ENERGY-PROTEIN RELATIONSHIPS

IN TURKEY POULT STARTERS

By

WILLIAM CLARENCE LOCKHART

Bachelor of Science

Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

1953

Submitted to the faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
July, 1955

ENERGY-PROTEIN RELATIONSHIPS

IN TURKEY POULT STARTERS

Thesis Approved:

Rollin H. Thayer

Thesis Adviser

R. J. Roberts

Robert MacVicar

Dean of the Graduate School

PREFACE

A majority of the turkey nutrition studies conducted during the past twenty years were concerned primarily in determining the crude protein level at which the best growth response could be obtained. An intensive review of these studies indicatesthat many of these experiments did not give the response desired. Approximately three-fourths of Chapter II is given to the discussion of crude protein, and amino acid availability and balance. The importance of protein and energy balance is presented in the latter part of this chapter.

This study, which includes six feeding trials, was conducted in an effort to obtain information about amino acid and protein-energy requirements of turkey poults during the first four weeks of the brooding period. This work should be considered only as preliminary but it is my most sincere hope that parts of the information may be used as an aid in the formulating of better and more efficient practical turkey poult starter rations.

I wish to express my gratitude and most sincere thanks to Rollin H. Thayer for his valuable criticisms, suggestions, guidance and encouragement given during the course of the research work and writing of the manuscript. His untiring efforts have been a great inspiration to me. The helpful criticism and assistance given by Drs. Franklin Graybill, Magnar Ronning, R. J. Sirny, W. R. Kirkham, V. G. Heller and Jack Long are greatly appreciated. My indebtedness to them is gratefully acknowledged.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

LIST OF ILLUSTRATIONS

Figure | Page

Figure		Page

CHAPTER I

INTRODUCTION

The basic criterion now used for the evaluation of the nutritive value of a poultry ration is crude protein. Crude protein, used as such, is considered by many nutritionists to be only of relative value in estimating the nutritive value of a poultry ration, regardless of the purpose for which it is to be used. Protein quality, which is only one measure of the basic value of a poultry ration, is now being given increased, critical consideration.

Protein quality is dependent upon the pattern of amino acid distribution and the availability of the amino acids. While these two principles are of great importance in the evaluation of a protein supplement, many of the protein requirement recommendations given for turkey poult starting rations are unreliable because these principles have not been considered. The extent to which a high quality protein may exert the desired response for tissue synthesis and growth is dependent upon the amount of energy present.

Available dietary energy from carbohydrate and fat sources should be present in sufficient amounts to support the most efficient utilization of protein as measured by nitrogen retention. In many studies made to obtain protein requirement data, the energy supply has been the first limiting factor rather than protein quality.

The effect of protein quality and the protein-energy ratio on the efficiency of feed utilization is reported in this study.

CHAPTER II

REVIEW OF LITERATURE

Crude Protein Requirements of Growing Turkeys

The crude protein in feedstuffs which go into formulated rations for poultry and livestock is measured by the total amount of organic and inorganic nitrogen which is present in the feedstuffs. The nitrogen content is multiplied by 6.25 to arrive at the percent of total crude protein. The term "crude protein" is used by all commercial feed manufacturers. While this term can be used with considerable success in the evaluation of the usable protein in a ration for ruminating animals, it is of little use in determining the relative biological value of the protein in a poultry ration.

The recommended crude protein levels for turkey poult starter ration have varied greatly during the past two decades. In general, recommendations have been increasing. Mussehl (1933) presented evidence that a turkey poult starter ration containing 20 percent of protein was satisfactory to support poult growth. Asmundson and Jukes (1939) disclosed that a turkey poult starter ration containing 24 percent protein was adequate to support poult growth from one to six weeks of age. A 22 percent protein poult grower ration gave a good response from seven to twelve weeks of age and a 15 percent protein ration appeared to be adequate for late growth and finishing. Hammond and Marsden (1939) after working with turkey poult starter rations containing from 18 to 30 percent protein, reported that the protein level of the ration had no consistent effect upon the amount of ration necessary to produce a unit of gain. All protein levels were considered to be adequate. On the basis of units of protein consumed per unit of gain, the 18 percent protein starter was the most efficient. Milby, Jaap and Thompson (1939) experimented with turkey starter and grower rations containing from 15.6 to 26.3 percent crude protein and concluded that the higher protein levels produced turkeys with the highest carcass quality. The 22.4 percent protein ration produced the most efficient gains when fed during the entire growing period.

Barrett, Card and Berridge (1940) showed that the feeding of turkeys in confinement on a 31 percent protein mash did not increase growth or grain consumption, nor reduce the units of feed consumed per unit of gain. Robertson and Carver (1941), however, demonstrated that feeding a 39.1 percent protein concentrate mix to growing turkeys resulted in more rapid growth, greater grain consumption and increased feed efficiency. Funk (1943) reported that turkey poults had been successfully grown to eight weeks of age on a poult starter ration containing 23 percent of protein. The young turkeys were then divided into four groups and each group was fed to maturity on a 27, 32, 36 or 40 percent turkey grower concentrate. The concentrate and grain was fed free choice. It was concluded that the higher protein concentrates did not give an increased growth response and the efficiency with which protein was utilized decreased as the protein level increased. Consequently, the high protein concentrates were not recommended for Missouri. Draper, Evans, Rhian and Brant (1943) showed that turkey poult starters should not contain more than 23 percent of protein for the most efficient utilization of protein. As the protein content of the starter was increased to 26, 29 and 32 percent, there was a progressive increase in the units of protein utilized per unit of gain.

Scott, Heuser and Norris (1948) considered the protein level of a turkey poult starter ration to be dependent upon the amount of energy of the ration. A low energy ration containing 24 percent protein was considered adequate to support a reasonable rate of growth. High energy rations containing 28 to 30 percent protein were found to support optimum growth and increase the efficiency of feed utilization over that obtained by feeding a 24 percent protein, low energy ration. Almquist (1952) reported that a turkey poult starter ration should contain 28 percent of protein for most efficient feed utilization and optimum growth. Poult growth was retarded by changing from a 28 percent to a 24 percent protein ration at approximately six weeks of age. Turkey poults which had made the quickest gains to 4 pounds of body weight were said to have carried this weight advantage to market age.

Current crude protein levels which are recommended for turkey poult starter rations are within a relatively narrow range as compared to the recommended protein levels given during the past two decades. Scott (1953) in reviewing the recent protein requirement studies concluded that a 28 percent protein level was in line with the poult's protein requirements.

Thayer (1953) conducted turkey starter and grower ration studies at the Oklahoma station. These studies showed that for the first eight weeks of the growing period, a 25 percent protein starter was as efficiently utilized as a 28 percent protein starter and more efficiently utilized than a 29.5 percent protein starter. It was shown that the body weight advantage of the poults fed the two higher protein starters to eight weeks of age, was not maintained to 25 weeks of age. All turkeys were fed on the same grower ration from 9 through 25 weeks of age. The difference in the effect of the three starter protein levels upon growth at the end of the first eight weeks of the growing period had negligible effect upon body weight and finish at 25 weeks of age. This finding was in disagreement with that reported by Almquist (1952).

Many workers have placed emphasis upon starter rations which would give faster growth during the first six or eight weeks of the growing period with but little consideration being given to the overall economy of the operation. From the standpoint of economy, feed efficiency and better nutrition, the inter-relationship of protein quality and available energy is very important.

Crude Protein and Amino Acid Relationships

In the foregoing review and discussion very little place was given to a discussion of protein quality, biological value of protein and amino acid balance. These points are, however, of great importance in the formulation of all turkey and poultry rations. Due to the fact that very little was known about the amino acid requirements of the turkey poult before the beginning of the present decade, very few of the crude protein recommendations made prior to this time had given any consideration to amino acid balance. Some of the early workers gave little consideration to the difference in the biological value of various protein supplements. However, the protein requirement values which were based upon these supplements are of only limited value since many of the protein feedstuffs then used have changed as a result changing processing methods.

Protein quality is dependent upon a number of factors. Almquist (1953) in discussing protein quality pointed out that the amino acid composition or distribution of a given protein was one outstanding criterion of quality. This factor is of great importance in the formulation of rations for animals that require certain amounts of indispensable amino acid for optimum performance. Amino Acids must also be considered from the standpoint of availability. Certain proteins which have a good amino acid distribution are rather ineffective as a source of these amino acids due to the poor digestability of the protein. Other factors are the destruction of amino acids in protein concentrates by overheating during the manufacturing process, the presence of an enzyme inhibitor which depresses normal enzymatic action in protein digestion and the destruction of protein by autolysis and spoilage. Scott (1953) pointed out that the availability of amino acids in natural feedstuffs represented a situation analogous to phosphorus in various feed materials. The National Research Council specifies both the total amounts of phosphorus required and also a requirement for readily available phosphorus. As soon as suitable procedures are worked out for determining the biological availability of each of the essential amino acids in natural feedstuffs, the present crude amino acid tables and requirements should be converted to give available amino acid and amino acid requirement data.

Amino acid balance is of great importance in meeting the amino acid requirement of simple stomached animals. This often requires the use of several sources of protein blended together in such amounts that the amino acid deficiency in one protein is supplemented by an excess of the same amino acid or its precursor in another protein. Almquist (1953) disclosed that high-quality fish meal is one of the few sources of protein which has an amino acid composition completely adequate to support normal chick growth. Meat scraps, milk protein, oil cake meals and cereal proteins are deficient in one or more of the indispensable amino acids. The greatest efficiency in growth, production and protein utilization will be attained if the amino acid composition of the ration is balanced so as to create an average amino acid supply as closely as possible to the requirement, being neither too far under nor too far over in any respect. "The primary consideration from the standpoint of the animal is to avoid serious deficiencies of required amino acids; a secondary consideration, from the standpoint of efficient protein utilization, is to avoid a wasteful surplus of one or more amino acids." Scott (1953) reporting on the work of Scott, Heuser and Norris (1948) stated that an amino acid balance could be attained by using combinations of animal and vegetable proteins. Although very little was known about the amino acid requirement of turkey poults at this date, the approximate amino acid requirement was considered to be 1.3 times greater than the amino acid requirements of the growing chick. Baldini, Rosenberg and Waddell (1954a) indicated that a 20 percent protein corn-soybean oil meal diet, with the addition of a small amount of lysine and methionine would give growth and efficiency of feed utilization comparable to the same type of ration containing 28 percent protein. By the addition of these two amino acids to the lower protein ration a better amino acid balance would be attained whereby the total amount of crude protein could be greatly reduced.

Russell, Taylor and Price, (1951) (1952) and Price, Taylor and Russell, (1953) reported on essential amino acid retention by the growing chick. Two growing rations were used. The analyses for amino acid retention and waste for each ration were compared. Ration A contained 21.9 percent protein, primarily from a vegetable (soybean) source and ration B contained 16.3 percent protein principally from an animal (dried whole beef, dried beef liver, dried egg and fish meal) source. On the basis of the amino acid analysis of each ration, ration B contained 11, 16 and 21 percent less of methionine, lysine and tryptophan, respectively, than did ration A. Efficiency of feed utilization of ration B was equal to ration A. On comparing the carcass retention of methionine, lysine and tryptophan with the amounts of each ingested, the chicks on ration B were found to have retained 18, 15 and 12 percent more of the amino acids, respectively, than did the chicks on ration A. Although ration B gave a better amino acid response, ration A had the best amino acid balance pattern on a calculated basis with which to meet the requirements of the chick. The apparent difference in the response of the two rations would appear to be caused by the greater availability of the amino acids in ration B over those in ration A.

The Time Factor in Protein Synthesis

The role of time is an important consideration in the feeding of supplementary proteins and amino acids. Gieger (1950) stated that protein synthesis is dependent upon the dietary supply of essential amino acids, and also upon the rate with which the dietary dispensable amino acids become available. The formation of the dispensible amino acids are not only dependent upon the amino group supplied by the deamination of other amino acids, but also by the supply of other easily available precusors of the amino acid, such as carbohydrate and fat. Cuthbertson, McCutcheon and Munro (1940) working with adult humans and rats, reported that the nitrogen-sparing effect of a carbohydrate was correlated with the time that elapsed between the feeding of the protein and the ingestion of the carbohydrate. Geiger (1948 b) reported that the growth of the young rat is retarded when the protein and the other constituents of the diet are fed with a time interval between each feeding. This worker considered it logical to assume that carbohydrates could be used optimally as a precursor of nonessential amino acids only when carbohydrates and protein which contains the essential amino acids were fed simultaneously. Almquist (1947) indicated that the nature of protein synthesis was such that the essential and nonessential amino acids must be present simultaneously and in sufficient quantities to promote protein synthesis. Although the simple stomached animals do not require that the nonessential amino acids be included in the diet, it is necessary that these be produced in the intermediary metabolism and be present as free amino acids in such quantities as to support optimum utilization of the essential amino acids. Rose, Oesterling and Womack (1948) in working with rats showed that the feeding of all the essential and nonessential amino acids simultaneously was more effective than feeding the essential amino acids alone. Almquist (1953) reported the forced synthesis of dispensable amino acids from indispensable amino acids is likely to proceed with considerable waste. It is important that a protein contain a reasonable quantity of dispensable amino acid for this exerts a "sparing" action on the indispensable ones.

Henry and Kon (1946) reported that complex foods when fed as a composite group exhibited a supplementary relationship. This relationship did not exist when each food was fed separately on alternate days. Geiger (1948 a) showed that feeding of two or more proteins which were characterized by a low biological value gave a better response than could be attained by feeding any one of the proteins separately. The proteins tended to give a supplementary effect when fed together. Sauberlich and Bauman (1948) showed that feeding incomplete protein or proteins of low biological value increased the excretion of urinary amino acids. An inverse relationship was found between the rate of growth and the percentage of ingested amino acids excreted in the urine.

Schoenheimer (1946) showed that adult rats which were partially depleted of body protein tissue did not respond to a tryptophan free diet. The feeding of a tryptophan free diet for 12 hours with delayed feeding of tryptophan 12 hours later gave no supplementary effect. The adult rats continued to lose weight just as though no dietary protein was being received. Cannon (1948) reported that protein depleted adult rats repleted protein tissue only when all of the essential amino acids were made available. The rebuilding of protein depleted tissue is essentially the same process as growth in the infantile rat. Two diets, each containing approximately one-half of the essential amino acids, were fed separately to rats with no growth response. When two rations were fed simultaneously they supplemented one another and affected protein tissue repletion. Geiger (1947) established, by amino acid analysis of the tissue, that amino acids which were not immediately used for protein synthesis were not stored in the body as such nor were they used as intermediary building stones from which protein synthesis could later proceed. Feeding an incomplete essential amino acid diet to rats did not promote protein synthesis as measured by growth. The amino acids not utilized for growth are metabolized, probably irreversibly. Henderson and Harris (1949) found that a delay of three hours or longer in the feeding of lysine to supplement a lysine low diet interfered with amino acid metabolism. Geiger (1950) indicated that a protein of low biological value could be supplemented by other proteins or amino acids within four to five hours after ingestion. Bolin, Klosterman, Butler, Schlamb and

Bryant (1951) reported that dl-methionine fed simultaneous with a methionine low diet had a supplementary effect when fed to chicks. The feeding of the methionine low diet with a 24-hour delay in feeding additional methionine proved to be without supplementary effect.

Amino Acid Requirements of the Turkey Poult

Current information dealing with the amino acid requirements of turkey poults is inadequate for use in ration formulation. Many of the poult amino acid requirement studies were made using highly purified types of protein. Scott (1953) raised the question as to whether or not the amino acid requirements obtained using purified proteins could be used in practical ration formulation. Natural ingredients supply smaller amounts of available amino acids per unit of crude protein than do purified proteins. It is suggested that greater amounts of certain amino acids may be necessary to support optimum metabolism than the present requirements would indicate. Almquist (1947) reported an increased metabolic destruction of the more rapidly absorbed free amino acids. If synthetic amino acids are more readily absorbed than amino acids from ingested protein, it would appear that the amounts of amino acids necessary to support optimal growth are in excess of the true requirement.

Arginine -- Kratzer, Bird, Asmundson and Lepkovsky (1947) used a purified diet which contained water washed casein, cystine, glycine and graded levels of arginine. A ration containing 25.34 percent crude protein was fed to Broad Breasted Bronze poults. Maximal poult growth was obtained at a 1.35 percent arginine level.

Glycine -- Kratzer and Williams (1948) gave a report on the experimental work which they had conducted to determine the glycine requirement of turkey poults. A synthetic ration containing 24 percent crude protein was fed to Broad Breasted Bronze poults. Maximal growth was attained when 0.75 percent of glycine was added to the natural diet which contained 0.15 percent glycine. The requirement for poults fed a 24 percent crude protein diet would appear to be 0.90 percent of the total ration.

Isoleucine -- Kratzer, Williams and Marshall (1952) used a synthetic type diet which contained blood meal and gelatin as the source of protein to study the isoleucine requirement of young poults. A ration which contained 26.8 percent crude protein and 0.3 percent of natural isoleucine was fed to Broad Breasted Bronze poults. Optimum growth was obtained when 0.5% synthetic isoleucine was added to the basal ration. It would appear that the l-isoleucine requirement is approximately 0.80 percent of the total diet.

Lysine -- Fritz, Hooper, Halpin and Moore (1946) reported that a 24.25 percent protein practical type ration containing 1.1 to 1.2 percent calculated lysine was adequate to promote normal feathering and good growth. Grau, Kratzer and Asmundson (1946) used synthetic sesame meal type diets which contained 20 and 24 percent protein. The natural lysine content of these rations was 0.56 and 0.67 percent, respectively. Total dietary lysine required to support maximal growth on the 24 percent protein ration was figured to be 1.3 percent. German, Schweigert, Sherwood and James (1949) showed that the lysine content of a 22.4 percent protein, practical type ration would neither support normal growth nor feather pigmentation. The ration contained 0.62 percent lysine as measured by microbiological assay. The addition of 1.2 percent dl-lysine dihydrochloride equivalent to 0.40 percent l-lysine, supported good growth and normal feather pigmentation. Kratzer, Williams and Marshall (1950b) made a study of the amount of lysine needed in a practical ration to prevent white barring in bronze feathering. Various levels of protein were fed. The workers concluded that the lysine level of a ration which would prevent white barring must be equal to, or slightly less than, the level required for optimal growth. Kratzer (1950a) compared the activities of d and l isomers of lysine. The d-isomer was found to have no activity for supporting poult growth and normal pigmentation. A sesame meal diet containing 0.75 percent lysine and 25 percent protein was used at all lysine supplementation levels. The use of supplementary l-lysine to raise the ration lysine level to 1.26 percent prevented white barring, but did not quite support maximum growth.

Sulfur Containing Amino Acids -- Kratzer, Williams and Marshall (1949) estimated the requirement of turkey poults for sulfur-containing amino acids. A synthetic ration containing an isolated soybean protein was fed. The ration contained, by calculated analysis, 24 percent protein, 0.37 percent methionine and 0.05 percent cystine. The optimum amount of methionine and cystine required to support maximum growth was found to be 0.49 and 0.30 percent, respectively. The poult requirement for sulfur amino acids appears to be approximately 0.80 percent of the total diet.

Tryptophan -- Bird (1950) fed poults a peanut meal-gelatin ration containing 0.13 percent l-tryptophan and 38 percent protein. The d-isomer was found to be only 38 percent as active in supporting poult growth as the l-isomer. An addition of 0.21 percent of dl or 0.15 percent of l-tryptophan was required to support maximum growth. A total of 0.28 percent of l-tryptophan was adequate for the 38 percent protein ration. Kratzer, Williams and Marshall (1951) first used a casein-gelatin type diet containing 0.224 percent of tryptophan and 24 percent protein. This diet required supplementation of 0.05 percent dl-tryptophan to support optimum poult growth. The total l-tryptophan requirement appeared to be 0.25 percent of the total diet. Corn gluten feed and gelatin were the protein sources for a second diet. This diet contained 25 percent protein and 0.093 percent l-tryptophan. The addition of 0.15 percent dl-tryptophan gave a total of 0.19 percent l-tryptophan. This amount was required to support optimum growth. A third diet contained corn gluten feed, meat scrap and gelatin. This diet required a total of 0.227 percent l-tryptophan for best performance. On the basis of these findings the l-tryptophan requirement for the turkey poult was considered to be approximately 0.92 percent of the dietary protein.

Almquist (1952) reviewed the different studies which had been made to estimate the turkey poult's requirement for several amino acids. By interpolation and extrapolation, estimates of the requirements of the various amino acid were made. The requirements were set up, in table form, at protein levels of 24 and 28 percent crude protein. The portion of the table which applies to turkey poult amino acid requirements is given in Table 1.

Scott (1953) disclosed that the essential amino acid requirements of young turkey poults were approximately 1.4 times that of young chickens based on the National Research Council recommendations for amino acids for chicks. The base levels multiplied by 1.4 gave the amino acid levels which should be supplied by a ration containing 28

Table 1.--Turkey poult requirements for some amino acids

Amino Acids	Percent of Diet		Amino Acids	Percent of Diet	
Arginine	1.4	1.6	Methionine	0.75	0.87
			or		
Glycine	0.9	1.0	Methionine	0.45	0.55
			and		
Isoleucine	0.72	0.84	Cystine	0.30	0.35
Lysine	1.3	1.5	Tryptophan	0.22	0.26
Protein Level	24.0 %	28.0 %		24.0 %	28.0 %

percent protein of an excellent quality. These values were valid for all amino acids with the exception of glycine and the sulfur amino acids. The sulfur amino acid requirement appeared to be 1.2 times the chick requirement and the glycine requirement appeared to be the same. Table 2 gives an estimate of the amino acid requirements of the poult which were calculated by Scott using the chick amino acid requirements given in Nutrient Requirements for Poultry (1954) as a base.

Grau (1948) reported that the lysine requirement of the chick must be identified as to protein level. The lysine requirement at one protein level was not the same at a different protein level. Grau and Kamei (1950) stated that as the protein level of the chick ration increased, the lysine and sulfur amino acid requirements also increased. However, it was found that lysine and the sulfur amino acid requirements expressed as a percentage of the total protein decreased as the percentage of protein in the ration increased. Almquist (1952) presented evidence which indicated that the percentage decrease of lysine and

Table 2.--Turkey poult requirements for essential amino acids

Amino Acids	Percent of Diet	Amino Acids	Percent of Diet
Arginine	1.68	Phenylalanine	2.24
Lysine	1.28	Phenylalanine and	1.26
Histidine	0.22	Tyrosine[c]	0.98
Methionine or	0.96	Leucine	1.96
Methionine and	0.54	Isoleucine	0.84
Cystine[a]	0.42	Threonine	0.84
Glycine[b]	1.00	Valine	1.12

[a]Cystine will probably replace methionine but a minimum of 0.54 percent methionine is required.

[b]It is probable that the poult can synthesize a portion of the required glycine, but at an insufficient rate to support optimum growth.

[c]Tyrosine will probably replace phenylalanine, but a minimum of 1.26 percent phenylalanine is required.

sulfur amino acids expressed as percent of the protein was not the same. For example, in a 20 and a 30 percent protein chick ration, the increase from 20 to 30 percent in protein reduced the units of lysine required per unit of protein by approximately 7 percent and of sulfur amino acids by 11 percent.

Effect of Antibiotics on Protein and Amino Acid Requirements

McGinnis, Stern, Wilcox and Carver (1951) reported that the antibiotics; aureomycin, streptomycin, terramycin and penicillin stimulated the growth rate of poults fed a practical diet to four weeks of age. Slinger, Morphet, Gartley and Arthur (1952) reported the growth promoting effect of antibiotics in poult rations as measured by increased feed efficiency to be greater as the protein level of the ration increased. It appeared that a 26 percent protein level was adequate without antibiotics, but a higher protein level seemed to be more adequate in the presence of antibiotics. Saxena, Starr, Blaylock, Carver and McGinnis (1953) indicated that the addition of 3 ppm of penicillin to rations containing varied levels of proteins gave a significant and consistent growth response and an increased efficiency of feed utilization at all protein levels. Almquist (1952) states:

> It is conceivable that the antibiotics might suppress some intestinal microorganisms that are particularly destructive to protein or indispensable amino acids, or the antibiotics may facilitate more efficient absorption of amino acids. It is inconceivable that the antibiotics could have any influence on the levels and proportions of amino acids required to be delivered to the body cells for optimal growth or production.

Preliminary work seemed to indicate that a normal growth response could be obtained by using lower protein levels when antibiotics were fed; however, the growth promoting effect of antibiotics appeared to be small, but seemed to be more pronounced at high protein levels. Slinger and Pepper (1954) indicated that penicillin may support greater growth and increased feed efficiency by causing the poults to eat an increased amount of feed.

Practical Diets Supplemented with Amino Acids

Some supplementation of practical chick and poult rations with dl-methionine or a methionine analogue has been practiced in areas of broiler and turkey production. Hill (1953) stated that many laboratory and large size field experiments had been conducted to determine the value of "free dl-methionine" in practical broiler rations. The addition of methionine has given favorable results in many instances, but the opposite in others. Slinger, Pepper and Hill (1953) reported that the addition of 0.025 percent of dl-methionine, to a practical type poult starter ration containing 28.8 percent protein slightly improved turkey poult gains above that of the controls.

Baldini, Rosenberg and Waddell (1954a) reported on a series of feeding trials in which practical type rations containing 20 to 28 percent protein were fed. The experimental subjects were Jersey Buff turkey poults. It was indicated that lysine and methionine are the first and second limiting amino acids, respectively, in a 20 percent protein corn-soya ration. When 0.20 percent dl-methionine, 0.30 percent l-lysine and 3 percent condensed fish solubles were added to a 20 percent protein corn-soya ration, growth and feed efficiency were found to be equal to that given by a 28 percent protein corn-soya ration containing 0.20 percent dl-methionine. The addition of 0.20 percent dl-methionine only, improved the corn-soya ration at both protein levels. Efficiency of protein utilization was much better at the lower protein level than at the higher. Approximately 30 percent more gain was made from a unit of protein at the lower protein level. By the addition of small amounts of readily available amino acids, 35 percent of the protein ordinarily put into turkey starters might possibly be saved.

Baldini and Rosenberg (1954b) reported on further studies of protein utilization by the turkey poult. The data given indicate that methionine is the first limiting amino acid at the 20 percent and 22 percent protein levels. Lysine additions, in general, were of very little value at these protein levels. Lysine appeared to be the first limiting amino acid at the 28 percent protein level. Methionine additions to the high protein diet had only a slight effect.

Klain, Hill and Slinger (1954) reported on the growth response of turkey poults brought about by the addition of supplementary l-lysine to a practical type poult starting ration. Three starting rations containing 21.8, 25.5 and 28.8 percent protein were used in this study. When the rations were not supplemented with lysine, efficiency of feed utilization at the different protein levels was in favor of the 25.5 percent protein ration. The addition of 0.68 percent l-lysine monohydrochloride to the 21.8 percent protein ration gave a marked increase in growth. Efficiency of feed utilization was increased by the addition of l-lysine at both the 21.8 and 25.5 percent protein levels.

Energy Requirements

The requirement for energy at various protein levels was given only little consideration in the early studies which were made to determine the optimum protein level in a turkey poult starter ration. Draper, Evans, Rhian and Brant (1943) started poults on six different levels of protein ranging from 17 percent to 32 percent protein with the increase being in increments of three percent. The 17 percent protein ration contained approximately 75 therms of productive energy per 100 pounds. The productive energy level increased slightly with each three percent protein increase to a maximum of 77 therms per 100 pounds. At 28 weeks of age, the turkeys fed the 29 percent protein starter weighed only 1.2 more pounds than those fed the 17 percent protein starter. The same starter rations were used as grower rations. During the growing period each mash ration and scratch grain were fed <u>ad libitum</u>. As the protein content of the ration increased, the efficiency of protein utilization decreased. The investigator indicated that probably a considerable quantity of protein concentrate could be saved by feeding a 23 percent protein starting mash and an 18 percent protein developing mash. Funk (1943) fed turkey poults to eight weeks of age on a 23 percent protein starter ration. The poults were then divided into four groups. Each group received one of the complete developing rations which contained either 22, 27, 31 or 39 percent protein. The investigator disclosed that the high protein content of the rations had no sparing effect on the carbonaceous portion of the ration. The waste of protein increased as the protein content of the ration increased. It was calculated that the waste of protein for the 31 and 39 percent protein rations was 23 and 85 percent, respectively, to 24 weeks of age.

Draper and Co-workers (1943) and Funk (1943) were aware that protein had been wasted. Each of them, apparently, was not aware that much of the protein had been used as a source of energy.

A number of protein requirement studies have been made within the past three years. A majority of these apparently have not given ample consideration to the quantity of energy necessary to support the most efficient utilization of the protein. Ackerson and Mussehl (1953) reported on the utilization of various nutrients by the turkey poult. The ratio of all feed ingredients within the 24 and 30 percent protein starting rations were alike, with the exception of yellow corn and wheat shorts. The protein quality remained essentially the same. The 24 and 30 percent protein rations contained 830 and 710 Calories of productive energy per pound, respectively. Nitrogen retention of the poults fed the lower protein starting ration was approximately 40 percent as compared to 34 percent for those fed the higher protein diet. The data indicates that protein was being used as a source of energy at the higher protein level.

Baldini, Rosenberg and Waddell (1954a) disclosed that the addition of small amounts of methionine and lysine to a 20 percent protein turkey starting ration would support growth equal to that of a 28 percent protein poult starting ration. The 28 percent protein diet contained from 730 to 770 Calories of productive energy per pound. It would appear that the response to the 28 percent protein level was penalized by the low energy content. Klein, Hill and Slinger (1954) conducted a protein study very similarly to that of Baldini and associates (1954). The productive energy levels of the 22 and 29 percent protein starting rations were 850 and 780 Calories per pound, respectively. Again, it appeared that the higher protein ration was deficient in productive energy.

Scott, Heuser and Norris (1948) appear to be the first workers to have given consideration to the dietary energy need of the turkey poult. These workers found that it was necessary for the dietary energy fraction of the ration to be increased as the protein level increased. Although no actual energy levels were established it was recognized that a low energy ration would support the efficient utilization of a 24 percent protein starting ration, but a high level of energy was needed for the efficient utilization of rations containing 28 to 30 percent protein. Robertson, Miller and Heuser (1948) reported 800 Calories of productive energy per pound of ration was satisfactory for good chick growth. However, the data indicated a minimum requirement of 840 Calories per pound of ration. The chicks fed the high energy rations gained 36 percent during the fifth week as compared to 20 percent gain for chicks fed low energy rations containing an average of 700 Calories.

Hill and Dansky (1950) studied the protein and energy requirements of the chick when diets containing 20, 25 and 30 percent of protein were fed. Each level was supported by high levels of productive energy. Gross efficiency was highest for the 20 percent protein ration. Feed intake was said to be directly related to the productive energy content of the ration. Panda and Combs (1950) indicated that the crude fiber level of a chick starting ration depressed growth only as the productive energy level of the ration was decreased. Peterson, Grau and Peek (1952) reported that cellu flour additions to high-energy chick starting rations, containing varied levels of excellent quality protein, increased the rate of gain. The amount of gain was characteristic of the protein level. The energy content of the ration was inversely related to the cellu flour additions. Body weight gain decreased as the cellu flour additions dropped the energy level below the minimum amount required to support the most efficient protein utilization. This indicated that there is a definite energy-protein ratio for the most efficient utilization of the ration.

Dymsza, Boucher and McCartney (1953) reported that the energy requirement for growing turkeys to ten weeks of age and older is within a range of 460 to 875 or more Calories per pound of ration. Gross feed efficiency was better when 5 percent of fiber was included in the diet. Energy was utilized most efficiently when the ration contained 20 percent fiber. Hill and Dansky (1954) showed that chicks fed graded levels of fiber with the dietary protein level remaining constant, utilized the energy of the ration with increased efficiency as the level of fiber increased. Chicks fed a diet containing 505 Calories of productive energy per pound of ration were able to gain as much in body weight during the first four weeks of growth as chicks fed a diet containing 975 Calories of productive energy. Increased consumption of the low energy ration was responsible for the good body weight gain. Blaylock, Hunt, Zeigler, Patterson and Stadelman (1954) conducted an experiment to determine the fiber level which would support the most efficient feed utilization. The ration which gave the best results contained 963 Calories of productive energy per pound and 2.5 percent fiber. The protein level remained constant at all fiber levels.

CHAPTER III

EXPERIMENTAL METHODS

General Procedure

Evaluation of Nutrients -- Feed ingredients used in the mixing of all basal rations within each feeding trial were purchased on the open market with the exception of dl-methionine and l-lysine monohydrochloride. Each feed ingredient was chemically analysed for moisture, crude protein, fat, crude fiber, calcium, phosphorus, and nitrogen free extract. The soybean and fish meals used in Trials III, IV, V and VI were microbiologically assayed* for methionine and lysine. The values obtained from these analyses were used as a basis for calculating the nutrient levels in all of the basal rations used in the four feeding trials.

The available energy from the protein, fat and nitrogen free extract in each feed ingredient was calculated as follows: The digestion coefficients for all given feed ingredient as given by Frape (1946) and Titus (1949) were used to calculate the approximate amounts of these three nutrients which were available to poultry. The available energy supplied by each of the three nutrients was then calculated by multiplying the amount of digestible nutrient in a given feed ingredient by the respective Calories of energy per unit of that feed ingredient. In Table 3 are

*By microbiological assay essentially as described by Alice M. Violante, R. J. Sirny and C. A. Elvehjem, Journal of Nutrition, XLVII (1952), 307.

Table 3.--Large calories of available energy per pound of feed ingredient

Ingredients	Carbohydrate		Fat	Total CHO and Fat	Protein	Total CHO, Fat and Protein
	NFE	Crude Fiber				
Gr. Yellow Corn	1224.43	2.00	156.24	1382.67	132.35	1519.02
Corn Starch	1805.56			1805.56		
Cerelose	1707.95			1707.95		
Gr. Oats	804.13	26.62	155.77	986.52	149.49	1136.01
Wheat Shorts	717.00	11.15	165.07	893.22	227.26	1120.48
Wheat Bran	471.89	13.41	103.04	588.34	177.20	765.54
Alf. Meal (17%)	139.24		26.13	165.37	205.70	371.07
Soybean Meal (44%)	457.97		19.25	477.22	670.10	1147.32
Fish Meal (60%)	16.19		238.08	254.27	837.63	1091.90
Fish Meal (64%)	37.80		151.96	189.76	939.43	1129.19
Meat and Bone Scrap (50%)	16.77		398.97	415.74	567.73	983.47
Brewers Yeast	470.35		75.98	546.33	628.20	1174.53
Buttermilk	462.56		200.51	663.07	410.98	1074.05
Soybean Oil			3595.7	3595.68		

The following Caloric values were used to evaluate each nutrient

Disaccharides contain	4.1 C/gm.[a]
Monosaccharides contain	3.8 C/gm.[b]
Fat from sources excluding oil bearing seed contains	9.3 C/gm.[a]
Protein all sources	4.1 C/gm.[a]
Fat from oil bearing seed	8.8 C/gm.[b]

[a]Paul Sturkie, Avian Physiology (Comstock Publishing Assn., 1954), p. 138.
[b]W. Ray Ewing, Poultry Nutrition (South Pasadena, California, 1951), p. 53.

Table 4.--Available amino acid values as a percent of ingredient

Ingredients	Crude Prot.[a]	Dig. Coef.	Dig. Prot.	Crude[b] Lys.	Crude[b] Meth.	Crude[b] Cyst.	Available Lys.	Available Meth.	Available Cyst.
	%	%	%	%	%	%	%	%	%
Dehyd. Alf. Meal	22.75	56.0	12.74	1.07	0.34	0.36	0.60	0.19	0.20
Corn (Yellow)	8.56	86.0	7.36	0.21	0.20	0.11	0.18	0.17	0.09
Oats (Heavy)	12.90	56.0	7.22	0.43	0.28	0.21	0.25	0.15	0.12
Wheat Grey Shorts	16.30	68.0	11.08	0.44	0.27	0.18	0.30	0.18	0.12
Wheat Bran	14.70	59.0	8.67	0.50	0.27	0.21	0.29	0.16	0.13
Dried Buttermilk	32.00	69.0	22.10	2.20	0.66	0.30	1.52	0.45	0.21
Dried Brewers Yeast	44.50	69.0	30.70	3.30	0.86	0.45	2.28	0.59	0.31
Meat and Bone Scraps (50%)	51.60	61.0	31.47	2.78	0.72	0.62	1.70	0.44	0.25
Fish Meal (60%)	64.00	90.0	57.60	5.80	1.96	1.08	5.22	1.76	0.97
Soybean Meal (Solvent 44%)	48.70	75.0	36.52	3.02	0.67	0.71	2.27	0.50	0.53

[a]Determined by chemical analysis.

[b]The crude amino acid values were taken from charts compiled by Titus[1], Almquist[2] and Sievert and Fairbanks.[3]

[1]Harry W. Titus, The Scientific Feeding of Chickens (Danville, Ill., 1949), p. 236.

[2]H. J. Almquist, Protein and Amino Acids in Animal Nutrition (New York, 1953), p. 14.

[3]The Feed Bag Red Book (Milwaukee, Wis.), 1955, p. 174.

given the available Calories of energy supplied by the protein, fat and carbohydrate in one pound of each of the feed ingredients which were used.

The approximate availability of lysine, methionine and cystine were calculated for each of the feed ingredients. The available amino acid content for each feed ingredient was calculated by multiplying the amount of the amino acid in the feed ingredient by the digestion coefficient for the protein in the feed ingredient. In Table 4 are given the approximate available amino acid values for lysine, methionine and cystine.

Varieties of Turkey Poults Used -- Turkey poults hatched from eggs produced by the Oklahoma Agricultural and Mechanical College Strains of Broad Breasted Bronze and White Holland Turkeys were used in Trials I and II. The number of poults from each variety placed within a pen were the same for all pens. White Holland turkey poults, from the Oklahoma Agricultural and Mechanical College Strain, were the only poults used in Trials III, IV, V and VI.

Location and Equipment Used -- All feeding trials with the exception of Trial II, were conducted in the battery room located on the Oklahoma Agricultural and Mechanical College Poultry Farm. Trial II was conducted in a room adjoining the poultry nutrition laboratory. The temperature and ventilation in each room was manually controlled. Within each room the humidity varied directly with the atmospheric humidity. The all-metal batteries used in the feeding trials were electrically heated and had thermostatic controls. Day and night lights were used throughout each trial.

Plan of Randomization -- A complete randomized experimental design was used for each feeding trial. Each pen was assigned a number at the beginning of the series of feeding trials. The pen numbers remained the same during each of the six trials. Using a set of random numbers, each replication of the experimental rations was given a battery pen number. Poults were taken from the hatcher, selected for health and vigor, and randomized into boxes, each representing a battery pen. Poults were randomized into the boxes by placing one poult into each box during a continuous cycle. The cycle process was repeated until the desired number of poults were distributed into the respective groups.

After the randomization procedure was completed the poults were wing banded. Initial weight of each poult or mass weight of each pen was recorded. Each group of poults was then put into a battery pen which had a number that corresponded to that of the box.

Statistical Methods Used -- An analysis of covariance as outlined by Snedecor (1946) was applied to the data from Trials I, II, III, IV and VI. The data from each Trial was analyzed seperately. Trial V was set up to obtain data to justify the use of this method. The data and reason for conducting this trial will be discussed in the purpose and results of Trial V. An analysis of variance as outlined by Snedecor (1946), was applied to the data of Trial V. The reason for using this method is discussed under the Trial procedure.

CHAPTER IV

FEEDING TRIALS

Trial I

Purpose of Trial -- The purpose of this feeding trial was twofold: (1) To determine the effect of low and high productive energy levels upon the utilization of four levels of protein; and (2) to ascertain whether supplementary l-lysine and dl-methionine would give an increased growth response when added to a practical ration containing a high quality protein.

Procedure -- The feeding trial consisted of 16 experimental rations, each run in duplicate. Each of the 32 pens contained five Broad Breasted Bronze and six White Holland turkey poults. The trial was started on January 28, 1954 and continued for 28 days. Individual poult weights were recorded at the beginning and end of the feeding trial. Feed consumption weights were taken by pens at the close of the feeding trial.

Basal rations used numbered 1 through 8 are given in Table 5. Four basic protein levels of 22, 24, 26 and 28 percent were used. A high and a low energy basal containing approximately 880 and 720 Calories of productive energy per pound of basal, respectively were formulated at each protein level. The amounts of available lysine, methionine and cystine within each basal were calculated from available amino acid values given in Table 4. The levels of lysine, methionine and cystine were first calculated for each of the four protein levels containing 880 Calories of productive energy per pound of ration and were used at the standard to which the amino acid in the low energy rations were standardized. Consequently, the low energy rations contained approximately one percent more crude protein than did the high energy rations.

Table 5.--Composition of basal rations used in trials I and II

Ration	1	2	3	4	5	6	7	8
Ingredients	%	%	%	%	%	%	%	%
Ground Yellow Corn	19.5	51.5	19.5	50.0	20.5	46.5	17.75	45.5
Ground Oats	10.0	5.0	8.0	3.0	8.0	6.0	10.00	3.0
Wheat Shorts	24.0	3.0	20.0	2.0	10.0		10.00	
Wheat Bran	10.0		10.0		15.0		12.00	
Dehyd. Alf. Leaf Meal	5.0	5.0	5.0	5.0	5.0	4.0	5.00	4.0
Soybean Meal (45%)	18.0	20.0	23.5	24.5	25.0	24.0	26.50	26.0
Fish Meal (65%)	5.0	4.0	5.5	5.0	7.0	7.5	10.00	10.0
Meat and Bone Scraps (50%)		3.0		2.5	2.0	5.0	1.50	5.0
Dried Buttermilk	2.0	2.0	2.0	2.0	2.0	2.0	2.00	2.0
Dried Brewers' Yeast	2.0	2.0	2.0	2.0	2.0	2.0	2.00	2.0
Calcium Carbonate	3.0	2.0	3.0	2.0	2.5	1.5	2.25	1.5
Di-calcium Phosphate	1.0	2.0	1.0	1.5	0.5	1.0	0.50	0.5
Salt (NaCl)	0.5	0.5	0.5	0.5	0.5	0.5	0.50	0.5
Calculated Crude Protein	22	22	24	24	26	26	28	28
Calculated Productive Energy (Cal.Per Lb.)	718	880	722	875	727	880	723	876

The growth responses of poults to amino acid levels S_0 and S_1 were compared in Trial I. The amino acid level S_0 represented the amounts of lysine and sulfur amino acids which were contained in the natural feed ingredients. The S_1 amino acid level represented the calculated requirement levels of lysine and sulfur amino acids for the turkey poult. Under level S_1 Table 7, are shown the amounts of available l-lysine monohydrochloride and dl-methionine additions which were necessary to raise level S_0 to the estimated requirement level of available lysine and sulfur amino acids for turkey poult starter rations. Table 8 gives the same type of data, but is presented as crude instead of available amounts. The

Table 6.--Vitamin additions per pound of basal ration in trial I and II

Vitamins	Natural Vitamin Level Per Pound of Basal Range	Vitamin Addition Per Pound of Basal
	Rations 2, 4, 6 and 8	
Vitamin A	4844-5446	3500 I.U.
Vitamin D_3	-- --	600 I.U.
Riboflavin	1.84-1.93	2.2 mg.
Niacin	16.00-17.22	16 mg.
Calcium Pantothenate	4.26-4.57	5.5 mg.
Vitamin B_{12}	?-?	3 mg.
Choline	482-560	*
	Rations 1, 3, 5 and 7	
Vitamin A	4575-4643	3500 I.U.
Vitamin D_3	-- --	600 I.U.
Riboflavin	1.98-2.15	2 mg.
Niacin	35.14-39.54	None
Calcium Pantothenate	5.86-6.12	4 mg.
Vitamin B_{12}	?-?	3 mg.
Choline	544-620	*

*Choline Chloride (25% mix) was added in quantities to meet the N.R.C. requirement of 900 mg. per pound of basal.

estimated lysine and sulfur amino acids requirements at the various protein levels as given in Table 9, were calculated by extrapolating and interpolating to the different protein levels taken from the poult

Table 7.--Available methionine and lysine levels in the rations fed in trial I

Productive Energy Level of Basal (Cal. Per Lb.)	Protein Level of Basal %	Level S_0[a] %	Supplement[b] %	Level S_1[c] %
		Sulfur-Containing Amino Acids		
880	22	0.544	0.075	0.619
	24	0.599	0.064	0.663
	26	0.667	0.063	0.730
	28	0.745	0.050	0.795
720	22	0.542	0.071	0.613
	24	0.603	0.064	0.667
	26	0.663	0.067	0.730
	28	0.744	0.049	0.793
		Lysine		
880	22	0.933	0.180	1.111
	24	1.064	0.163	1.227
	26	1.213	0.147	1.360
	28	1.379	0.116	1.495
720	22	0.931	0.185	1.116
	24	1.067	0.163	1.230
	26	1.199	0.147	1.346
	28	1.373	0.123	1.496

[a]Levels of available l-lysine and sulfur containing amino acids in natural feed ingredients.

[b]Amounts of available supplementary l-lysine monohydrochloride and dl methionine added to raise l-lysine and sulfur containing amino acids to levels shown in S_1.

[c]S_1 represents the approximate poult requirement level for available l-lysine and sulfur containing amino acids at graded protein levels.

Table 8.--Total crude methionine and lysine levels in the rations fed in trial I

Productive Energy Level of Basal (Cal. Per Lb.)	Protein Level of Basal %	Level S_0[a] %	Supplement[b] %	Level S_1[c] %
		Sulfur-Containing Amino Acids		
880	22	0.717	0.077	0.794
	24	0.782	0.065	0.847
	26	0.866	0.064	0.930
	28	0.959	0.051	1.010
720	22	0.745	0.072	0.817
	24	0.797	0.065	0.862
	26	0.872	0.068	0.940
	28	0.981	0.050	1.031
		Lysine		
880	22	1.224	0.237	1.461
	24	1.390	0.215	1.605
	26	1.559	0.194	1.753
	28	1.765	0.153	1.918
720	22	1.233	0.237	1.470
	24	1.403	0.215	1.618
	26	1.574	0.194	1.768
	28	1.765	0.162	1.927

[a]Levels of crude lysine and sulfur containing amino acids in natural feed ingredients.

[b]Amounts of crude supplementary l-lysine monohydrochloride and dl methionine added to raise l-lysine and sulfur containing amino acids to levels shown in S_1.

[c]S_1 represents the approximate poult requirement level for crude l-lysine and sulfur containing amino acids at graded protein levels.

Table 9.--The estimated poult requirement levels for lysine and sulfur amino acids at various protein levels

Basal Protein Levels	Lysine		Sulfur Amino Acids	
	Available	Crude	Available	Crude
%	%	%	%	%
22	1.05	1.21	0.632	0.69
24	1.144	1.32	0.686	0.75
26	1.239	1.43	0.741	0.81
28	1.334	1.54	0.779	0.87

requirement data given by the various works cited in the literature review. The amino acid differential between protein levels differing by 2 percent is of the same proportion regardless of protein level. Although Grau (1948), Grau and Kamei (1950) and Almquist (1952) disclosed that lysine and sulfur amino acids expressed as percent of the protein decreases as the protein level in chick diets increase, the writer believed the estimated requirements to be adequate for preliminary studies. It should be pointed out that the available lysine and sulfur amino acid levels given in Table 9 and the S_1 amino acid levels Table 7 do not exactly coincide. This discrepancy is due to the changing of the original lysine and methionine values for soybean meal to those given by Almquist (1953).

Results -- Figure 1 shows the relationship of the productive energy level of a ration to the efficiency with which protein is utilized. The adjusted means at each protein level indicate that 880 Calories of productive energy per pound of ration was adequate to support efficient protein utilization at all protein levels. Seven-hundred and twenty

Figure 1.--Effect of productive energy at different protein levels upon body weight gain in trial I

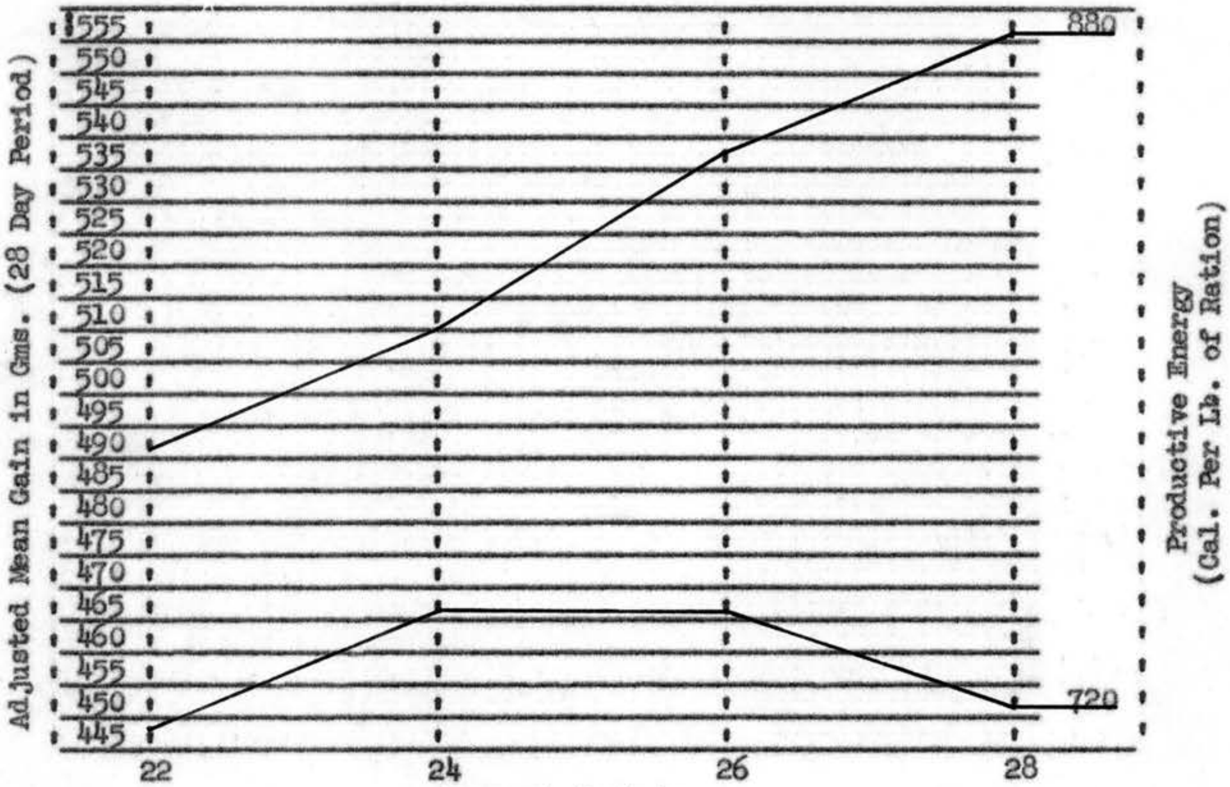
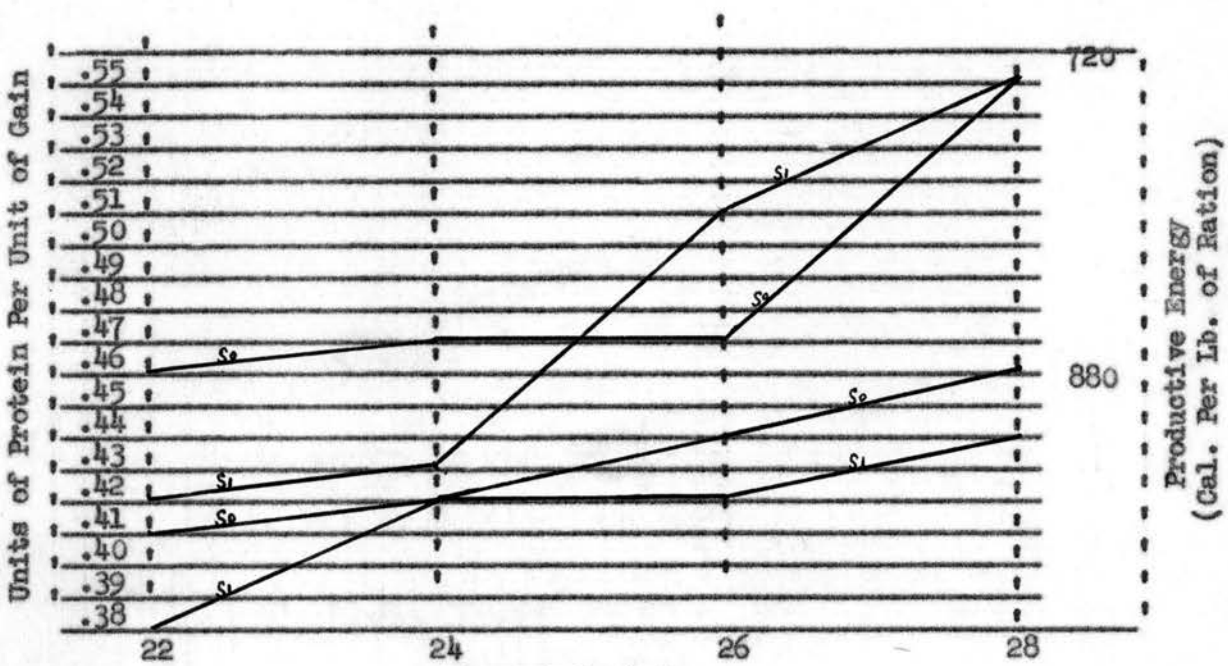


Figure 2.--Units of protein per unit of gain in trial I



Calories of productive energy was adequate to support efficient protein utilization at the 22 and 24 percent protein levels. The growth response curve breaks sharply at the 26 percent protein level and more so at the 28 percent protein level. Analysis of adjusted gains, Table 11, indicates that there was an interaction between protein and energy to a 0.96 probability level and between energy and amino acids to a 0.86 probability level.

Figure 2 shows the effect of productive energy and the addition of methionine and lysine, level S_1, upon the units of protein required per unit of gain. The high energy diets as compared to low energy diets are characterized by bringing about more efficient protein utilization at all protein levels. The addition of lysine and methionine, level S_1, to the high energy diets was responsible for an increase in the efficiency of protein utilization. The addition of lysine and methionine, level S_1, to the low-energy diets gave inconsistent effect. A comparison between the S_0 and S_1 amino acid level response curves shows S_1 to have had a better amino acid balance at the 22 and 24 percent protein levels than did the S_0 level. For some unknown reason the superiority of level S_1 does not hold at the 26 and 28 percent protein levels. At the 28 percent protein level there appears to be no difference in the effect of S_0 and S_1. At the 26 percent protein level S_0 appears to be much better than S_1. The changes in the original trend of S_0 and S_1, at the protein levels indicated above, are apparently responsible for causing the energy and amino acids interaction to approach significance to the 0.86 percent level.

The only hypothesis offered for the energy-amino acid interaction is a possible amino acid toxicity caused by the high levels of amino acids in level S_1. The crude levels of both methionine and lysine were well above the requirement levels given by the National Research Council (1954). With an apparent limited energy supply at the 26 and 28 percent protein levels a considerable amount of protein was used as a source of energy as was indicated by the sharp increase in the units of protein used per unit of gain. Considering methionine and lysine as being in excess of the required amounts, the increase in protein metabolism for energy further decreased the amount of protein available to be utilized in protein tissue synthesis. The protein synthesis may have been reduced to a point at which there existed an imbalance between protein synthesis and either or both absorbed lysine and methionine. If an imbalance did occur, it would appear that an increased amount of the feed eaten was wasted or used in eliminating the excessive amounts of one or both amino acids.

In Figure 3 is shown the effect of S_o and S_1 amino acid levels upon poult growth with rations containing 880 Calories of productive energy. The response curves, which in a general way run parallel to one another, indicate that level S_1 has an amino acid balance superior to level S_o. The data indicate that the poults receiving the S_1 amino acid level held an average weight advantage of 20 grams over the poults receiving level S_o. According to the slight break in the growth response curves between the 26 and 28 percent protein levels, it appears that 880 Calories of productive energy per pound of ration may have become a limiting factor at this point. The average final body weight, weight gain, adjusted weight gain, feed consumption and efficiency of gain observed in Trial I are given in table 10.

Figure 3.--Body weight gain at different protein levels as effected by methionine and lysine additions in trial I

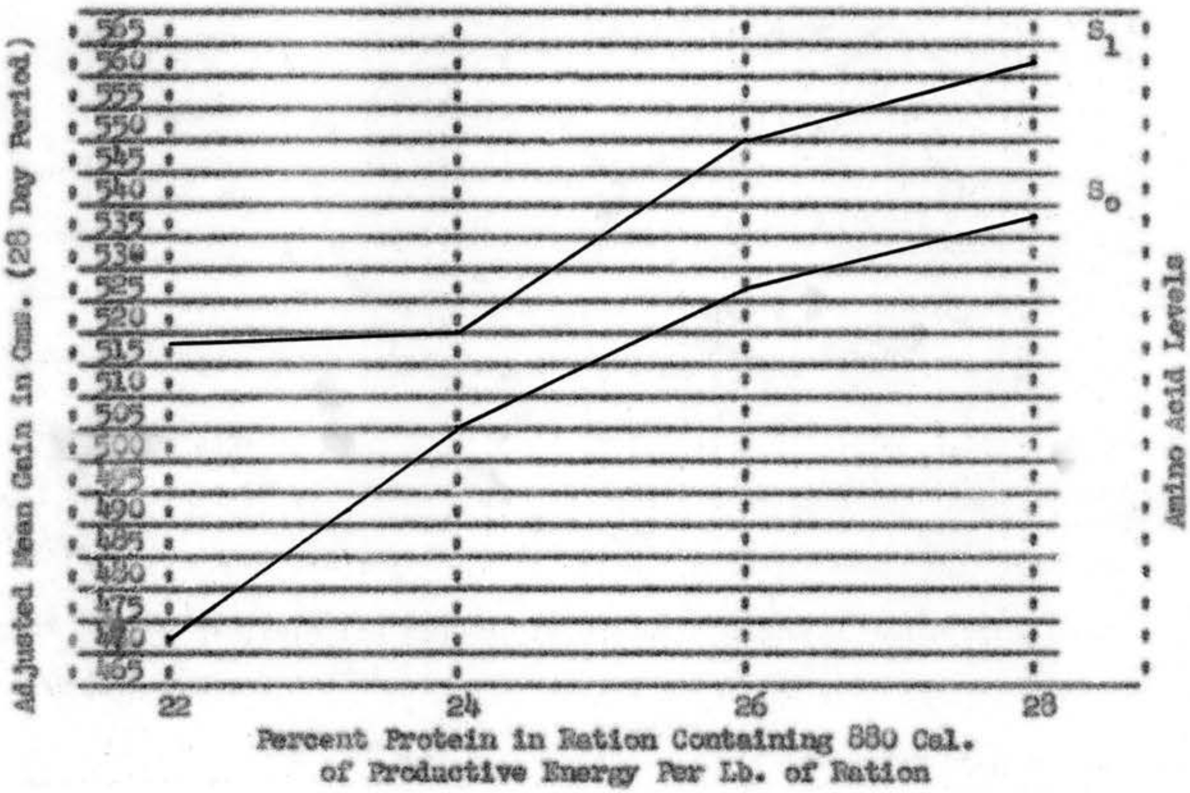


Table 11 gives the results of the statistical analysis on Trial I. The adjusted means, standard error of treatment mean differences and F test values are given.

feed consumption and efficiency of gain in trial I

Ration	1		2		3		4		5		6		7		8	
Percent Protein	22		22		24		24		26		26		28		28	
Available Energy from CHO and Fat (Cal. Per Lb.)	770		940		740		910		710		880		690		850	
Productive Energy (Cal. Per Lb.)	720		880		720		880		720		880		720		880	
Amino Acid Level	S_o[a]	S_1[b]	S_o	S_1	S_o	S_1	S_o	S_1	S_o	S_1	S_o	S_1	S_o	S_1	S_o	S_1
Average Body Weight at 28 Days (gms.)	472.0	523.0	496.0	560.0	514.0	544.0	533.0	547.0	538.0	539.0	568.0	614.0	556.0	531.0	604.0	610.0
Average Weight Gain in 28 Days (gms.)	416.0	467.0	439.0	504.0	459.0	488.0	477.0	492.0	485.0	484.0	512.0	556.0	499.0	475.0	548.0	556.0
Average Adjusted Weight Gain in 28 Days (gms.)	436.0	463.0	472.0	513.0	457.0	474.0	505.0	515.0	483.0	448.0	527.0	550.0	455.0	445.0	538.0	563.0
Average Total Feed Consumption Per Poult (lb.)	1.88	1.97	1.83	1.92	1.96	2.01	1.84	1.86	1.96	2.10	1.90	1.98	2.13	2.08	1.99	1.93
Pounds of Feed Per Pound of Gain	2.09	1.92	1.87	1.73	1.95	1.78	1.75	1.75	1.83	1.97	1.68	1.62	1.95	1.97	1.65	1.57
Units of Protein Per Unit of Gain	0.46	0.42	0.41	0.38	0.47	0.43	0.42	0.42	0.47	0.51	0.44	0.42	0.55	0.55	0.46	0.44

[a] S_o represents rations containing only lysine and sulfur containing amino acids from natural feed ingredients.

[b] S_1 represents rations containing the approximate poult requirement level for l-lysine and sulfur containing amino acids at graded protein levels.

Table 11.-- Analysis of adjusted gains in trial I

		Percent Protein				
		22	24	26	28	$\bar{X}$
Ration Productive Energy Level (Cal. Per Lb.)	880	472	505	527	538	523
		513	515	550	563	
	Mean	492	510	538	550	
	720	436	457	483	455	458
		463	474	448	445	
	Mean	450	465	465	450	
Amino Acid Levels	a_0	472	505	527	538	484
		436	457	483	455	
	Mean	454	481	505	496	
	a_1	513	515	550	563	517
		463	474	448	445	
	Mean	488	494	499	504	
	$\bar{X}$	471	487	502	500	

Std. Error of Mean Difference

Protein	9.27
Energy	7.85
Amino Acids	6.29

Confidence Limits

s_D X t

s_D = Std. Error of Mean Diff.

t = Value for t given in t table

F Test

Source	Degrees of Freedom	F Value	% Probability Level
Protein	3	4.70	97.5
Linear	1	8.42	97.5
Energy	1	72.12	99.95
Amino Acids	1	2.05	92.75
Protein X Energy	3	3.55	96.0
Protein X Amino Acids	3	1.32	70.0
Energy X Amino Acids	1	2.67	86.0
Error	15		

Trial II

Purpose of Trial -- The addition of supplementary lysine and methionine to high-energy turkey poult starter rations increased feed efficiency and growth response at all protein levels in Trial I. It was then considered desirable to determine if further additions of methionine and lysine to high-energy poult starter rations would give greater increases in growth and efficiency of feed utilization. Increased amounts of supplementary dl-methionine and l-lysine were added to rations containing 22,24, 26 and 28 percent protein.

Procedure -- Feeding Trial II consisted of 16 experimental rations, each fed in duplicate. Each of 32 pens contained four Broad Breasted Bronze and five White Holland turkey poults. The trial was started on February 16, 1954 and continued for 28 days. Individual poult weights were recorded at the beginning and end of the feeding trial. Feed consumption weights were taken by pens at the close of the feeding trial.

The basal rations used in Trial II were numbers 2, 4, 6 and 8 given in Table 5. The basis for calculating each ration was the same as described in the procedure in Trial I. The amino acid additions made above the estimated available requirement level S_1 are given in Table 13 under the headings level S_2 and S_3. Level S_2 represents the levels of lysine and sulfur amino acids which would be present at a protein level 1 percent higher than the basal protein level, and S_3 represents the lysine and sulfur amino acid levels at a protein level 2 percent higher than that of the basal. In this Trial the basal rations contain the amino acid levels given under level S_1. Synthetic dl-methionine and l-lysine monohydrochloride were added to the basal rations in amounts that would raise the lysine and sulfur amino acids levels to that given under

Table 12.--Total crude methionine and lysine levels in the rations fed in trial II

Protein Level of Basal	Level S_o[a]	Supplement[b]	Level S_1[c]	Supplement[b]	Level S_2[d]	Supplement[b]	Level S_3[e]
%	%	%	%	%	%	%	%
	Sulfur Containing Amino Acids						
22	0.717	0.077	0.794	0.10	0.817	0.129	0.846
24	0.782	0.065	0.847	0.092	0.874	0.119	0.901
26	0.866	0.064	0.930	0.093	0.954	0.121	0.987
28	0.959	0.051	1.010	0.079	1.038	0.107	1.066
	Lysine						
22	1.224	0.237	1.461	0.276	1.500	0.320	1.544
24	1.390	0.215	1.605	0.251	1.641	0.300	1.693
26	1.559	0.194	1.753	0.233	1.792	0.280	1.839
28	1.765	0.153	1.918	0.193	1.958	0.241	1.986

[a]The amounts of crude amino acids in the natural feed ingredients in the basals.

[b]Percent crude supplementary l-lysine and dl methionine additions to attain certain amino acid levels.

[c]S_1 represents the calculated poult requirement for crude l-lysine and sulfur containing amino acids at graded protein levels.

[d-e]S_2 and S_3 represent the levels of crude lysine and sulfur amino acids which would be present at protein levels 1 percent and 2 percent higher than the protein in S_1 basal.

Table 13.--Available methionine and lysine levels in the rations fed in trial II

Protein Level of Basal	Level S_0[a]	Supplement[b]	Level S_1[c]	Supplement[b]	Level S_2[d]	Supplement[b]	Level S_3[e]
%	%	%	%	%	%	%	%
			Sulfur Containing Amino Acids				
22	0.544	0.075	0.619	0.098	0.642	0.126	0.670
24	0.599	0.064	0.663	0.090	0.689	0.116	0.715
26	0.667	0.063	0.730	0.091	0.758	0.118	0.785
28	0.745	0.050	0.795	0.077	0.822	0.104	0.849
			Lysine				
22	0.933	0.180	1.113	0.210	1.143	0.243	1.176
24	1.064	0.163	1.227	0.191	1.291	0.228	1.292
26	1.213	0.147	1.360	0.177	1.390	0.213	1.426
28	1.379	0.116	1.495	0.146	1.525	0.183	1.562

[a]The amounts of available amino acids in the natural feed ingredients in the basals.

[b]Percent available supplementary l-lysine and dl methionine additions to attain certain amino acid levels.

[c]S_1 represents the calculated poult requirement for available l-lysine and sulfur containing amino acids at graded protein levels.

[d-e]S_2 and S_3 represent the levels of available lysine and sulfur amino acids which would be present at protein levels 1 percent and 2 percent higher than the protein in S_1 basal.

Figure 4.--Effect of productive energy at different protein levels upon body weight gain in trial II

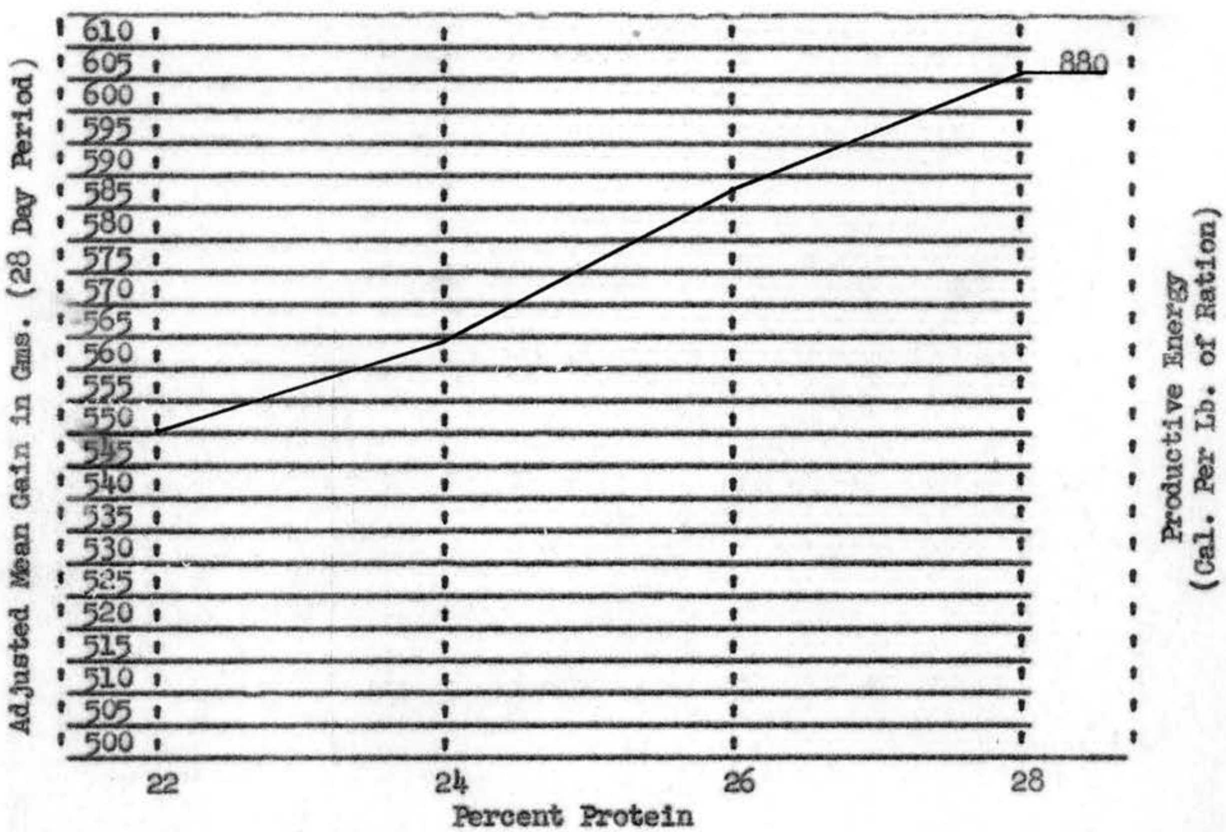
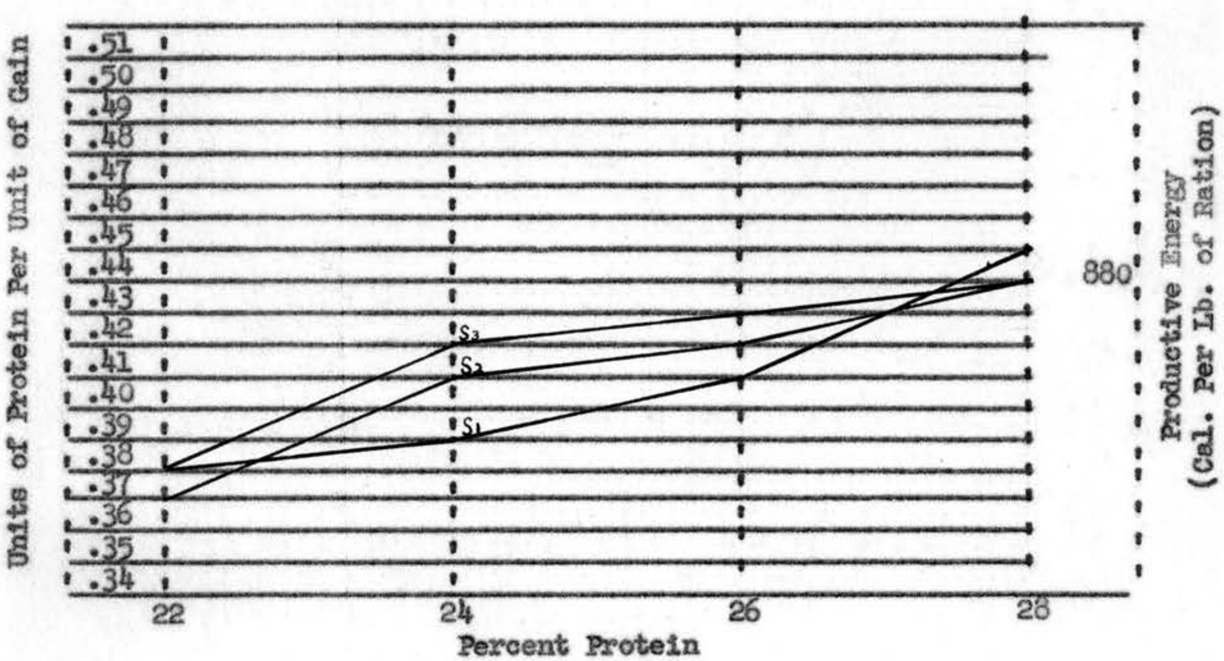


Figure 5.--Units of protein per unit of gain in trial II



S_2 and S_3. The crude and available levels for S_2 and S_3 are given in Tables 12 and 13 respectively.

<u>Results</u> -- Figure 4 gives a growth response curve which indicates that 890 Calories of productive energy per pound of diet was adequate to support efficient protein utilization at protein levels ranging from 22 to 28 percent. However, it appears from Figures 4 and 5 that 890 Calories of productive energy was slightly limited for supporting the most efficient protein utilization at the 28 percent protein level. The effect of protein level upon efficiency of ration utilization is indicated by a general increase in the efficiency of ration utilization at protein levels of 22 through 28 percent. Table 15 and Figure 5 show that the average efficiency of protein utilization decreased as the protein level increased.

Figure 6 shows the plotted adjusted mean gain for each treatment. The growth response curves indicate, in a general way, that the amino acid balance of level S_1 was superior to levels S_2 and S_3, and level S_2 was superior to level S_3. The differences between the effect of the amino acid levels were significant to a 0.95 probability level. This indicates, that for some unknown reason, the addition of lysine and methionine to the basal in amounts specified under levels S_2 and S_3, Table 13, had a depressing effect upon growth. Comparisons between the adjusted mean gains and the unadjusted mean gains of levels S_1, S_2 and S_3 given in Table 14 indicate that something other than quantity of feed consumed was responsible for the lack of growth. Although the adjusted means were slightly different from the unadjusted means, the same general picture existed regardless of which were considered. Table 14, also, shows that the efficiency with which feed was utilized decreased as the methionine and lysine levels increased. The differences in the efficiency with which the

Figure 6.--Body weight gain at different protein levels as effected by methionine and lysine additions in trial II

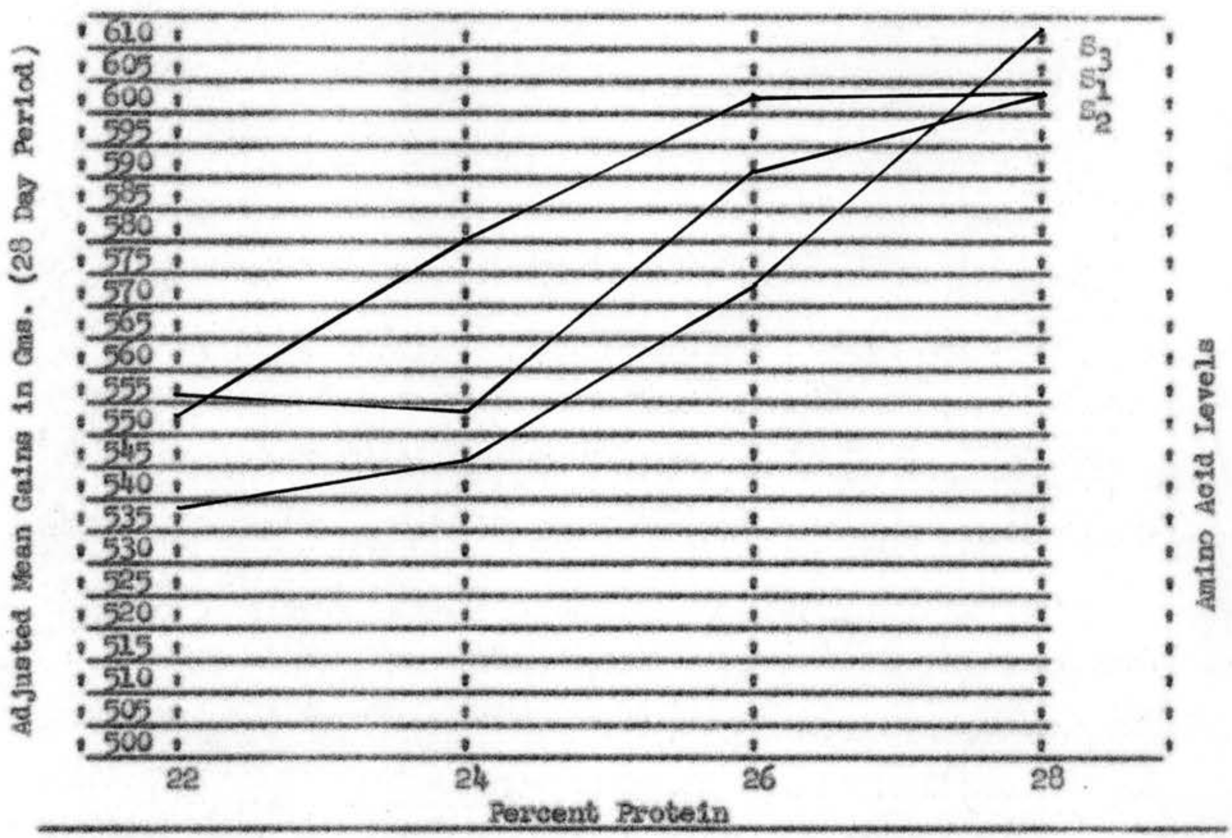


Table 14.--Feed efficiency and body weight gain at various amino acid levels in trial II

Amino Acids Levels	S_1	S_2	S_3
Unadjusted Means (gms.)	588	578	564
Adjusted Means (gms.)	585	576	568
Feed Efficiency	1.63	1.65	1.69

different rations were utilized were not great. It does not appear that the differences in the feed conversion of rations containing level S_1, S_2 or S_3 were of such magnitude that the adjusted mean gains would be significantly different. The adjusted mean gain differences are, however, significant to the 0.95 probability level.

A further study was made applying the regression of the X values (feed intake) on the Y values (body weight gains). The regression of the Y values on the X values in the original analysis adjusted the body weight gains to a constant feed intake basis. The only thing which would then seem to account for the differences between the adjusted mean gains was the difference in the efficiency with which the feed was utilized at amino acid levels S_1, S_2 and S_3. It does not appear, however, that there was enough difference between the feed efficiency as affected by levels S_1, S_2 and S_3 to be responsible for the differences in the adjusted mean gains. It was then reasoned that should the differences with which the feed was utilized at these levels be responsible for the differences between the adjusted mean gains, an application of the analysis of covariance, X being a function of Y, should indicate that the differences between the efficiency with which feed was utilized at levels S_1, S_2 and S_3 would approach significance to the 0.95 probability level. The analysis of the X values as a function of Y did approach significance to the 0.92 probability level. This statistical analysis tends to lend increasing evidence to the contention that the efficiency with which the feed was utilized was responsible for the differences between the adjusted mean gains.

High levels of methionine and lysine in each experimental ration under level S_2 and S_3 could be responsible for the decrease in feed efficiency.

Table 15.--Average final body weight, weightgain, adjusted weight gain, feed consumption and efficiency of gain in trial II

Basal Ration Number	2			4			6			8		
Percent Protein	22			24			26			28		
Available Energy from CHO and Fat Cal. Per Pound	940			910			880			850		
Productive Energy Cal. Per Pound	880			880			880			880		
Amino Acid Level	S_1[a]	S_2[b]	S_3[c]	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Average Body Weight at 28 Days (gms.)	613.0	607.0	568.0	619.0	625.0	603.0	673.0	645.0	626.0	678.0	668.0	687.0
Average Weight Gain to 28 Days (gms.)	556.0	549.0	506.0	562.0	567.0	551.0	616.0	587.0	570.0	620.0	611.0	636.0
Average Adjusted Weight Gain to 28 Days (gms.)	552.0	559.0	538.0	590.0	554.0	546.0	603.0	592.0	574.0	603.0	603.0	614.0
Average Total Feed Consumption Per Poult (lbs.)	2.12	2.04	1.93	2.01	2.17	2.12	2.16	2.07	2.08	2.19	2.13	2.20
Pounds of Feed Per Pound of Gain	1.73	1.69	1.73	1.62	1.73	1.75	1.59	1.60	1.66	1.60	1.58	1.50
Pounds of Protein Per Pound of Gain	0.38	0.37	0.39	0.39	0.41	0.42	0.41	0.42	0.43	0.45	0.44	0.40

[a]S_1 represents rations containing the approximate poult requirement level for l-lysine and sulfur containing amino acids at graded protein levels.

[b-c]S_2 and S_3 represent the levels of lysine and sulfur containing amino acids which would be present at protein levels 1 and 2 percent higher than the protein in S_1 basal.

Table 16.--Analysis of adjusted gains in trial II

Amino Acid Levels	Percent Protein 22	24	26	28	$\bar{X}$
S_1	553	580	603	603	585
S_2	557	554	592	603	576
S_3	536	546	574	616	568
$\bar{X}$	549	560	590	607	

Std. Error of Mean Difference

Protein 12.34
Amino Acids 9.60

F Test

Source	Degrees of Freedom	F Value	% Probability Level
Protein	3	9.10	99.5
Linear	1	24.96	99.95
Residual	2	2.06	79.0
Amino Acids	2	4.08	95.0
Linear	1	8.65	98.0
Quadratic	1	1.39	72.0
Protein X Amino Acids	6	1.07	55.0
Error	11		

An average difference of 0.03 pounds in the efficiency of feed utilization between levels S_1 and S_2, and S_2 and S_3, at all protein levels, appears to account for the depressed growth rather than a lowered diet palatability or a high level amino acid toxicity. Table 12 shows the crude lysine and sulfur amino acids in each treatment ration. These amounts are considerably above those reccomended by the National Research Council (1954). A low level amino acid toxicity may have caused the decrease in efficiency of feed utilization. This condition could have been effected by high levels of either or both amino acids. The average final body weight, weight gain, adjusted weight gain, feed consumption and efficiency of gain observed in Trial II are given in Table 15.

Statistical analysis data given in Table 16 include adjusted body gain means, standard error of difference between treatment means and F test values.

Trial III

Purpose of Trial -- The primary purpose of this feeding trial was to develop a semi-purified ration to be used in further trials. A secondary purpose was that of determining the amounts of available energy that should be supplied by carbohydrate and fat to support the most efficient utilization of the protein within a ration.

Procedure -- Trial III contained 15 experimental rations, each fed in duplicate. Each of the 30 experimental pens contained five male and five female White Holland turkey poults. The feeding trial was started on May 27, 1954 and continued for 26 days. Each turkey poult was weighed individually at one day of age, at the end of each seven day period and at the close of the trial. Feed consumption was taken by pens at the close of the feeding trial.

The two protein materials, soybean and fish meal, used in the formulation of all rations were biologically assayed for their lysine and methionine content. A protein mix composed of 94 percent soybean meal and 6 percent fish meal was used in the mixing of all rations. Cerelose was used as the source of carbohydrate energy. Two percent soybean oil was put in each ration to control the dust, but also contributed to the energy fraction of the rations. Ground oat hulls were included in each

Table 17.--Vitamin and trace mineral additions per pound of basal ration in trial III and IV

Vitamin Additions Per Pound of Basal			
Vitamin A	10,000 I.U.	Biotin	70 mcg.
Vitamin D_3	750 I.U.	Thiamine	1 mg.
Riboflavin	3.32 mg.	Pyridoxine	2 mg.
Calcium Pantothenate	7.08 mg.	Choline Chloride	
Niacin	20.00 mg.	22% Protein Basal	300 mg.
Vitamin B_{12}	3.00 mcg.	24% Protein Basal	250 mg.
Vitamin K	2.00 mg.	26% Protein Basal	200 mg.
Vitamin E	9.00 mg.	28% Protein Basal	155 mg.
Folic Acid	1.30 mg.	30% Protein Basal	111 mg.
P. A. B. A.	50.00 mg.	Inositol	10 mg.
Trace Mineral Additions Per Pound of Basal			
Manganese Sulphate	108.00 ppm	Iron	20.00 ppm
Iodine	0.96 ppm	Copper	1.80 ppm
Cobalt	0.64 ppm	Zinc	1.65 ppm

ration to regulate the ration energy level. The vitamin additions made per pound of basal ration are given in Table 17.

The experimental rations used in this study are numbers 1 through 15 as given in Table 19. Three levels of available energy from carbohydrate and fat were calculated using the caloric values given in Table 3. Available energy values of 700, 780, and 860 calories per pound of ration were studied at crude protein levels of 22, 24, 26, 28 and 30 percent.

Biological assay values for methionine and lysine were used in

Table 19.-- Composition of basal rations used in trials III, IV and VI

Rations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Protein Mix *	46.8	46.8	46.8	51.0	51.0	51.0	55.3	55.3	55.3	59.5	59.5	59.5	63.8	63.8	63.8
Soybean Oil	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin Mix	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Cerelose or Starch	25.5	30.0	33.7	24.7	29.2	33.5	23.1	27.5	32.0	21.5	26.0	29.9	19.8	24.3	27.0
Oat Hulls	18.6	14.1	10.4	15.3	10.8	6.5	12.6	8.2	3.7	10.7	5.6	2.4	7.7	3.2	0.5
Calcium Carbonate	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Di-calcium Phosphate	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.2	3.2	3.2
Salt (NaCl)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Protein Calculated	22.0	22.0	22.0	24.0	24.0	24.0	26.0	26.0	26.0	28.0	28.0	28.0	30.0	30.0	30.0
Calcium Calculated	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Phosphorus Calculated	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

*The protein mix consists of 94 percent soybean meal and 6 percent fish meal.

Table 18.--Amounts of lysine, methionine and cystine at basal protein levels

Percent Protein		22	24	26	28	30
Percent of Available Amino Acids	Lysine	1.08	1.18	1.28	1.38	1.48
	Methionine	0.23	0.25	0.27	0.29	0.31
	Cystine	0.26	0.28	0.31	0.33	0.35
Percent of Crude Amino Acids	Lysine[1]	1.41	1.54	1.67	1.80	1.93
	Methionine[1]	0.29	0.32	0.35	0.38	0.41
	Cystine[2]	0.34	0.37	0.40	0.43	0.46

[1]Calculated from microbiological assay data. Determinations were run on all protein ingredients used in the formulation of the rations.

[2]Calculated from data presented by Sievert and Fairbanks, The Feed Bag Red Book (Milwaukee, Wis.), 1955.

calculating the levels of these amino acids at all protein levels. Heretofore, average amino acid values given by Almquist (1953) were used to calculate the crude and available amounts of these amino acids. The crude and available levels of lysine, methionine and cystine for each basal protein level are given in Table 18. Fish meal was added to the soybean meal to give a better amino acid balance and quality. Synthetic amino acids were not added to the rations to attain certain amino acid levels. The ratio of fishmeal to soybean meal was 1:15.7 in all rations. The quality of protein in each ration remained the same regardless of the protein level of the ration.

Results -- Tabular results of the feeding trial are given in Table 20. The body weight gains to 26 days of age indicate the poults made satisfactory gains on all of the semi-purified diets. The efficiency with which feed was utilized at each protein level increased as the energy content of the ration increased. In addition, as the protein level of the rations increased, feed efficiency was imporved, provided that the dietary energy level was adequate. The units of dietary protein required per unit of gain decreased as the dietary energy level increased. In general the efficiency with which the protein was utilized decreased as the protein level increased.

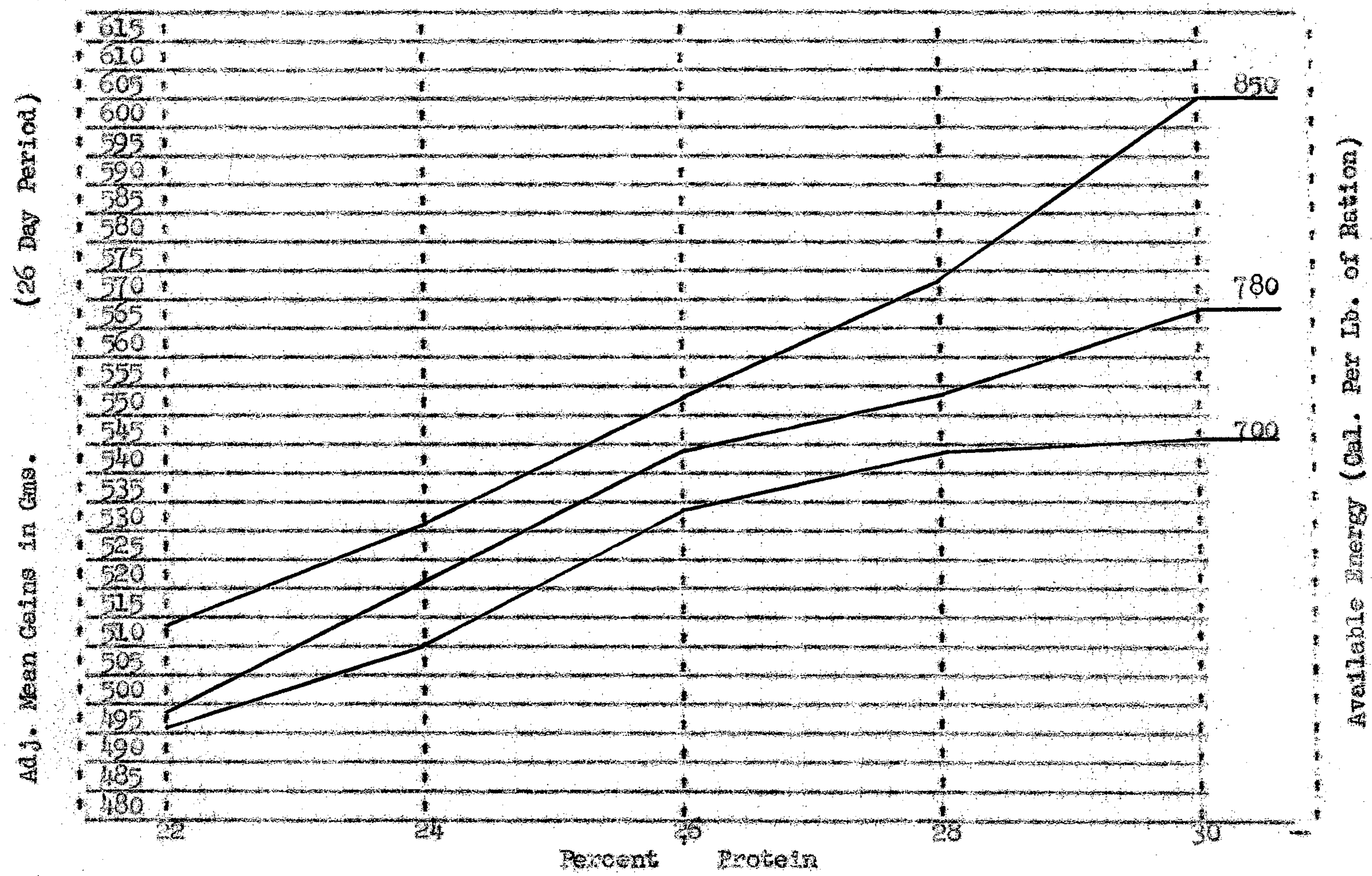
Plotted adjusted means of body weight gains are shown in Figure 7. The paralleled growth response curves indicate that each energy level adequately supported growth at protein levels of 22, 24 and 26 percent. At each of the three protein levels the vertical differences between the paralleled response curves indicate that each increase of 80 available Calories per pound of diet gave an increased gain of approximately 10 grams. A part of the increase in weight was probably protein tissue, but according to the data obtained in Trial 5, Table 28, it appears that the major part of the increase in gain was fat. The growth response curves began to depart from the paralleled linear trend at the 28 percent protein level, and a deviation was very pronounced at the 30 percent protein level. It was apparent from the break in the response curve that 700 Calories of available energy per pound of ration was a limiting factor at the 28 percent protein level and was even more limiting at the 30 percent level. The 780 Caloric energy level gave better results than did the 700 Caloric level at 28 and 30 percent dietary protein levels, but it was considerably less effective than 850 Calories of available dietary energy. Eight-hundred and fifty Calories of available energy was apparently sufficient to support efficient protein utilization at all protein levels.

The efficiency with which protein was utilized is shown graphically

Table 20.--Average final body weight, weight gain, adjusted weight gain, feed consumption and efficiency of gain in trial III

Rations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Percent Protein		22			24			26			28			30	
Available Energy from CHO and Fat (Cal. Per Lb.)	700.0	780.0	850.0	700.0	780.0	850.0	700.0	780.0	850.0	700.0	780.0	850.0	700.0	780.0	850.0
Av. Body Weight to 26 Days (gms.)	521.0	512.0	523.0	588.0	552.0	560.0	603.0	599.0	581.0	608.0	633.0	658.0	636.0	648.0	654.0
Av. Body Weight Gain to 26 Days (gms.)	469.0	459.0	469.0	535.0	499.0	509.0	551.0	548.0	529.0	556.0	579.0	606.0	584.0	595.0	601.0
Av. Adj. Body Wt. Gain to 26 Days (gms.)	497.0	499.0	513.0	510.0	522.0	532.0	534.0	543.0	543.0	543.0	554.0	573.0	547.0	568.0	605.0
Av. Total Feed Consumption Per Poult (lbs.)	1.92	1.86	1.84	2.20	1.95	1.95	2.15	2.09	1.94	2.14	2.20	2.24	2.26	2.21	2.05
Pounds of Feed Per Pound of Gain	1.88	1.84	1.78	1.87	1.77	1.74	1.77	1.73	1.66	1.75	1.72	1.68	1.76	1.69	1.55
Units of Protein Per Unit of Gain	0.413	0.404	0.391	0.448	0.424	0.417	0.460	0.449	0.431	0.490	0.481	0.470	0.528	0.507	0.465

Figure 7.--Effect of available energy at different protein levels upon body weight gain in trial III



by Figure 8. The graph shows the units of protein required to be consumed by the poult per unit of body weight gain. The response curves indicate that protein was utilized more efficiently per unit of gain with each increase in available energy. The response curves appear to indicate that beyond the 26 percent dietary protein level, the units of protein required per unit of gain, tends to increase slightly with diets containing 700 and 780 Calories of energy per pound of ration and decreases with the higher energy diets.

The use of cerelose as the main source of carbohydrate energy was believed to be the cause of an above normal incidence of pendulous crops in the poults in this feeding trial. The hypothesis was made that cerelose immediately goes into solution within the crop and fermentative action takes place because the crop of the affected bird is unable to function normally by emptying the contents completely in each 24 hour period. In some cases the crops were distented with a gas which apparently helped to weaken the crop muscles. Weakening of the crop by gaseous pressure and an increased accumulation of fluids made it impossible for the crop muscles to contract sufficiently to effect complete emptying of the crop. The incidence of pendulous crops was inverse to the oat hull content of the ration. This indicated that the movement of the crop content into the lower digestive tract was to a degree dependent upon the mechanical size and level of fiber within the diet. The average pH for four pendulous poults averaged 4.4, and the average pH of the crops for four normal poults was 5.86. Sturkie (1954) shows the acidity of the turkey crop to be pH 6.07. The increase in crop acidity indicated an abnormal bacterial or fermentative process within the crop.

The growth of the pendulous cropped poults did not seem to be seriously

Figure 8.--Units of protein per unit of gain in trial III

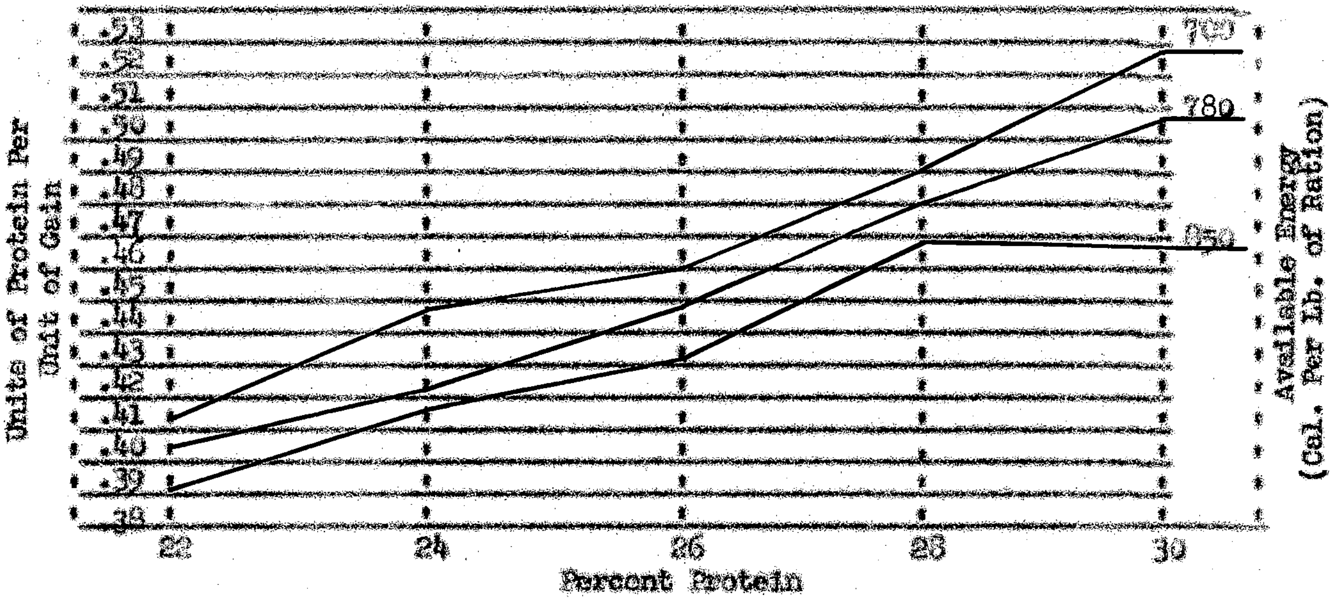


Table 21.--Analysis of adjusted mean gains in trial III

Productive Energy Level (Cal. Per Lb.)	Percent Protein 22	24	26	28	30	$\bar{X}$
700	497	518	534	543	547	506
770	499	522	543	554	568	537
850	513	532	553	573	605	555
$\bar{X}$	503	521	543	557	573	

Std. Error of Mean Difference

Protein 7.09
Energy 4.89

F Test

Source	Degrees of Freedom	F Value	% Probability
Protein	4	18.56	99.95
Linear	1	62.89	99.95
Energy	2	15.66	99.95
Linear	1	16.35	99.8
Quadratic	1	2.75	86.4
Protein X Energy	8	1.61	75.0
Error	14		

affected. The body weights of the affected poults taken after the crop had been drained, showed that each made body weight gains comparable to normal pen mates. These body weight gains were used in the statistical analysis of the feeding trial. The accuracy of the analysis was therefore decreased. The writer believes, however, this analysis of the data to be more accurate than excluding from the analysis the affected poults and making approximate corrections for feed consumption.

The statistical analysis of this feeding trial is given in Table 21. The differences in gain as effected by energy levels is significant to the 0.9995 probability level.

Trial IV

Purpose of Trial -- The structural outline of this feeding trial was essentially a replication of Trial III. At the close of Trial III it was hypothesized that the pendulous crop condition was due to the rapid solubility of cerelose within the turkey poult's crop and to some degree dependent upon the crude fiber level of the ration. In an attempt to correct this condition cornstarch was used to fully replace the cerelose in each ration. This material was thought to be less soluble than cerelose within the crop. A second purpose of the trial was that of checking the information gained in Trial III with regards to the effect of energy level upon protein utilization.

Procedure -- The procedure carried out in this feeding trial was essentially the same as that for Trial III. The experimental rations used were numbers 1 through 15 as given in Table 19. One hundred percent of the cerelose with the exception of that in the vitamin premix was replaced by feeding grade cornstarch. The vitamin additions made per pound of basal are given in Table 17. The available energy from carbohydrate and fat was calculated to be 720, 800 and 880 Calories per pound of diet. These energy levels were studied at dietary protein levels of 22, 24, 26, 28 and 30 percent.

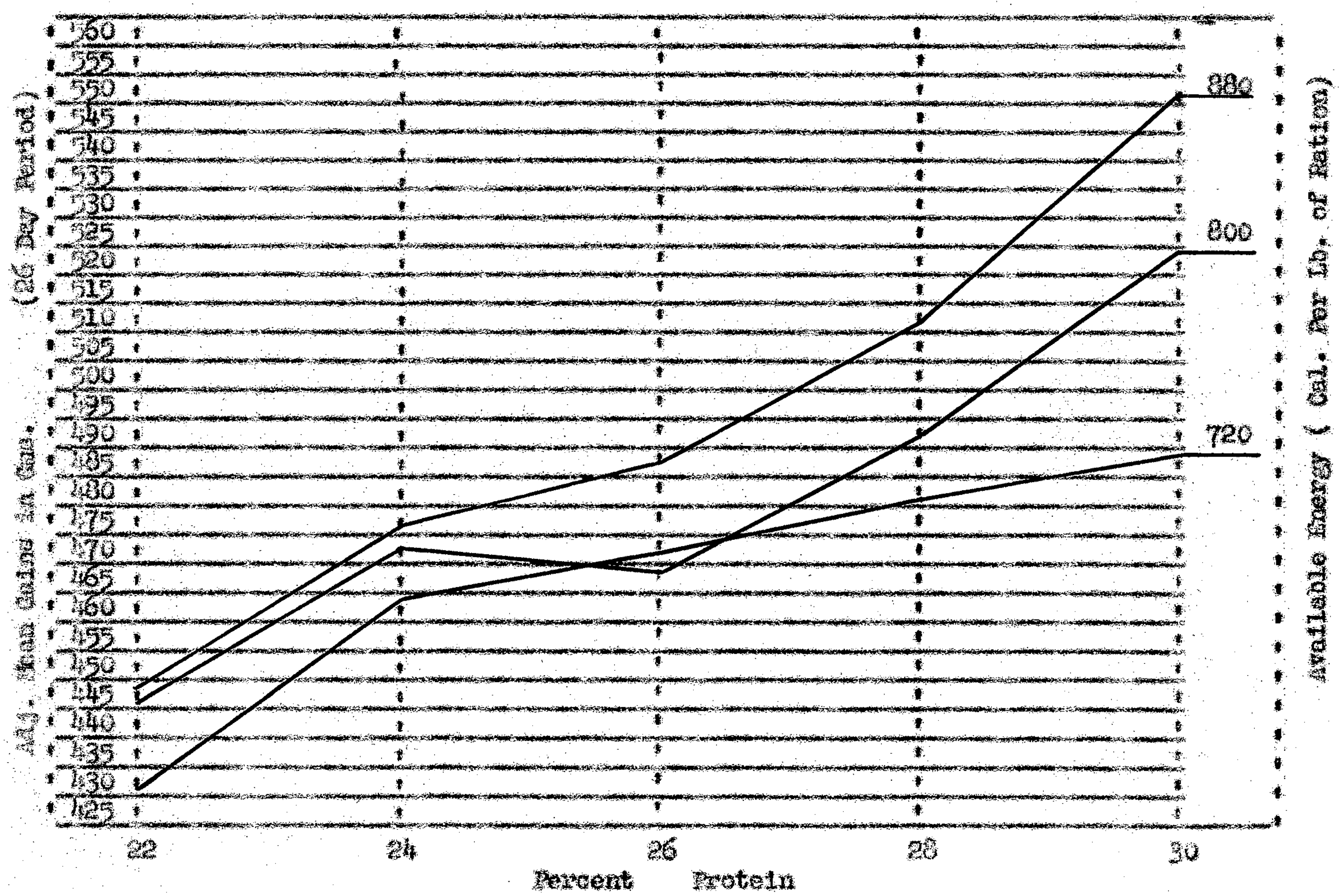
Four white Holland male and female poults were the experimental subjects in each pen. A practical type ration was fed to the poults for the first 16 hours after they were placed in the experimental pens. The feeding trial was started on July 2, 1954 and continued for 26 days. The initial and final poult weights were measured and recorded in grams. Total feed consumption was recorded at the close of the trial for each pen.

An additional four pens of poults were raised on diets containing cerelose instead of starch. Two pens of poults were fed 28 and 30 percent protein rations. These two high protein rations contained high levels of energy and low levels of medium ground oat hulls. These rations were used as controls for measuring the success or failure of the cornstarch substitute.

Results -- The poults in Trial IV did not attain as high an average weight as did those in Trial III. Temperatures ranging from around 105 to 110 degrees in the shade were quite common through the entire course of the feeding trial, and these above normal temperatures were very likely responsible for the lesser growth. Average temperature readings within the battery house at 2 P. M. were between 95 and 100 degrees F. The use of a 48 inch circulating fan blowing air through a cool spray of water helped to hold the room temperature within this range.

Plotted adjusted means of body weight gains are shown in Figure 9.

Figure 9.--Effect of available energy at different protein levels upon body weight gain in trial IV



The trend of results given in this figure is in relatively good agreement with the trend given in Figure 7 for Trial III. The paralleled growth response curves shown in Figure 9 indicate that each energy level adequately supported poult growth at basal protein levels of 22, 24 and 26 percent. An exception to this trend was the ration containing 26 percent protein and 800 Calories per pound. Here the response curve fell below that of the ration containing 26 percent protein and 720 Calories per pound of ration. The plotted adjusted means of this diet could have been influenced by a one in twenty chance that the poults fed this diet were not characteristic of the poult population. However, it appeared that the deviation of the response curve was more likely due to an error in feed consumption recording or ration mixing. The response curves for the three energy levels in diets containing 28 and 30 percent protein show that the efficiency of feed utilization was definitely influenced by the energy content of the ration. As the energy content of the ration was increased, the efficiency of feed utilization likewise increased.

The units of protein consumed per unit of gain are shown in Figure 10. The response curves indicate that at protein levels higher than 26 percent, the efficiency with which protein was utilized was dependent upon the available energy level of the ration. The response curves of the rations containing 720 Calories of energy at protein levels of 28 and 30 percent, clearly indicate that a considerable amount of protein is being utilized to provide energy.

The four pens of turkey poults which received rations containing cerelose had a high incidence of pendulous crops as did the poults fed the same rations in Trial III. Poults fed the rations containing starch, which was used to replace cerelose, did not develop the pendulous condition. It

Figure 10.--Units of protein per unit of gain in trial IV

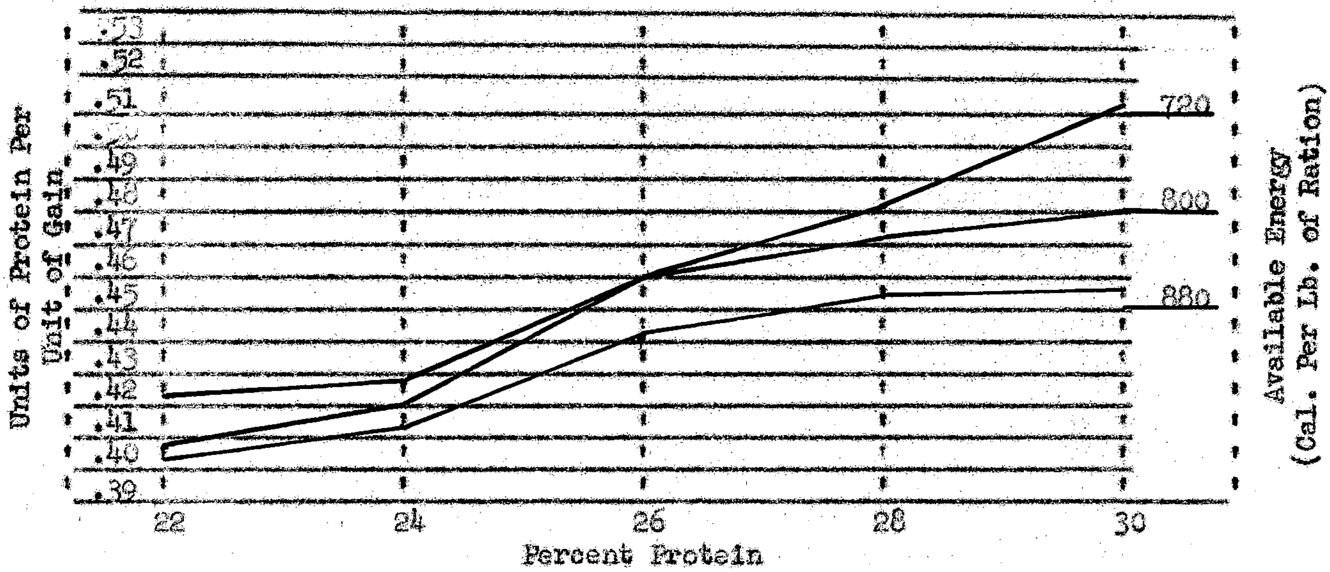


Table 22.--Analysis of adjusted mean gains in trial IV

Productive Energy Level (Cal. Per Lb.)	Percent Protein 22	24	26	28	30	$\bar{X}$	
720	432	464	473	482	488	468	Std. Error of Mean Difference
800	446	473	468	492	523	480	
880	448	477	487	512	552	495	Protein 10.61
$\bar{X}$	443	471	476	495	521		Energy 6.24

F Test

Source	Degrees of Freedom	F Value	% Probability
Protein	4	15.75	99.95
Linear	1	36.12	99.95
Energy	2	8.41	99.5
Linear	1	16.57	99.5
Quadratic	1	0.05	
Protein X Energy	8	1.38	70.0
Error	14		

Table 23.--Average final body weight, weight gain, adjusted weight gain, feed consumption and efficiency of gain in trial IV

Rations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Percent Protein		22			24			26			28			30	
Available Energy from CHO and Fat (Cal. Per Lb.)	720.0	800.0	880.0	720.0	800.0	880.0	720.0	800.0	880.0	720.0	800.0	880.0	720.0	800.0	880.0
Av. Body weight to 26 Days (gms.)	488.0	446.0	466.0	495.0	505.0	489.0	571.0	529.0	552.0	543.0	571.0	586.0	572.0	604.0	623.0
Av. Weight Gain to 26 Days (gms.)	432.0	392.0	411.0	439.0	457.0	436.0	516.0	475.0	495.0	491.0	514.0	532.0	508.0	547.0	568.0
Av. Adj. Body Wt. Gain to 26 Days (gms.)	432.0	446.0	440.0	464.0	473.0	477.0	473.0	468.0	437.0	482.0	492.0	512.0	488.0	523.0	552.0
Av. Total Feed Consumption Per Poult (lbs.)	1.83	1.60	1.67	1.72	1.74	1.66	2.01	1.86	1.86	1.86	1.92	1.91	1.91	1.93	1.90
Pounds of Feed Per Pound of Gain	1.92	1.86	1.85	1.78	1.75	1.73	1.77	1.77	1.71	1.72	1.69	1.63	1.71	1.60	1.52
Units of Protein Per unit of Gain	0.422	0.409	0.407	0.427	0.420	0.415	0.460	0.460	0.444	0.481	0.473	0.456	0.513	0.480	0.456

would appear for this reason that starch was a better source of carbohydrate in the semi-purified rations.

The average final weights, weight gains, adjusted weight gains, feed consumption and efficiency of gains observed in Trial IV are given in Table 22.

A statistical analysis of the data is given in Table 23. Adjusted gain means, standard error of the treatment mean differences and F test data are presented. Protein and energy effects were found to be statistically significant to the 0.9995 probability level.

Trial V

Purpose of Trial -- This feeding trial was set up to determine if the level of oat hulls incorporated into any of the various rations, fed in Trials III and IV, had a depressing effect upon the amount of feed consumed, measured by weight, that the poults were able to consume. Cochran and Cox (1950) implied that the use of covariance analysis was not valid if the treatments affect the feed intake, (X values). Accordingly, should the diets containing the higher levels of oat hulls be so bulky that the poults were incapable of consuming approximately the same weight of each ration, covariance analysis would be invalid since the measure of the value of each ration was dependent upon adjusted body weight gain means.

In another respect it was not possible to completely keep the effect of the treatments from influencing the X values. Two nutritional factors which influence the feed intake are given here. (1) The average feed intake at protein levels of 22 through 30 percent tended to decrease as the energy level of the diet was increased from 700 to 880 Calories per pound of ration. As the protein level of the ration increased this trend was less noticable. This factor is most likely the results of a protein-energy imbalance. It appeared that the rate of feed consumption at a given protein level was regulated by the protein-energy ratio. Energy level is here influencing the feed intake. (2) An increase in protein with adequate energy supported faster growth within all protein levels studied. As a result of growing faster, the increase in body size and capacity demanded a slight increase in daily feed intake over that of the poults on the lower protein rations. To exclude these two treatment effects from influencing the X values was impossible since the poults were fed ad libitum.

These two treatment effects which influenced the X values did not necessarily invalidate the results of the various feeding trials when analysed by the covariance method. These two effects were responsible for making possible the maximum accumulative evaluation of a ration for a given period of time. The accumulative evaluation of each ration for the first 4-week period of poult growth was the objective of all feeding trials herein reported. Cochran and Cox (1950) state that treatments which do affect the X values, analysed by the covariance method may add information about the way in which the treatment effects were produced.

Procedure -- The highest level of oat hulls used in any ration during this series of studies was 18.6 percent of the total diet. To determine if this level of oat hulls or a lower level might influence feed intake, five diets were formulated to contain a 22 percent protein level and oat hull content ranging from 5 to 25 percent of the ration. The rations given in Table 24 contained the same ingredients used in Trial IV and the vitamin premix is given in Table 25. The oat hulls were ground through a 1/4 inch screen as were those previously mixed into the diets fed in Trials III and IV.

Table 24.--Composition of basal rations used in trial V

Rations	1	2	3	4	5
	%	%	%	%	%
Protein Mix	46.6	46.6	46.6	46.6	46.6
Soybean Oil	2.0	2.0	2.0	2.0	2.0
Vitamin Mix	1.0	1.0	1.0	1.0	1.0
Starch	39.4	34.4	29.4	24.4	19.4
Oat Hulls	5.0	10.0	15.0	20.0	25.0
Calcium Carbonate	2.0	2.0	2.0	2.0	2.0
Di Ca. Phosphate (20% Phos.)	3.5	3.5	3.5	3.5	3.5
Salt (NaCl)	0.5	0.5	0.5	0.5	0.5
Percent Protein	22.0	22.0	22.0	22.0	22.0
Percent Crude Fiber (Analyzed)	4.10	5.58	7.30	8.70	10.12
Percent Calcium (Calculated)	1.99	1.99	1.99	1.99	1.99
Percent Phosphorus (Calculated)	0.99	0.99	0.99	0.99	0.99
Total Available Energy from Protein CHO and Fat (Cal. Per Lb.)	1320.00	1230.00	1140.00	1060.00	970.00
Available Energy from CHO and Fat (Cal. Per Lb.)	1000.00	910.00	820.00	730.00	640.00

Ten unsexed White Holland poults were placed in each battery pen. Each diet was replicated to four pens, making a total of 20 pens for the feeding trial. The mass weight of the poults by pens was taken at the beginning, and individual weights were taken at the close of the trial. Total feed

Table 25.--Vitamin and trace mineral additions per pound of basal ration in trials V and VI

Vitamin Addition Per Pound of Basal			
Vitamin A	10,000 I.U.	Biotin	.07 mg.
Vitamin D_3	750 I.U.	Thiamin	1.00 mg.
Riboflavin	3.32 mg.	Pyridoxine	2.00 mg.
Calcium Pantothenate	7.08 mg.	Folic acid	1.30 mg.
Choline Chloride	800.00 mg.	P.A.B.A.	50.00 mg.
Niacin	20.00 mg.	Inositol	10.00 mg.
Vitamin B_{12}	3.00 U.G.	Vitamin E	9.00 mg.
Vitamin K	2.00 mg.		
Trace Mineral Additions Per Pound of Basal			
Mn	108.00 P.P.M.	Iron	20.00 P.P.M.
Iodine	0.96 P.P.M.	Copper	1.80 P.P.M.
Cobalt	0.64 P.P.M.	Zinc	1.69 P.P.M.

consumption was recorded by pens. The feeding trial was started on January 16, 1954 and continued for 28 days.

The poults were sacrificed at the end of the feeding trial and sex was determined. The feed intake per pen was then corrected to an equal sex basis. This correction was made by determining the percent net gain of each sex within each pen. The percent net feed consumption of each sex within a pen was considered to be proportional to body weight gain. Almquist (1951) disclosed that the efficiency with which feed was utilized by turkey poults to be the same for both sexes to approximately six weeks of age. As this feeding trial was conducted for only four weeks, it was considered to have fallen within the approximate range presented by Almquist. Using this as a basis, each pen feed intake was corrected to the amount which five males and females, proportional in size to the average of each sex within a pen, would have been expected to consume.

The feed intake per pen, corrected to an approximate even sex basis, was statistically analysed. The analysis of variance as outlined by Snedecor (1946), was used to analyse this data. Early studies showed that the population of turkeys from which the poults were obtained was very heterogeneous for growth response studies. Because of this heterogeneous condition four replicated pens were fed each treatment ration. The accuracy of the feeding trial was increased approximately 600 percent by increasing the number of replications per treatment from 2 to 4 pens. The formula used for estimating the increase in accuracy is given below.

$$\text{Percent Accuracy Increase} = \frac{\dfrac{2\,\sigma}{2 \text{ reps}}}{\dfrac{2\,\sigma}{4 \text{ reps}}} \text{ times } 100$$

Cochran and Cox (1950)

The experimental errors for 2 and 4 replications of each treatment contains 5 and 15 degrees of freedom, respectively.

Results -- It can be hypothesised that the inclusion of 25 percent oat hulls in a turkey poult starting ration will not reduce feed consumption significantly at the 0.95 probability level.

The statistical analysis of this feeding trial is given in Table 26. The F test shows that the differences in ration consumption did not approach significance at the 0.95 probability level. The hypothesis is accepted. This information supports the use of covariance analysis for analysing feeding Trials I, II, III, IV and VI.

Table 26.--Analysis of feed intake data in trial V

Reps.	Percent Oat Hulls in Rations					
	5	10	15	20	25	
1	16.20	18.57	17.90	13.60	19.74	Std. Error of Mean Difference
2	19.02	17.94	17.81	18.95	15.81	3.98
3	18.37	17.40	16.20	20.39	21.36	
4	17.90	17.62	17.28	19.20	14.84	
$\bar{X}$	17.87	17.88	17.40	18.03	17.94	

Analysis of Variance

Source	DF	SS	MS	F Test
Oat Hull Level	4	1.3550	.339	.0801
Linear	1	.0004	.0004	.0000
Quadratic	1	.2100	.2100	.0496
Residual	2	1.1446	.5723	.1352
Error	15	63.463	4.23	
Total	19	64.818		

The units of ration required per unit of gain are given in Figure 11. The plotted body weight gains show the importance of having adequate levels of available energy in a diet. The available energy content of each ration was inversely proportional to the oat hull level. A response curve given in Figure 12 shows the decline in efficiency of protein utilization as the energy levels of the ration decreased. It appears that energy levels of 1000 and 910 Calories per pound of ration are sufficiently high to support efficient protein utilization. Protein was utilized with decreasing

Table 27.--Relationship of diet bulk to gizzard size in trial V

Percent of Oat Hulls in Basal	5.0	10.0	15.0	20.0	25.0
Percent of Crude Fiber in Basal	4.10	5.58	7.30	8.70	10.12
Volume Per Gram of Basal (ml.)	1.63	1.72	1.82	1.92	2.04
Average Volume Intake per Poult (ml.)	1317.00	1398.00	1405.00	1569.00	1596.00
Average Volume Intake per Lb. of Gain	1399.00	1484.00	1628.00	1848.00	2001.00
Average Weight of Basal Intake per Poult	1.79	1.79	1.74	1.80	1.79
Average Gizzard Weight[a] Empty (gms.)	17.81	22.41	22.75	25.76	27.34
Average Gizzard Content Weight (gms.)	5.51	7.64	7.20	8.25	9.80

[a]Each average gizzard weight is the mean weight of the gizzards taken from six poults on each treatment.

Table 28.--Chemical analysis of poult carcasses at each oat-hull-level in trial V

Percent of Oat Hulls in Basal	5.0	10.0	15.0	20.0	25.0
Percent Moisture	69.00	70.24	71.47	70.95	72.76
Percent Protein*	67.72	70.17	71.27	72.03	72.64
Percent Fat*	14.13	12.23	9.06	8.39	8.34
Percent Ash*	11.82	12.71	12.71	13.21	12.36
Percent Ca.*	3.55	3.93	3.84	4.24	3.88
Percent P.*	1.78	1.91	1.92	1.96	1.93

*Dry weight basis.

Table 29.--Average final body weight, weight gain, adjusted weight gain, feed consumption and efficiency of weight gain in trial V

Percent Oat Hulls in Basal	5	10	15	20	25
Average Body Weight at 28 Days (gms.)	482.00	480.00	445.00	440.00	404.00
Average Body Weight Gain to 28 Days (gms.)	428.00	428.00	391.00	386.00	353.00
Average Adj. Body weight Gains to 28 Days (gms.)	420.00	415.00	405.00	373.00	373.00
Average Total Feed Consumption Per Poult (lbs)	1.78	1.79	1.70	1.80	1.68
Units of Feed Per Unit of Gain	1.89	1.90	1.97	2.12	2.16
Units of Protein Per Unit of Gain	0.416	0.418	0.433	0.466	0.475
Calories Used Per Pound of Gain	2496.00	2337.00	2246.00	2247.00	2095.00

decreasing efficiency as the available energy levels were reduced to 820, 730 and 640 Calories per pound.

The data given in Table 27 demonstrates the ability of turkey poults to adjust to diets with varied fiber levels. As the volume per unit of feed increased, a greater volume of feed was consumed per poult with the exception of the ration containing 25 percent oat hulls. There was a striking difference between rations in the volume of feed consumed per unit of gain. To facilitate the usage of an increasingly bulky diet, the size of the poults gizzards increased both in weight and capacity with an increase in ration bulk. A comparison of the low and high oat hull levels, shows the high oat hull level gizzards to be 93 percent

Figure 11.--Units of ration per unit of gain at different fiber levels in trial V

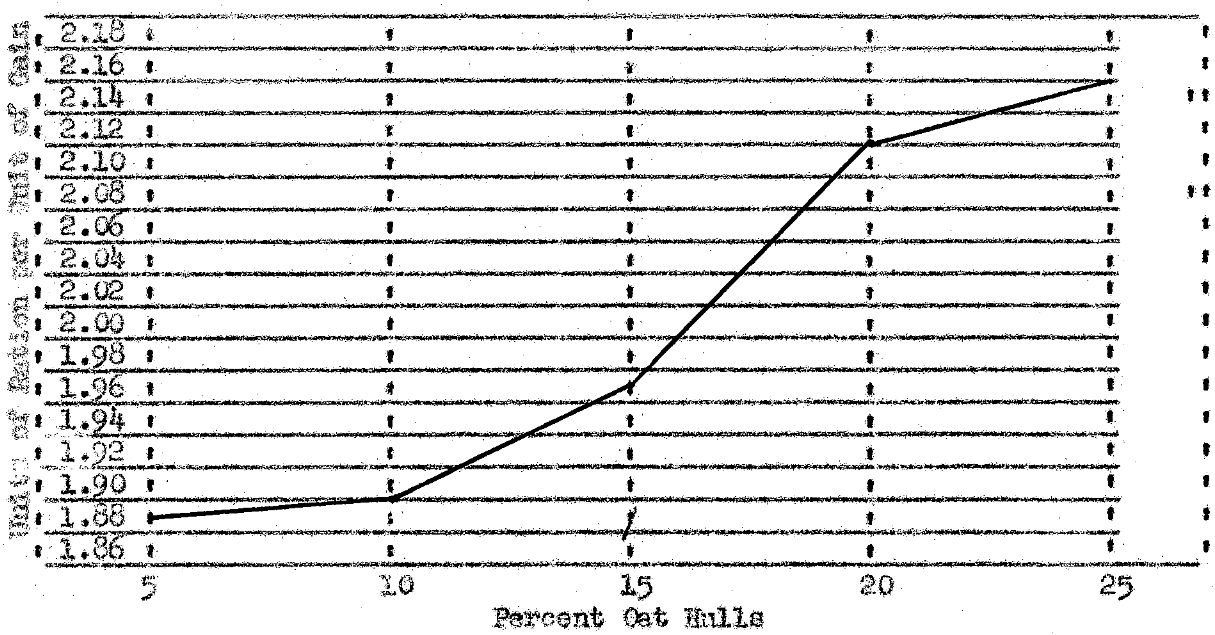
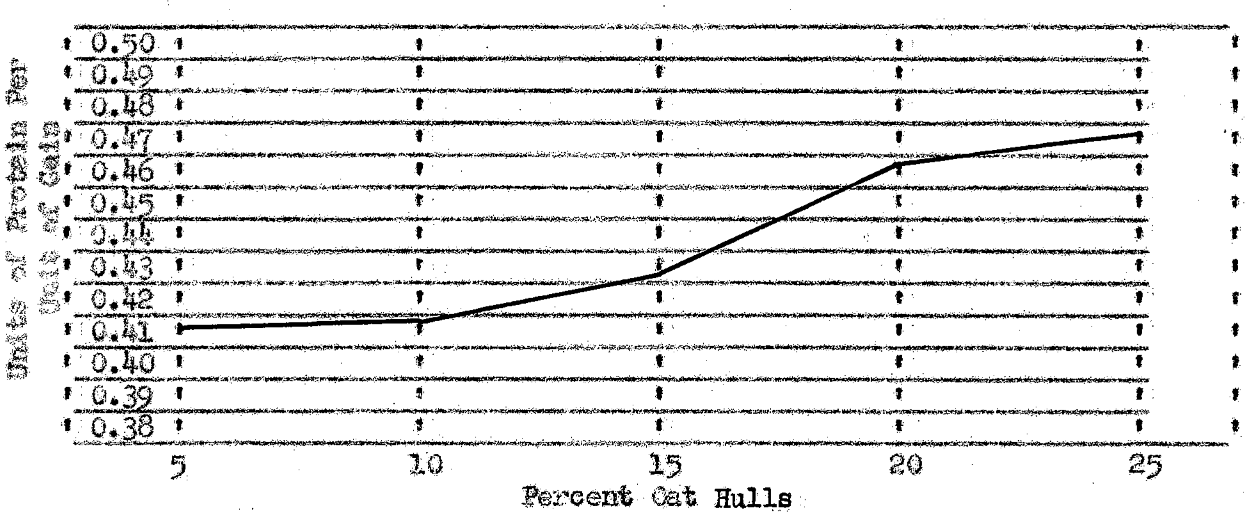


Figure 12.--Units of Protein Per unit of gain at different fiber levels in trial V



larger with a 78 percent greater volume capacity than those of the low oat hull level.

The average volume intake per poult as shown in Table 27 indicates that 20 percent oat hull in a turkey poult starting ration should be considered the maximum amount for good experimental results. The poults fed the ration containing 25 percent oat hulls grew at a markedly slower rate at the beginning of the trial than the poults on the other 4 rations. The mortality for poults fed the 25 percent oat hull ration was 15 percent as compared to zero for the poults fed the other 4 rations. A leg weakness and hock soreness was characteristic of the poults fed the 25 percent oat hull ration. The condition resembled that of a mild perosis.

Chemical analyses of poult carcasses for each diet are given in Table 28. The data show the variability of carcass elements as affected by energy level of the rations. Fat and protein, respectively, appear to be the most variable on a dry weight basis. The percent fat in the carcass tends to affect the percentage of carcass protein and moisture, but had very little effect upon the ash content.

Final body weight means and feed efficiency results are presented in Table 29. It is of special interest to note the efficiency with which the total Caloric value of each ration was utilized. As the Caloric value of the diets decreased, the Calories of energy from each were utilized with greater efficiency. Hill and Dansky (1954) disclosed that broilers utilized each available Calorie of energy more efficiently as the energy content of the diet decreased.

Trial VI

Purpose of Trial -- Baldini, Rosenburg and Waddell (1954a) reported lysine and methionine to be the first and second limiting amino acids, respectively, in a corn-soya 20 percent protein turkey starter ration. Methionine was found to be the first limiting amino acid in a 28 percent poult starting ration. This feeding trial was conducted to determine whether lysine or methionine was the first limiting amino acid in a 22 and 26 percent protein poult starting ration.

Procedure -- Ten unsexed White Holland turkey poults were placed in each experimental battery pen. The experimental rations were fed in duplicate. Mass initial and final poult weights were taken by pens. Feed consumption was recorded for each pen at the close of the trial. The feeding trial was started on January 1, 1955 and continued for 28 days.

Rations 2 and 6 given in Table 19 were used as the basal ration for the experimental rations. Table 30 shows the experimental rations with the various additions and levels of lysine and methionine. A 3 by 3 factorial having all possible combinations of 3 different levels of lysine and methionine, was conducted at the 22 percent protein level. A similar 2 by 2 factorial was conducted at the 26 percent protein level. The vitamin mix used in all diets is given in Table 25. The vitamin and mineral additions were the same for all rations.

The available energy from carbohydrate and fat was held constant in all rations. An available energy level of 800 Calories per pound of ration was considered to be sufficient to support efficient protein utilization at both the 22 and 26 percent protein levels. Figures 7 and 9 of feeding Trials III and IV indicate that this was true.

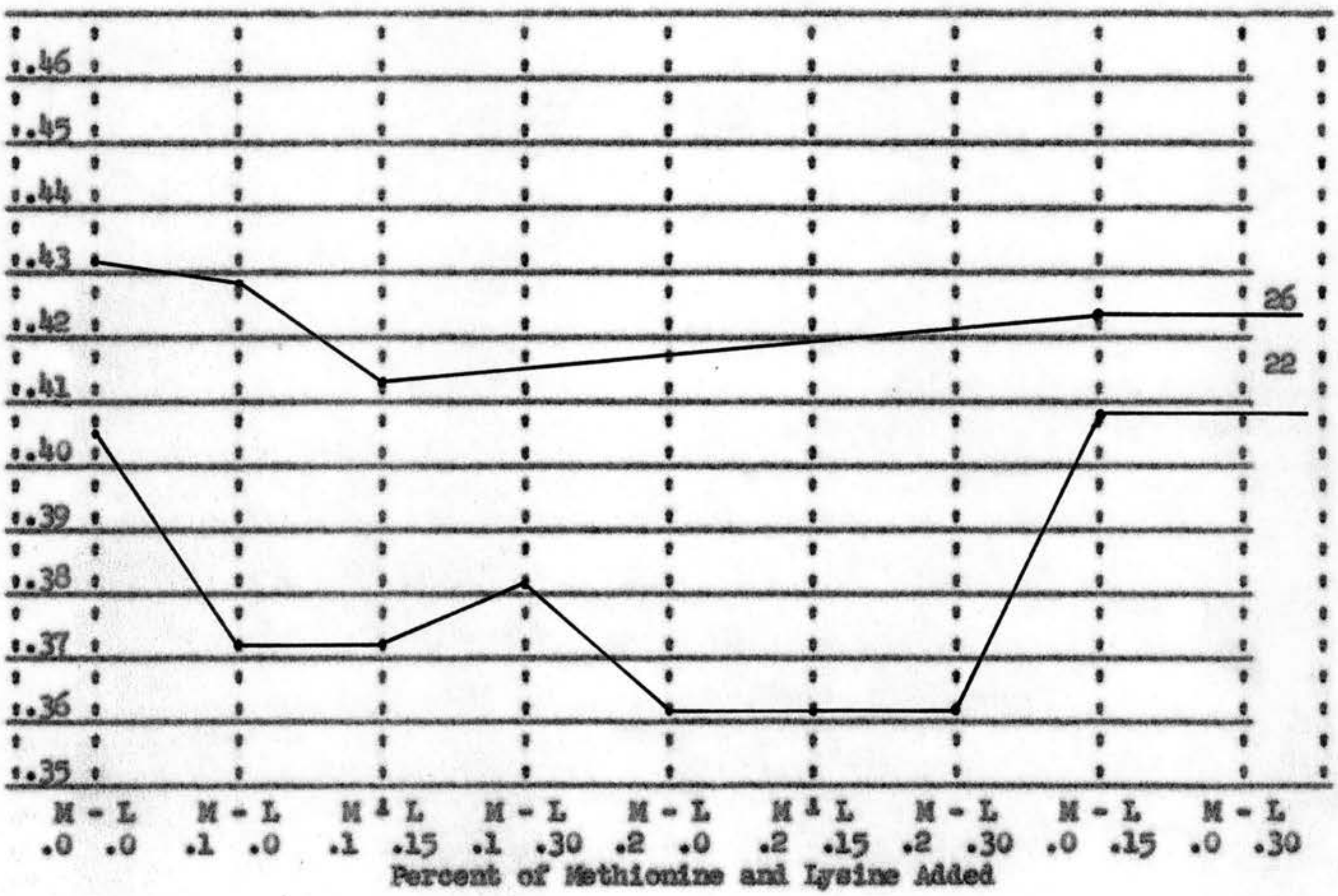
At the 26 percent protein level, four rations were formulated to contain 680, 720, 760 and 800 Calories of available energy per pound of diet. The calculated amounts of energy were supplied by carbohydrate and

Table 30.--Methionine and lysine levels in the rations fed in trial VI

Rations	Percent of Amino Acids Added to Basals		Percent of Total Crude Sulfur Containing Amino Acids	Percent of Available Sulfur Containing Amino Acids	Percent of Total Crude Lysine	Percent of Available Lysine
	Methionine	Lysine*	22% Protein Basal			
1	.0	.0	0.605	0.454	1.40	1.055
2	.1	.0	0.705	0.551	1.40	1.055
3	.1	.15	0.705	0.551	1.55	1.195
4	.1	.30	0.705	0.551	1.70	1.340
5	.2	.0	0.805	0.636	1.40	1.055
6	.2	.15	0.805	0.636	1.55	1.195
7	.2	.30	0.805	0.636	1.70	1.340
8	.0	.15	0.605	0.454	1.55	1.195
9	.0	.30	0.605	0.454	1.70	1.340
			26% Protein Basal			
10	.0	.0	0.73	0.55	1.67	1.26
11	.1	.0	0.83	0.645	1.67	1.26
12	.1	.15	0.83	0.645	1.82	1.40
13	.0	.15	0.73	0.550	1.82	1.40

*Synthetic dl-methionine and l-lysine were used. The methionine was considered to be 98 percent available and the lysine to be 76 percent available.

Figure 13.--Units of protein per unit of gain as effected by methionine and lysine additions in trial VI



fat. The increment of energy between each diet was approximately one-half the size of those used in Trials III and IV.

Results -- The response curves formed by the plotting of the adjusted body weight gains are shown in Figure 14. The addition of 0.1 and 0.2 percent of dl-methionine to the 22 percent protein rations gave an increased growth response. The growth increase was greater for the 0.1 percent addition level than for the 0.2 percent level. The over-all picture at this protein level shows methionine to be limiting. The addition of supplementary l-lysine gave no growth response at the 22 percent level.

Table 31.--Average final body weight, weight gain, adjusted weight gain, feed consumption and efficiency of gain in trial VI

Rations*	1	2	3	4	5	6	7	8	9	10	11	12	13
Percent Protein	22	22	22	22	22	22	22	22	22	26	26	26	26
Methionine and Lysine Levels Added (percent)	M .0 L .0	M .1 L .0	M .1 L .15	M .1 L .30	M .2 L .0	M .2 L .15	M .2 L .30	M .0 L .15	M .0 L .30	M .0 L .0	M .1 L .0	M .1 L .15	M .0 L .15
Average Body Weight at 28 Days (gms.)	430	502	525	540	555	554	560	403	474	549	585	640	575
Average Body Weight Gain to 28 Days (gms.)	372	445	468	482	495	496	503	348	415	492	526	581	518
Average Adjusted Body Weight Gain to 28 Days (gms.)	439	472	475	463	490	488	489	437	436	485	491	515	495
Average Total Feed Consumption Per Poult	1.51	1.66	1.74	1.84	1.79	1.81	1.83	1.42	1.69	1.80	1.91	2.03	1.86
Units of Feed Per Unit of Gain	1.84	1.69	1.69	1.73	1.64	1.66	1.65	1.85	1.85	1.66	1.65	1.59	1.63
Units ofProtein Per Unit Of Gain	0.405	0.372	0.372	0.381	0.361	0.365	0.363	0.407	0.407	0.432	0.429	0.413	0.424

*All rations contained 800Calories of Available carbohydrate and fat energy per pound of ration.

The addition of 0.1 percent dl-methionine to the 26 percent protein poult starting rations gave a slight increase in growth response. The addition of 0.15 percent l-lysine monohydrochloride supported a growth response greater than that demonstrated by the methionine addition. A greater growth response was obtained when the diet was supplemented with 0.1 and 0.15 percent dl-methionine and l-lysine monohydrochlorides respectively.

The units of protein required per unit of gain are given in Table 31 and Figure 13. The response curve shows the efficiency of protein utilization to be more favorable at the 22 percent protein level than at the 26 percent level. The addition of methionine greatly increased protein utilization efficiency at the 22 percent protein level. The addition of lysine seemed to neither increase nor decrease protein efficiency at this protein level. Supplementary lysine and methionine added singly to the 26 percent protein rations increased the efficiency of protein utilization. The addition of both amino acids simultaneously gave an even greater efficiency response.

Comparing the adjusted body weight gain means of the 4 energy levels, given in Table 32, there appeared to be a trend in favor of the increased energy levels. The differences between adjusted means approach significance to the .90 probability level. The linear effect of the differences approach significance to the 0.945 probability level.

Table 33 gives the adjusted body weight gain means for the 3 by 3 and 2 by 2 factorials, the standard error of the mean differences and the F test data. The F test indicated the methionine addition at the 22 percent protein level to be significant to the 0.9995 probability level. The addition of methionine and lysine at the 26 percent protein level were

Figure 14.--Effect of methionine and lysine additions on weight gain in trial VI

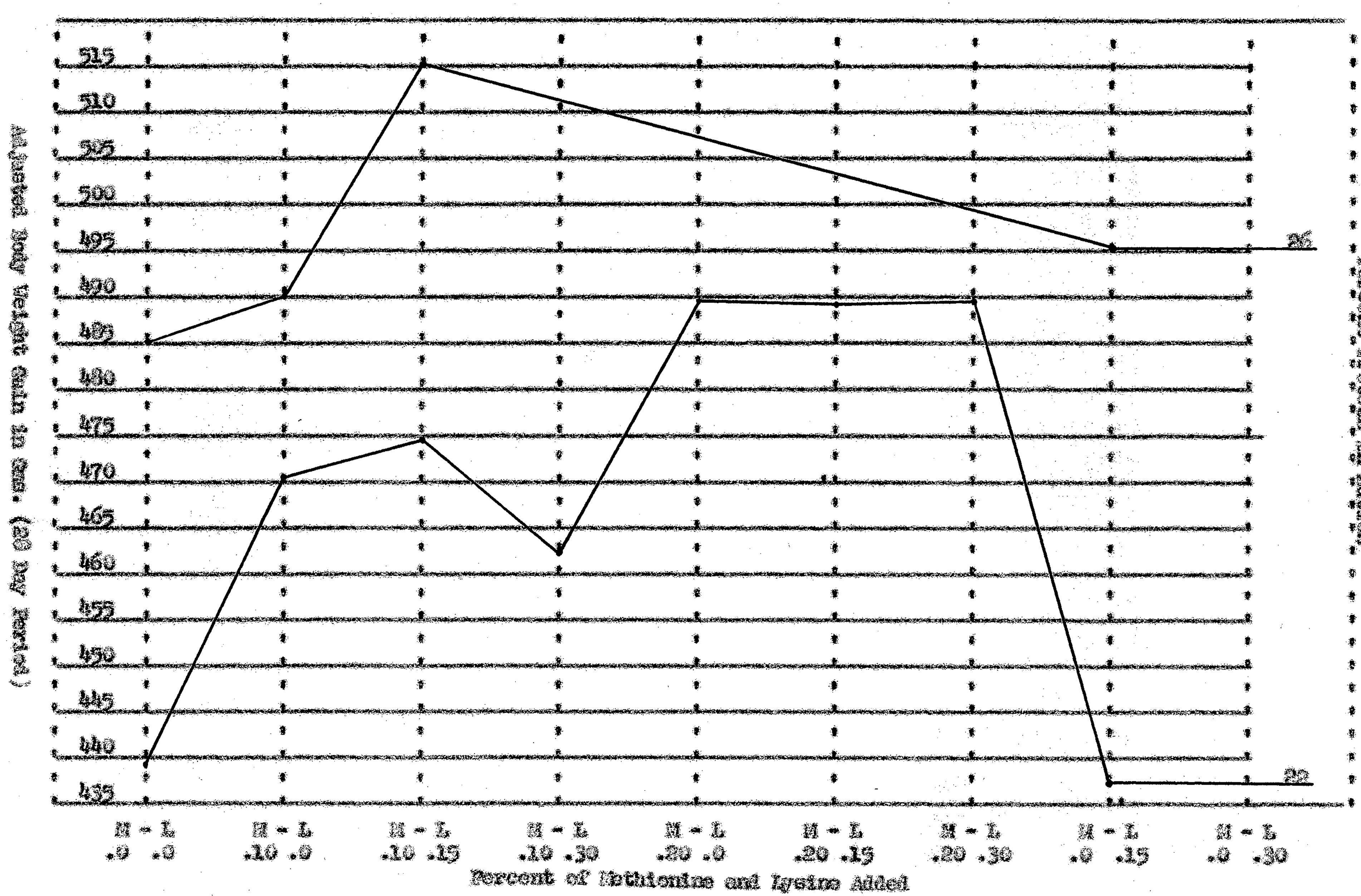


Table 32.--Adjusted Body Weight Gain Means

Ration Calorie Levels	680	720	760	800
Weight Gain Means in Grams	464	484	477	485

responsible for mean differences which established 0.90 and 0.975 probability levels, respectively. Statistically there was no difference between the response given by the 26 percent protein ration unsupplemented and the 22 percent protein ration containing 0.2 percent of supplementary dl-methionine.

Table 33.--Analysis of adjusted mean gains in trial VI

	Percent Protein 22					Percent Protein 26				Std. Error of Mean Diff.	
Percent Lysine Added	Percent Methionine Added .0	.1	.2	$\bar{X}$	Percent Lysine Added	Percent Methionine Added .0	.1	$\bar{X}$			
.0	439	472	490	467	.0	485	491	488		Protein	0.24
.15	437	475	488	467	.15	485	515	505		Methionine (22% Protein Level)	6.83
.30	436	463	489	463	$\bar{X}$	490	503			Lysine (22% Protein Level)	5.79
$\bar{X}$	437	470	489							Methionine (26% Protein Level)	7.21
										Lysine (26% Protein Level)	6.83

F Test

Source	Degrees Of Freedom	F Value	% Probability Level
Protein	1	44.63	99.90
Treatements at 22 Percent Protein Level	8	7.05	99.90
Methionine	2	21.42	99.95
Linear	1	42.88	99.95
Quadratic	1	1.78	76.60
Lysine	2	0.04	
Linear	1	0.44	
Quadratic	1	0.21	
Methionine X Lysine	4	0.51	
Treatments at 26 percent Protein Level	3	3.12	93.90
Methionine	1	3.12	90.00
Lysine	1	6.38	97.50
Methionine X Lysine	1	1.13	70.00
M-L M--L Prot. 26 0-0 vs Prot. 22 .2-.3	1	0.28	
Error	15		

CHAPTER V

DISCUSSION

Energy and Protein Relationship

The available energy from carbohydrate and fat required to support efficient utilization of protein is shown in Figures 7 and 9 of Feeding Trial III and IV, respectively. The response curves for the rations containing 700 and 720 Calories of available energy per pound, break at the 28 and 30 percent protein levels. These breaks in the response curves indicate that protein is being utilized less efficiently for the synthesis of protein tissue. Figures 8 and 10 show marked increases in the units of protein required per unit of body weight gain at these protein and energy levels.

The purpose of feeding graded levels of available energy in Trials III and IV was that of determining the amount of available carbohydrate and fat energy which would be required to support the most efficient utilization of protein. The use of protein as a source of energy is a waste of tissue building material. Considering the cost of protein on a Caloric basis, the cost of one Calorie of protein is usually greater than one Calorie of carbohydrate. If the initial cost of one Calorie of protein is greater than that of one Calorie of carbohydrate, it is economically unsound to use protein as a source of energy. A second loss in the Caloric value of protein is encountered as a result of the deamination process. Almquist (1953), states, "It is unlikely that forced synthesis of dispensable amino acids from indispensable amino acids will proceed without considerable waste". It would, therefore, seem likely that energy is lost in the physiological function of amino acid catabolism. Brody (1945) disclosed that the excretion of urea and other protein end products by the kidneys is at the expense of 1 to 2 Calories of energy per gram of nitrogen excreted. The oxidation of the deaminized fragment causes a further increase in energy loss. The amount of energy expended during the oxidation process is characteristic of the amino acid involved. The deaminized fragment of alanine is oxidized at a loss of 30 Calories per gram of nitrogen excreted. When proteins are used as a source of energy the specific dynamic effect is greatly increased.

The specific dynamic effect or heat increment is decreased as the nutrient balance approaches the optimum. The reduction of the specific dynamic effect would appear to be very important during the summer months. An increase in body heat, above that which normally occurs during this period, demands greater body activity by means of breathing to dissipate the heat. It is, therefore, an advantage to consider amino acid balance and the protein-energy ratio in each diet formulated.

Productive energy is the measure most often used for evaluating the energy value of feedstuffs. This is the best method available at the present time. Productive energy values were used to determine the amount of energy within each ration fed in trials 1 and 2. Available energy values could well have been used for the same purpose.

The use of available energy values for determining the amounts of carbohydrate and fat energy within a ration has advantages and disadvantages. The greatest disadvantage is the complexity of protein quality. A low quality protein has a sparing action upon the amount of carbohydrate and fat energy required in a ration. The protein quality as affected by amino acid balance determines the quantity of available amino acids which will be used as a source of energy. Protein quality and quantity determines the amount of available carbohydrate and fat energy that is required to support the most efficient protein utilization. With a better knowledge of amino acid availability and balance coupled with a better understanding of the available energy requirements, rations can be balanced with greater precision for a specific purpose.

It is the opinion of the writer that available energy values are more stable than productive energy values. A ration may have a feed ingredient added to it that contains a certain amount of productive energy. The actual productive energy contribution of the feed ingredient will, however, depend upon the nutrient composition of the ration before the feed ingredient is added. It should be pointed out that available energy values for carbohydrate and fat can well be used for measuring the efficacy of the energy content of the ration to support all physiological process, whether it be growth, carcass finish, maintenance or reproduction. Available energy requirement values for each of these processes can be worked out only by analyzing data of feeding trials. The use of available energy values can become increasingly useful as purified sources of protein, starch and fats are used in the formulation of poultry diets.

Comparing the productive energy values from Trials I and II with those from Trials III and IV there appeared to be less value in a calculated Calorie of productive energy in a diet composed of natural feedstuffs than in a semi-purified diet which contained cornstarch as a source of energy. The question was then raised as to whether or not the productive energy value of cornstarch is 1140 Calories per pound as given by Fraps (1946). It appears that should cornstarch be used in certain rations it would contain more than 1140 Calories when compared to the productive energy ratings of natural ingredients. It was because of this apparent discrepancy in productive energy values that available energy values were used in calculating the carbohydrate and fat energy levels in the diets fed in Trials III, IV, V and VI.

It appears from Figures 7 and 9 that 700 and 720 Calories of available energy per pound of diet support efficient protein utilization at the 22, 24 and 26 percent protein levels. However, these amounts of available energy were found to be limiting at the 28 and 30 percent protein levels. When dietary energy levels of 780 and 800 Calories were fed, protein was efficiently utilized up to and including the 28 percent level. The diets containing 850 and 880 Calories, supported efficient protein utilization at protein levels of 22 through 30 percent. While the calculated energy levels in Trial III and IV differed by approximately 20 and 30 Calories of productive energy per pound of diet, it does not appear, according to the experimental data, that the molecular energy difference between cerelose and starch existed.

Protein and Amino Acids

The available sulfur amino acids and lysine content of rations fed in Trials I and II were calculated from the amino acid values given in table 4. The diets which contained the S_1 levels of sulfur amino acids and lysine were utilized more efficiently than the control diets which contained the S_o amino acid levels. In Trial II the S_2 and S_3 sulfur amino acids and lysine levels seemed to have retarded poult growth. When 0.1 or 0.2 percent methionine was added to a 22 percent protein semi-purified diet the growth response of the poults was considerably greater than the response given by the unsupplemented diet. The addition of the same amounts of supplementary methionine to a 26 percent protein semi-purified diet gave an increased growth response, but considerably less than that given at the 22 percent protein level. The available sulfur amino acids at the 26 percent protein level appeared to be approximately 0.645 percent. This level was 0.83 percent when calculated on a crude amino acid basis. This amount of sulfur amino acids whether considered as crude or available was lower than that contained in levels S_2 and S_3 of Trial II. A comparison of the crude sulfur amino acid values of the 22 and 26 percent protein diets fed in Trials II and VI shows that the levels of crude sulfur amino acids in S_1, S_2 and S_3, Table 12, are considerably higher than those of Diets 2, 3, 4, 11 and 12 which are given in Table 30. The sulfur amino acids and lysine values used for calculating the available and crude amino acid levels in Trial VI were taken from current biological assay data. The fish and soybean meal used in the mixing of these diets were assayed for methionine and lysine by the Oklahoma A and M College Agricultural Chemistry Department. Since fish and soybean meal were the only protein concentrates used, the levels of both amino acids are considered to be a better estimate of the true amino acid content than the level calculated for $S_{[illegible]}$ in Trials I and II.

At the beginning of this series of feeding trials the assumption was made that the availability of amino acids were proportional to the respective protein digestion coefficients. This assumption appears to be only partially correct. The data of Trial II indicate that amino acid values obtained by biological assay indicate greater availability to poults than crude protein digestion coefficients. Albanese, Frankston and Irby (1944) disclosed that the absorption of methionine from the gastrointestinal tract was approximately one-half of the amount ingested.

Melnick, Oser and Weiss (1946), showed the invitro enzymatic hydrolytic release of methionine and l-lysine to be affected by time. A 24 hour enzymatic hydrolysis of heat treated soybean meal liberated 10 and 56 percent of the crude methionine and lysine, respectively, while hydrolytic action for 120 hours liberated 73 and 84 percent of the methionine and lysine, respectively. Liberation of methionine was found to be much slower than lysine or leucine. Kalckan and Lyman (1948) presented data showing the percent absorption of amino acids from the gastrointestinal tract of rats. Methionine and lysine absorption was, respectively, for beef 100 and 99 percent, cottonseed flour 80 and 64 percent, peanut flour 96 and 97 percent and wheat 95 and 93 percent. According to the results obtained it was considered impossible to evaluate the biological value of a protein with the absence of amino acid data.

The crude sulfur amino acids and lysine levels of S_1, S_2 and S_3 are higher than the requirement levels presented by Almquist (1952) and Scott (1953). The natural levels of crude sulfur amino acids and lysine of S_3 are in excess of 0.06 and 0.26 percent, respectively, of the requirements given by Almquist. The data of feeding Trial VI indicate that the efficiency of feed utilization was increased only slightly when the sulfur amino acid level in the 26 percent protein ration was increased from 0.73 to 0.83 percent. Extrapolating from the 0.83 percent level for a 26 percent protein ration it appears that a sulfur amino acid level of 0.89 percent in a 28 percent protein starter would closely approach the requirement level. The available sulfur amino acid requirement level for a 28 percent protein starter appears to be within the proximity of 0.69 percent. This percentage figure is approximately 0.1 percent lower than the approximate available sulfur amino acid requirement level calculated for the 28 percent protein starter fed in Trial II.

The apparent depression of feed efficiency in rations containing S_2 and S_3 amino acid levels is probably caused by a multiple error. One error could exist in the using of protein digestion coefficients as a base from which to calculate the availability of amino acids in each ration. The availability of the amino acids are probably slightly higher than that shown in Table 4. Should the first probable error be true a second error will evolve from the method used to figure the amino acid values for the natural feed ingredients. The crude amino acid levels of highly purified diets were first calculated and later reduced to the available level. Rations containing natural feedstuffs were then formulated to contain the same levels of available sulfur amino acids and lysine as were contained in the purified diets. In general the protein in the natural feedstuffs was less digestible than the proteins used in the purified diets. Therefore, the crude amino acid levels of the natural diets were higher than those of the synthetic diets. The presence of these two errors could easily raise the methionine or lysine level to a point at which a low level toxicity would exist.

In Figures 8 and 10 From Trials III and IV, respectively is shown the efficiency with which the units of protein within each ration was utilized. The curve which represents the response of protein as affected by 850 and 880 Calories of energy appears to plateau at the 28 and 30 percent levels. The plateau shows that protein was being utilized more efficiently at these protein levels. According to Almquist (1952) and Scott (1953) an increase in the amount of a good quality protein within a ration will give an amino acid balance more in line with the physiological demand of the growing chick. It is very probable that this trend is applicable to the growing poult. As the protein level increases, the physiological demand for methionine and lysine expressed as a percentage of the ration protein level tends to decrease.

The writer is of the opinion that a ration containing a protein level well in excess of 30 percent can be balanced by using natural sources of methionine and lysine. The level of protein which the poult can no longer utilize with maximum efficiency in the presence of adequate energy is believed to be in excess of 30 percent. With the increasing use of high energy fats and oils in practical poultry nutrition it is highly feasible that high efficiency turkey starters containing 30 percent or more of protein will be in practical use within the near future.

Statistical Analysis

The data of each feeding trial with the exception of Trial V was analysed by covariance analysis. The turkey population from which the poults were obtained was found to be very heterogeneous in growth response. The experimental error which would have been large using the analysis of variance method was greatly reduced by using covariance analysis. The efficiency in each trial was greatly increased by using this method of analysis. The use of covariance increased the efficiency of each experiment by approximately 2 to 4 times that which could have been attained by using the analysis of variance method. When the poults were more evenly distributed between pens with respect to growth response, the efficiency gained by using covariance as compared to analysis of variance seemed to decrease.

BIBLIOGRAPHY

Ackerson, C. W., and F. E. Mussehl, 1953. The utilization of food elements by growing poults. 2. A comparison of diets containing 25 and 30 percent protein. Poultry Sci. 32:958-960.

Albanese, A. A., J. E. Frankston, and V. Irby, 1944. The estimation of methionine in protein hydrolysates and human urine. J. Biological Chemistry 156:293-302.

Almquist, H. J., 1947. Evaluation of amino acid requirements by observations on the chick. J. Nutri. 34:543-563.

Almquist, H. J. Comparative Mash Consumption, Grain Consumption and Feed Efficiency of Broad Breasted Bronze and Beltsville Small White Turkeys. Modesto, California: The Grange Company, 1951.

Almquist, H. J., 1952. Amino acid requirements of chickens and turkeys. Poultry Sci. 31:966-981.

Almquist, H. J. Proteins and Amino Acids in Animal Nutrition. Third Edition, Reprinted through the courtesy of U. S. Industrial Chemicals Company, 1953.

Asmundson, V. S. and T. H. Jukes, 1939. Turkey production in California. Cal. Agr. Ext. Service Cir. 110.

Baldini, J. T., H. R. Rosenberg and J. Waddell, 1954a. The protein requirement of the turkey poult. Poultry Sci. 33:539-543.

Baldini, J. T., and H. R. Rosenberg, 1954b. Low protein diets for the turkey poult. Poultry Sci. 33:1041.

Barrett, F. N., C. G. Card and A. Berridge, 1940. Feeding and confinement rearing experiment with turkeys during 1939. Mich. Agr. Exp. Sta. Quarterly Bull. 23:85-92.

Bird, F. H., 1950. The tryptophan requirement of turkey poults. Poultry Sci. 29:737-740.

Blaylock, L. G., J. R. Hunt, F. Ziegler, E. B. Patterson and W. J. Stadelman, 1954. The effect of energy level of the diet on growth, feed efficiency and degree of fattening of turkeys. Poultry Sci. 33:864-866.

Bolin, D. W., E. W. Klosterman, L. Butler, K. Schlamb and R. Bryant, 1951. Effect of delayed methionine supplementation in chick ration. Poultry Sci. 30:42-46.

Brody, S. Bioenergetics and Growth, With Special Reference to the Efficiency Complex in Domestic Animals. Reinhold Publishing Corporation, 1945.

Cannon, P. R., 1948. The problem of tissue protein synthesis. Fed. Proc. 7:391-396.

Cochran, W. G., and G. M. Cox. Experimental Designs. Wiley, 1950.

Cuthbertson, D. P., A. McCutcheon and H. N. Munro, 1940. The relationship of carbohydrate metabolism to protein metabolism. Biochem. Journal 34:1002-1007.

Draper, C. I. R. J. Evans, M. Rhian and A. W. Brant, 1943. Protein requirements of Broad Breasted Bronze turkeys. Wash. Agr. Exp. Station V-Cir. No. 14.

Dymsza, H., R. V. Boucher and M. G. McCartney, 1953. Response of growing turkeys to variations in the fiber and energy content of mash and pelleted diets. Poultry Sci. 32:898.

Fraps, G. S., 1946. Composition and productive energy of poultry feeds and rations. Texas Agr. Exp. Sta. Bull. 678.

Fritz, J. C., J. H. Hooper, J. L. Halpin and H. P. Moore, 1946. Failure of feather pigmentation in Bronze poults due to lysine deficiency. J. Nutri. 31:387-396.

Funk, E. M., 1943. Protein content of concentrates for turkeys. Mo. Agr. Exp. Sta. Bull. 471.

Geiger, E., 1947. Experiments with delayed supplementation of incomplete amino acid mixtures. J. Nutri. 34:97-111.

Geiger, E., 1948a. The role of the time factor in feeding supplementary proteins. J. Nutri. 36:813-819.

Geiger, E., 1948b. The importance of the time element in feeding of growing rats: Experiments with delayed supplementation of protein. Science 108:42-43.

Geiger, E., 1950. The role of the time factor in protein synthesis. Science 111:594-599.

German, H. L., B. S. Schweigert, R. M. Sherwood and L. E. James, 1949. Further evidence of the role of lysine in the formation of normal Bronze turkey feathers. Poultry Sci. 28:165-167.

Grau, C. R., F. H. Kratzer and V. S. Asmundson, 1946. The lysine requirement of poults and chicks. Poultry Sci. 25:529-530.

Grau, C. R., 1948. Effect of protein level on the lysine requirement of the chick. J. Nutri. 36:99-108.

Grau, C. R., and M. Kamel, 1950. Amino acid imbalance and the growth requirements for lysine and methionine. J. Nutri. 41:89-101.

Hammond, J. C., and S. J. Marsden, 1939. The effect of the level of protein intake on the growth and feed utilization of turkeys. Poultry Sci. 18:11-18.

Henderson, R., and R. S. Harris, 1949. Concurrent feeding of amino acids. Fed. Proc. 8:385.

Henry, K. M., and S. K. Kon, 1946. The supplementary relationships between the proteins of dairy products and those of bread and potato as affected by the method of feeding. With a note on the value of soyabean protein. J. Dairy Res. 14:330-339.

Hill, F. W., and L. M. Dansky, 1950. Studies of the protein requirements of chicks and its relation to dietary energy level. Poultry Sci. 29:763.

Hill, F. W., 1953. New information on lysine and methionine requirements of chicks. Proc. of the 1953 Cornell Nutrition Conference for Feed Manufacturers. 44-61.

Hill, F. W., and L. M. Dansky, 1954. Studies of the energy requirements of chickens 1. The effect of dietary energy level on growth and feed consumption. Poultry Sci. 33:112-119.

Klain, G. J., D. C. Hill and S. J. Slinger, 1954. Supplementation of Poult diets with lysine. Poultry Sci. 33:1280-1282.

Kratzer, F. H., F. H. Bird, V. S. Asmundson and S. Lepkovsky, 1947. The arginine requirement of young turkey poults. J. Nutri. 34:167-171.

Kratzer, F. H., and D. E. Williams, 1948. The glycine requirement of young poults. J. Nutri. 35:315-320.

Kratzer, F. H., D. E. Williams and B. Marshall, 1949. The sulfur amino acid requirements of turkey poults. J. Nutri. 37:377-383.

Kratzer, F. H., 1950a. The activities of d and l lysine for turkey poults. J. Nutri. 41:153-158.

Kratzer, F. H., D. E. Williams and B. Marshall, 1950b. The relation of lysine and protein level in the ration to the development of feather pigment in turkey poults. Poultry Sci. 29:285-292.

Kratzer, F. H., D. E. Williams and B. Marshall, 1951. The tryptophan requirement of young turkey poults. J. Nutri. 43:223-233.

Kratzer, F. H., D. E. Williams and B. Marshall, 1952. The requirement for isoleucine and the activities of its isomers for the growth of turkey poults. J. Nutri. 47:631-635.

Kuiken, K. A., and C. M. Lymon, 1948. Availability of amino acids in some foods. J. Nutri. 36:359-368.

McGinnis, J., J. R. Stern, R. A. Wilcox and J. S. Carver, 1951. The effect of different antibiotics on growth of turkey poults. Poultry Sci. 30:492-496.

Melnick, D., B. L. Oser and S. Weiss, 1946. Rate of enzymic digestion of Proteins as a factor in nutrition. Science 103:326-329.

Milby, T. T., R. G. Jaap and R. B. Thompson, 1939. Turkey production. Okla. Agr. Exp. Sta. Bull. 236.

Mussehl, F. E., 1933. Turkey production. Nebraska Agr. Exp. Sta. Bull. 280.

______. Nutrient Requirements for Poultry. National Research Council, 1954.

Panda, J. N., and G. F. Combs, 1950. Studies on the energy requirement of the chick for rapid growth. Poultry Sci. 29:774-775.

Peterson, D. W., C. R. Grau and N. F. Peek, 1952. Growth and food utilization with diets of varying protein and cellulose levels. Poultry Sci. 31:931.

Price, W. A., Jr., M. W. Taylor and W. C. Russell, 1953. The retention of essential amino acids by the growing chick. J. Nutri. 51:413-422.

Robertson, E. I., and J. S. Carver, 1941. Concentrate feeding of turkeys. Wash. Agri. Exp. Sta. Bull. 402.

Robertson, E. I., R. F. Miller and G. F. Heuser, 1948. The relation of energy to fiber in chick rations. Poultry Sci. 27:682.

Rose, W. C., M. J. Oesterling and M. Womack, 1948. Comparative growth on diets containing ten and nineteen amino acids, with further observations upon the role of glutamic and aspartic acids. J. Biol. Chem. 176:753-762.

Russell, W. C., M. W. Taylor and W. A. Price, Jr., 1951. Retention of essential amino acids by growing chicken. Fed. Proc. 10:392-393.

Russell, W. C., M. W. Taylor and W. A. Price, Jr., 1952. Retention of essential amino acids when inadequate quantities are fed to the growing chick. Fed. Proc. 11:455.

Sauberlich, H. E., and C. A. Baumann, 1948. Amino acid excretion as influenced by dietary proteins of different biological value. Fed. Proc. 7:183.

Saxena, H. C., M. E. Starr, L. G. Blaylock, J. S. Carver and J. McGinnis, 1953. Effect of dietary penicillin on the efficiency of protein utilization by chicks. Arch. Biochem. and Biophys. 44:346-350.

Schoenheimer, R. The Dynamic State of Body Constituents. Harvard University Press, 1946.

Scott, M. L., G. F. Heuser and L. C. Norris, 1948. Energy, protein and unidentified vitamins in poult nutrition. Poultry Sci. 27:773-780.

Scott, M. L., 1953. Amino acid requirements of turkeys. Proc. of the 1953 Cornell Nutrition Conference for Feed Manufacturers. 97-102.

Slinger, S. J., A. M. Morphet, K. M. Gartley and D. Authur, 1952. Effect of penicillin on the growth of turkeys fed diets of varying protein content. Poultry Sci. 31:881-887.

Slinger, S. J., W. F. Pepper and D. C. Hill, 1953. Value of methionine supplementation of chick and poult diets containing a high percentage of wheat. Poultry Sci. 32:573-575.

Slinger, S. J., and W. F. Pepper, 1954. Effect of penicillin on the growth and feed consumption of turkey poults. Poultry Sci. 33:746-753.

Snedecor, G. W. Statistical Methods. Ames, Iowa: The Iowa State College Press, 1946.

Sturkie, P. D. Avian Physiology. Comstock Publishing Associates, 1954.

Titus, H. W. The Scientific Feeding of Chickens. Danville, Illinois: The Interstate Press, 1949.

Thayer, R. H., 1953. Data unpublished. Oklahoma Agricultural and Mechanical College Station.

VITA

William Clarence Lockhart
candidate for the degree of
Master of Science

Thesis: ENERGY-PROTEIN RELATIONSHIPS
IN TURKEY POULT STARTERS

Major: Poultry Nutrition

Biographical and Other Items:

Born: October 6, 1922 at Blossom, Texas

Undergraduate Study: Bethany Nazarene College, 1948; John Brown University, 1949; O. A. M. C., 1949-1950 and 1951-1953

Graduate Study: O. A. M. C., 1953-55

Experiences: Poultry farming, 1943-44; Army, Philippine Islands, Japan 1945-46; Poultry farming, 1947; Worked for O. A. M. C. Poultry Department while taking undergraduate and graduate work.

Member of Spur and Comb Club, Alpha Zeta and Phi Kappa Phi at O. A. M. C.

Date of Final Examination: July, 1955

THESIS TITLE: ENERGY-PROTEIN RELATIONSHPS
IN TURKEY POULT STARTERS

AUTHOR: William Clarence Lockhart

THESIS ADVISER: Rollin H. Thayer

The content and form have been checked and approved by the author and thesis adviser. The Graduate School Office assumes no responsibility for errors either in form or content. The copies are sent to the bindery just as they are approved by the author and faculty adviser.

TYPIST: Betty Jo Cummings

OKLAHOMA AGRICULTURAL AND MECHANICAL COLLEGE

THE GRADUATE SCHOOL

To the Members of the Committee:

You are requested to act as a committee for the examination of William C. Lockhart for the master's degree.

This examination is scheduled to be held in Room 202, Poultry Industries Building at 10:00 a.m. on Friday, July 22, 1955

Major: Poultry

Minor:

Robert MacVicar

Dean of the Graduate School

COMMITTEE:
Rollin H. Thayer, Chairman
Frank Graybill
Magnar Ronning
James Webster
C. A. Roberts

The Graduate Council recommends that the thesis or research be given special attention during the examination. Questions in major and minor departments should be over the fields rather than on specific courses. Questions requiring thought and use of information are preferable to those requiring memory only.

Each member of the committee will please arrange to be present during the entire examination.

IF YOU CANNOT ATTEND, ARRANGE FOR A SUBSTITUTE AND NOTIFY THE CHAIRMAN OF THE COMMITTEE OF THE CHANGE

Date of Degree: August, 1955

Name: William Clarence Lockhart Position: Research Fellow

Institution: Oklahoma A. and M. College Location: Stillwater, Oklahoma

Title of Study: ENERGY-PROTEIN RELATIONSHIPS IN TURKEY POULT STARTERS

Number of Pages in Study: 98 Candidate for What Degree: Master of Science

Under Direction of What Department: Poultry

Statement of Problem: From January 28, 1954 to January 28, 1955 a series of six feeding trials were conducted. The purpose of Trials I, II, III and IV was to determine the dietary energy level that was required to support the most efficient utilization of a good quality protein. Trial V was conducted to find whether or not covariance analysis as outlined by Snedecor (1946) was valid when used to analyse the data of Trials I, II, III, IV and VI. Trial VI was run to determine whether lysine or methionine was the first limiting amino acid in corn-soya turkey poult starter rations containing 22 and 26 percent protein.

Method of Procedure: The natural feed ingredients used in each feeding trial was chemically analysed for moisture, crude protein, fat, crude fiber, calcium, phosphorous and nitrogen free extract. Average values and biological assay values were used in calculating the ration level of methionine and lysine in Trials I, II, and III, IV and VI, respectively. The rations in these Trials were fed to White Holland and Broad Breasted Bronze turkey poults. The poults were confined in electrically heated, wire floored metal batteries for the duration of each trial which was from 26 to 28 days.

Findings and Conclusions: The experimental data indicate that 720 Calories of available energy per pound of ration supported efficient protein utilization at dietary protein levels of 22, 24 and 26 percent. It appears that 780 Calories of available energy supported efficient protein utilization at dietary protein levels of 22 through 28 percent. The dietary energy level of 880 Calories supported efficient protein utilization at protein levels 22 through 30 percent.

The first limiting amino acid at the 22 percent protein level was found to be methionine. The addition of 0.2 percent supplementary dl-methionine at the 22 percent dietary protein level gave an added growth response and increased the efficiency with which feed was utilized. At the same protein level the addition of 0.3 of l-lysine monohydrochloride was ineffective. The addition of 0.1 percent dl-methionine or 0.15 percent l-lysine monohydrochloride gave only a slight growth response at the 26 percent protein level. The simultaneous addition of both amino acids at these levels gave a growth response much greater than when either supplementary level was fed separately. The approximate poult starter requirement level for crude sulfur amino acids appears to be 0.83 and 0.89 percent at the 26 and 28 percent protein levels, respectively.

ADVISER'S APPROVAL Rollin H. Thayer