet (EF 2). However, chicks fed diet EF 3 were better feathered and pigmented to a greater degree than were chicks fed diet EF 1 (20 percent protein-53:1 C/P ratio) in Experiment I. This may be attributed to the feedstuffs found in diet EF 3 and not included in the formula of diet EF 1.

Average body weights or feed conversions of battery reared chicks, fed diets from which feedstuffs thought to contain unidentified "growth factors" were deleted, were not significantly different from those of chicks fed a control diet.

However, when similar diets were fed to chicks on litter, there was a significant difference at the 1 percent level of probability between the average body weights of chicks fed the control diet and those of chicks fed diets from which fish meal or whey and methionine had been omitted. Other researchers, Combs and Nicholson (1958), Combs et al. (1959), Stephenson (1954), Snetsinger and Scott (1958), and Day (1960), have reported on similar studies, but the results obtained by these workers are not in complete agreement. However, in the reported instances, the levels of the protein and energy of the diets seemed to influence the results obtained. This is not applicable to the studies reported in this thesis, as the diets were iso-nitrogenous and contained approximately the same number of Calories per pound of diet.

The conflicting results in these studies (Experiments III and IV) may have been caused by several factors, especially since one of the studies was conducted with chicks in batteries and terminated when the chicks were four weeks of age, and the other was a nine-week study with

chicks on litter. However, the average body weights of four-week old birds grown on litter and fed a diet containing no fish meal or whey and methionine were significantly smaller ($P \leq 0.01$) than those of birds fed the control diet. There is the possibility that some type of "stress" caused the factors to be expressed by the chicks on litter, or that a subclinical level of a disease, such as coccidiosis, was present in only part of the pens.

In view of the results of the above experiments, it was decided to leave all the present ingredients in diets ES 2 and EF 2 and attempt improvement of the diets by modification of the protein and/or energy levels. Calorie levels were selected so that 25 and 30 percent protein diets with equal C/P ratios could be studied. The C/P ratio was lowered to 38:1 because of the extremely high level of added fat needed to obtain a 41:1 C/P ratio when a diet contains 30 percent protein.

Although the performance of chicks fed either of these diets in Experiment V was acceptable, only the 25 percent protein-38:1 C/P ratio starter diet was retained for use in future experiments in this series. This diet was retained because the performance of chicks measured by average body weights and feed required per unit of body weight was equal to, or better than, those fed the other diets in this experiment.

In Experiments VI and VII, a 25 percent protein-38:1 C/P ratio diet was supplemented with varying levels of glycine, methionine and lysine. Chicks fed the basal diet with 0.2 percent added glycine, had slightly heavier, but not significantly different ($P \leq 0.05$), average body weights than those of chicks fed the basal diet. Because of the

0.1 percent added methionine in the formula of the basal diet, the increase in chick body weight received when 0.2 percent glycine was added to this diet is comparable to results of a similar study by Combs (1958). A growth response by chicks fed diets supplemented with glycine and methionine was also reported by Douglas et al. (1958), however these researchers fed diets containing only 21 percent protein.

In Experiments VIII, IX, and X, diet ES 8 plus 0.2 percent added glycine was used as a base diet to which varying levels of lysine and/or methionine were added. Although no statistically significant differences were found in these experiments ($P \geq 0.05$) there was an increase of 12 grams in the average body weight of the chicks (Experiments VIII and IX) where a combination of amino acids was added, over that of the average body weight of the chicks in Experiments VI and VII where only one amino acid was added to the basal diet. It may be concluded from the results of these experiments that the 25 percent protein-38:1 C/P ratio diet contains sufficient glycine, methionine, and lysine to meet the requirements of the growing chick, and that the levels of these amino acids which were added to the diet were not detrimental to the chicks.

Considering the performance of chicks fed the various diets in this series of studies, the 25 percent 38:1 C/P ratio starter diet (ES 8) and the 23 percent protein-48:1 C/P ratio finisher diet (EF 2) appear to be the best diets. However, diets ES 8 and EF 2 were not used in combination with each other. Although chicks fed the 25 percent protein starter diet with a 41:1 C/P ratio (ES 2) required less feed per unit of body weight than did chicks fed diet ES 8, the difference

was not significant at the 5 percent level of probability. Average body weights of chicks fed either diet ES 2 or ES 8 were approximately equal. The lower percentage of added fat in diet ES 8, hence easier mixing, would indicate that this diet might be more desirable than diet ES 2.

At the time of this writing, the high fat content of the 25 percent protein 48:1 C/P ratio finisher diet (EF 4) used in these studies does not seem feasible due to the cost of the fat, the difficulty of mixing, and poor handling properties of the feed. However, chicks fed this diet had average body weights and feed conversions comparable to those of chicks fed diet EF 2.

SUMMARY

A total of 8,400 broiler chicks were used in three nine-week and two eight-week floor studies and five four-week battery studies in an attempt to improve complex, high-protein, high-energy broiler starter and finisher diets.

Chicks fed either a diet containing 25 percent protein-41:1 C/P ratio, a diet containing 23 percent protein-48:1 C/P ratio, or a combination of the above diets had heavier average body weights and required less feed per unit of body weight than did chicks fed either a diet containing 21 percent protein-43:1 C/P ratio, a diet containing 20 percent protein-51:1 C/P ratio, or the latter two diets combined.

No differences were found between the average body weights and the feed required per unit of body weight of battery reared chicks fed either a 25 percent-41:1 C/P ratio starter diet from which either methionine, feather meal, fish meal, or whey was deleted, and those of chicks fed a basal diet which contained all four of these ingredients. However, when grown on litter to nine weeks of age, chicks fed diets with either fish meal or whey and methionine deleted were significantly lighter in body weight than were chicks fed the basal diet.

Diets containing 25 percent protein-38:1 C/P ratio, 30 percent protein-30:1 C/P ratio, 30 percent protein-38:1 C/P ratio, and 25 percent protein-48:1 C/P ratio were fed in various combinations. Heaviest average weights were obtained from chicks fed starter and finisher diets containing 25 percent protein-38:1 C/P ratio and 25 percent protein-48:1 C/P ratio, respectively, but chicks fed starter and finisher diets

containing 30 percent protein-38:1 C/P ratio and 25 percent protein-48:1 C/P ratio, respectively, required significantly less feed per unit of body weight than did chicks fed any of the other diets in this study.

No significant differences were found in the average body weights of chicks fed a 25 percent protein-38:1 C/P ratio starter diet to which glycine, lysine, and high levels of methionine were added either separately or in combination and at varying levels.

REFERENCES

CRANES  CREST

REFERENCES

- Aitken, J. R., G. S. Lindblad, and W. G. Hunsaker, 1954. Beef tallow as a source of energy in broiler rations. Poultry Sci. 33:1038. (Abstract).
- Baldini, J. T., and H. R. Rosenberg, 1955. The effect of productive energy level of the diet on methionine requirements of the chicks. Poultry Sci. 34:1301-1307.
- Biely, J., and B. March, 1954. Fat studies in poultry. 2. Fat supplements in chick and poult rations. Poultry Sci. 33:1220-1227.
- Cochran, W. G., and Gertrude M. Cox, 1957. Experimental Design, 2nd Ed. John Wiley and Sons, Inc. New York, N. Y.
- Combs, G. F., 1956. Maryland Research-Studies on Calorie-protein ratio, fat and methionine in poultry rations. Proc. Univ. of Maryland Nutrition Conf. for Feed Mfgs. 49-60.
- Combs, G. F., 1958. Studies with practical broiler rations. Proc. Univ. of Maryland Conf. for Feed Mfgs. 18-28.
- Combs, G. F., 1959. Energy and amino acids in poultry. The Merck Agricultural Memo. 4:1:1-2.
- Combs, G. F., and J. L. Nicholson, 1958. Maryland Broiler Trial. Corn fermentation solubles, tranquilizer, C/P ratio, and protein supplements tested with sexes separated. Feedstuffs 30:47:18-19.
- Combs, G. F., J. L. Nicholson, and N. V. Helbacka, 1959. Maryland Broiler Trial. Dried whey product, methionine, glycine, protein level, animal protein supplement, and time on starter tested with sexes separated. Feedstuffs 31:14:26-32.
- Day, E. J., 1960. Fish meal and fat studied in broiler rations. Mississippi Farm Research 27:11:2.
- Donaldson, W. E., G. F. Combs, and G. L. Romoser, 1956. Studies on energy levels in poultry rations. 1. The effect of Calorie-protein ratio of the ration on growth, nutrient utilization, and body composition of chicks. Poultry Sci. 35:1100-1105.
- Donaldson, W. E., G. F. Combs, G. L. Romoser, and W. C. Supplee, 1957. Studies on energy levels in poultry rations. 2. Tolerance of growing chicks to dietary fat. Poultry Sci. 36:807-815.
- Douglas, C. R., H. J. Hochreich and R. H. Harms, 1958. Glycine in broiler nutrition. Poultry Sci. 37:620-624.

- Duncan, D. R., 1955. Multiple range and multiple F tests. *Biometrics* 11:1-42.
- Fraps, G. S., 1928. Digestibility and production coefficients of poultry feeds. *Texas Agri. Exp. Sta. Bul.* 372.
- Fraps, G. S., 1946. Composition and productive energy of poultry feeds and rations. *Texas Agri. Exp. Sta. Bul.* 678.
- Hill, F. W., and Ruth Renner, 1957. Metabolizable energy values of feedstuffs for poultry and their use in formulation of rations. *Proc. Cornell Nutrition Conf. for Feed Mfgs.* 22-32.
- Hubbell, C. H., 1958. Analysis table for feed ingredients. *Feedstuffs* 30:12:84.
- Leong, K. C., M. L. Sunde, H. R. Bird, and C. A. Elvehjem, 1955. Effect of energy:protein ratio on growth rate, efficiency, feathering, and fat deposition in chickens. *Poultry Sci.* 35:1165 (Abstract).
- Leong, K. C., M. L. Sunde, H. R. Bird, and C. A. Elvehjem, 1959. Interrelationships among dietary energy, protein, and amino acids for chickens. *Poultry Sci.* 38:1267-1285.
- Maddy, K. H., 1958. The role of amino acids in broiler nutrition. *Feedstuffs* 30:18:26.
- Maddy, K. H., R. S. Gordon, J. L. Machlin, and G. L. Romoser, 1958. Effect of increasing the level of dietary energy during the finishing period on growth and feed conversion of broilers. *Poultry Sci.* 37:1223. (Abstract).
- Mangold, Ernst, 1934. The digestion and utilization of crude fiber. *Nutr. Abs. and Rev.* 3:647-656.
- Matterson, L. D., and L. M. Potter, 1958. Observations on protein and energy relationships for broilers. *Proc. 1958 Distillers Feed Conf.* 31-34.
- Mraz, Frank R., R. V. Boucher, and M. G. McCartney, 1956. The influence of dietary productive energy and fiber on growth response in chickens. *Poultry Sci.* 35:1335-1340.
- Mraz, Frank R., R. V. Boucher, and M. G. McCartney, 1958. The influence of dietary energy and protein on growth response in chickens. *Poultry Sci.* 37:1308-1313.
- National Research Council, 1954. Nutrient Requirements for Domestic Animals, No. 1. Nutrient Requirements for Poultry.

- Potter, L. M., L. D. Matterson, Doris Carlson, and E. P. Singsen, 1956. Studies on the effect of varying protein level and calorie-protein ratios in poultry rations on growth and feed efficiency. Poultry Sci. 35:1165 (Abstract).
- Rand, N. T., H. M. Scott, and F. A. Kummerow, 1958. Dietary fat in the nutrition of the growing chick. Poultry Sci. 37:1075-1085.
- Robertson, E. I., R. F. Miller, and G. F. Heuser, 1948. The relation of energy to fiber in chick rations. Poultry Sci. 27:736-741.
- Rosenberg, H. R., J. T. Baldini, M. L. Sunde, H. R. Bird, and T. D. Runnels, 1955. The concomitant use of fat and methionine in broiler diets. Poultry Sci. 34:1308-1313.
- Scott, H. M., L. D. Matterson, and E. P. Singsen, 1947. Nutritional factors influencing growth and efficiency of feed utilization. 1. The effect of the source of carbohydrate. Poultry Sci. 26:554 (Abstract).
- Scott, H. M., L. C. Sims, and D. L. Slakeli, 1955. The effect of varying protein and energy on performance of chicks. Poultry Sci. 34:1220. (Abstract).
- Snedecor, G. W., 1956. Statistical Methods, 5th Ed. Iowa State College Press, Ames, Iowa.
- Snetsinger, D. C. and H. M. Scott, 1957. The adequacy of soybean oil as a sole source of protein for chick growth. Poultry Sci. 36:1158:1159. (Abstract).
- Snetsinger, D. C. and H. M. Scott, 1957. The adequacy of soybean oil meal as a sole source of protein for chick growth. Poultry Sci. 37:1400-1403.
- Stephenson, E. L., 1954. Amino acid supplementation of broiler diets. Poultry Sci. 33-1083. (Abstract).
- Sunde, M. L., 1956. A relationship between protein level and energy level in chick rations. Poultry Sci. 35:350-354.