THE SUPPLEMENTARY VALUE OF TURKEY PROTEIN TO PLANT PROTEINS

by

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CHAPTER I

INTRODUCTION

The Problem

It has been said that improvements during the past years in breeding and feeding of turkeys have resulted in improvements in the protein content of turkey meat (1). Comparison of photographs of birds used in studies in 1940 and 1941 by Harshaw and co-workers (1) with similar turkeys used in 1956 studies (2) indicate a marked improvement in body conformation over the past fifteen years. Turkey producers are concerned with promoting the consumption of turkey. Between 1931 and 1961, the world per capita consumption of turkey increased 6.1 pounds while chicken increased 16.4 pounds, and beef, 36.6 pounds (3). The future of the turkey market depends upon greater consumer acceptance of turkey as an important meat in family meals.

Concurrent with the technological improvements in the production of turkey meat, researchers have become interested in the nutritional quality of the meat in relation to that of other animals. Since it is an animal protein, one would expect it to have a higher biological value than that of plant proteins. Due to the world-wide shortage of protein and the prevalence of protein malnutrition as a serious nutritional problem, it appears that the value of turkey meat

should not be underestimated. Plant protein is financially and geographically within reach of most of the people who are suffering from protein malnutrition. To overcome the relatively low biological value of plant proteins, researchers are utilizing the techniques of supplementation.

The Objective

The purpose of this study was to estimate the supplementary value of turkey protein when fed with intact, natural proteins, peanut flour and corn gluten meal, by measuring the growth rate of animals fed isocaloric diets. It was believed that the study might support the following hypotheses: plant protein supplemented with animal protein will support growth better than plant protein alone, plant protein supplemented with animal protein will support growth as well as animal protein alone, and a single animal protein will support growth better than will protein from a single plant source.

CHAPTER II

REVIEW OF LITERATURE

General Principle of Protein Supplementation

Supplementation of plant proteins may be accomplished by the addition of synthetic amino acids, animal protein, or other plant proteins which have a complementary amino acid content. All of the important amino acids are commercially available. Since the demand for synthetic amino acids has increased to the point of large scale production, the price of these chemicals is not as high as when originally developed.

Early studies (4) with experimental animals demonstrated the supplementary effect of different proteins when used together. Due to the amino acid composition, proteins of milk are superior to those of cereals. A diet combining these two proteins in the right proportions could be as effective as milk alone. An examination of amino acids in foods shows possibilities of combining them so that various proteins may supplement each other. For example, "tryptophan is limited in amount in corn and wheat flour, whereas foods of animal origin provide tryptophan generously (4)."

Because of its ready availability and widespread use, the nutritive value of the soybean protein has been intensively

studied. Due to the fact that seed proteins of legumes and grains constitute the principle and sometimes the only dietary protein of a major segment of the world's population, it is important that their nutritive values be studied in terms of supplementation.

Thus no matter what method is being used for supplementation, the basic principle involved is amino acid nutrition. Amino acid supplementation is based on the results of over fifty years of research on the nutritional quality of proteins and their constituent amino acids. Osborne and Mendel (5) did much of the fundamental work by studying the growth-promoting qualities of isolated proteins. They recognized that specific amino acids were missing or present in low concentrations in those proteins which did not support adequate growth of the animal.

Rose (6) in 1937-38 classified the amino acids found in proteins into two categories: essential, those which the body cannot synthesize at all or not at the rate commensurate with maximum growth, and non-essential, those which the body can readily synthesize from normal food constituents when the essential amino acids are present in an adequate amount in the diet. On the basis of this classification, definite requirements for the various essential amino acids have been determined for various animals, including man. Mitchell and Block (7) tabulated amino acid analyses for various foods and proteins. They compared the pattern of each protein with the tentative requirement

figures. From these comparisons, they established the concept of the first limiting amino acid of a protein. The limiting amino acid is defined as being the amino acid which is present in the least amount in comparison with the desired ratio.

Evolving from studies with animals and especially of poultry diets a general principle of practical and theoretical importance for supplementation has been developed (5). A protein should be supplemented with its first limiting essential amino acid in such an amount that the total of this amino acid in the diet balances with the amount of the second limiting amino acid. Attainment of over-all balance is referred to as a balanced protein or a complete protein.

Factors Affecting Amino Acid Supplementation of Foods

Energy Value of the Diet

A protein can fulfill its nutritional value only if there is sufficient energy in the diet from non-protein sources to satisfy the requirements of the organism for calories. Rosenberg's (8) work with chick diets illustrates the energy-protein relationship. The addition of the first and second limiting amino acid to a corn-soybean meal diet resulted in growth improvement in chicks but the addition of fat to the diet produced better growth and more efficient utilization

of the ration. In the calculation of protein-energy relationships, ideally only the completely balanced portion of the protein should be calculated as protein and the remainder as energy.

Protein Content of the Diet

It is evident that the amount of protein in the diet will affect the amount of the limiting amino acid that should be added. As the percent of protein in the diet is increased at a constant energy level, a point will be reached where the second limiting amino acid will be in balance with the energy content of the diet (5).

Differences in Amino Acid Requirements of a Species

The difference in amino acid requirements between sexes is relatively small. For rat growth (5) the largest difference in amino acid requirements between sexes exists for lysine which is about 0.08 percent of the diet greater for the male than for the female weanling rat. The smallest difference was observed for the amino acid, tryptophan, with the male needing 0.01 percent of the diet more than the female. The age of the organism has the same effect on amino acid supplementation as it does on amino acid requirements.

Availability of Amino Acids from Foods and Feeds

Experimental evidence supports the idea that a portion of the analytically determined amino acids may not be available for assimilation. Gupta and co-workers (9) concluded from their studies

that the biological availability of lysine in corn was about 50 percent, in wheat flour about 70 percent, and in rice about 80-85 percent. Therefore, a research worker cannot assume that a value obtained from an amino acid analysis of a protein is representative of biological activity.

Methods for Evaluation of the Effects of Amino Acid Supplementation of Foods

In general any method used for the evaluation of the nutritive value of a protein should also be useful for the evaluation of the improvement in nutritive value brought about by supplementation of a protein with one or more amino acids.

The rat growth test as discussed by Albanese (5) is recommended as a basis for any program for the evaluation of amino acid supplementation. The level of protein in the designed diet must be low enough to permit the measurement of the first limiting amino acid. For routine evaluation, a 10 percent protein level is usually chosen.

The protein efficiency ratio (PER) may be defined as the ratio between the body weight gained and the weight of the protein consumed. This concept was originated by Osborne and Mendel and according to a recent survey by Derse (10) it is the method of choice for evaluating protein quality. It is usually determined in rat growth experiments in which the test animals are fed diets containing 10-15 percent

protein. This valuable technique does have two limitations which must be kept in mind. Sure (11) pointed out that the PER varies according to the level and type of protein in the diet. The PER also varies with the length of the experimental period, a 3-week period yielding a higher PER than a 4- or 5-week experiment when the same animals and diets are utilized (5).

The nitrogen efficiency ratio is defined as the ratio between the weight gained and the weight of the dietary nitrogen consumed. This is used when synthetic amino acids are used or added to the diet. The commonly used factors to express analytically determined nitrogen in terms of protein do not apply to synthetic amino acids.

Determination of body composition is important in studies of protein value because of the possibility of two groups of animals obtaining identical weight gains from two different types of proteins and yet having considerable difference in body composition. An analysis of the carcasses for water, nitrogen, and fat will reveal such differences if they exist.

Other methods which have been found useful are nitrogen retention, net protein utilization, nitrogen balance index, and protein utilization index. Each problem of supplementation is different in some respect from others. Therefore, each must be treated in an individual manner.

Protein Malnutrition

Proper amino acid supplementation will increase considerably the world's protein supply, a goal of inestimable value in many countries. Protein malnutrition is common in many underdeveloped countries, particularly among young children and pregnant and nursing women. The condition which results from the syndrome of inadequate protein in relation to calories is termed kwashiorkor. It is fatal unless the quantity and quality of protein in the diet is improved.

Kwashiorkor (12) is characterized by edema, pigmented skin lesions, changes in the color and texture of the hair, apathy, anorexia, growth failure, serious biochemical imbalances and pathologic tissue change. The condition is nearly always precipitated in an already chronically malnourished child by an infectious episode, most commonly either dysentery or a childhood disease.

Kwashiorkor (13) is very common in children 1 to 5 years of age and begins to develop as soon as the quantity or quality of protein contained in the mother's milk becomes inadequate for the needs of the growing child (eighth to the tenth month). The inadequacy increases at the time of weaning when the child is likely to receive a diet containing a high proportion of carbohydrate and little or no protein of animal origin. The syndrome develops as growth and maturation are slowed.

The specific mortality rates per 1,000 population of children, 1 to 4 years old in selected countries given in Table 1, shows clearly the areas where protein malnutrition is prevalent.

TABLE I

SPECIFIC MORTALITY RATES PER 1,000 POPULATION OF CHILDREN 1-4 YEARS OLD IN SELECTED COUNTRIES (12)

1955-1956

Country	Mortality rate
	Where kwashiorkor is rare or unknown
Sweden	1.0
United States	1.1
Netherlands	1.2
Australia	1.3
Canada	1.5
Belgium	1.6
France	1.6
Argentina	3.8
Japan	3.8
	Where kwashiorkor is common
Venezuela	12.5
Thailand	14.5
Colombia	20.3
Mexico	24.0
El Salvador	22.7
Ecuador	28.8
Guatemala	42.7
Guinea	55.4
Egypt	60.7

In view of the existing scarcity in many countries of foods which provide protein and the difficulty of increasing rapidly the production of meat, milk, and legumes, it is necessary to consider other sources of protein not at present widely used, which could be made available. These should have the following characteristics (14):

1) They should have a high protein content with a biological value sufficient to support growth, and be easily digested.
2) They should be non-toxic.
3) They should be acceptable to the extent that the majority of the population is willing to include them in the ordinary diet.
4) They must possess characteristics that make it possible to keep them in a good state of preservation under ordinary conditions, until they are consumed.
5) They must be inexpensive.
6) They should preferably be locally produced.

In 1955, the Director General of the World Health Organization (WHO) recognizing the need for the development of new foods, appointed a Protein Advisory Group (15). The purpose of this group was to make recommendations for the development of new food products for human consumption and to stimulate a broad program of research and development

of protein sources. The Advisory Group strongly influences the policies of not only WHO but also the Food and Agriculture Organization (FAO) and the United Nations International Children's Emergency Fund (UNICEF).

This Committee (15) has been, in part at least, responsible for the development of "soya protein in Brazil; fish flour in Mexico, Peru, and Chile; a cereal-cottonseed mixture (Incaparina) in Central America; leaf protein concentrates in Jamacia; peanut-cereal mixtures in Uganda and Nigeria; a protein supplemented maize in South Africa; peanut flour in Senegal; various oil seed meals in the Congo; a chick pea-peanut flour mixture for India; fermented soybean products, such as 'natto and tofri' for Japan and 'tempeh' for Indonesia; plus other promising developments of similar nature."

Studies of the Nutritive Value of Turkey Protein

The nutritional value of turkey protein has not been fully established. Scott (1, 16, 17) and Yang (18, 19, 20) have conducted much of the research in this area. Yang (19) compared the proteins in turkey leg to those of turkey breast meat by feeding young rats an otherwise adequate diet containing 10 percent protein. The two meats were found to have similar biological values. The nutritional value (18) of turkey protein for young rats was greater than that of

casein when tested at protein levels of 5 or 10 percent, was lower than that in eggs due to the lower content of sulfur containing amino acids, and was higher than that of milk proteins, when fed as non-fat milk solids.

Yang (20) also compared the nutritional value of the proteins in turkey meat with that of milk or egg proteins when fed as a protein supplement to white wheat flour. The diets contained 10 percent protein supplied by wheat flour alone or with various combinations in which flour provided 8.75, 7.50, or 5.00 percent protein and dehydrated turkey meat, whole egg solids, or whole milk solids provided 1.25, 2.50, or 5.00 percent protein, respectively. The weight gains, protein efficiency ratios and biological values obtained with the diets containing turkey meat were greater than those with the comparable diets containing egg or milk solids. It was suggested that the superiority of the turkey meat protein may be due to its higher lysine content. Table 2 presents a comparison of nutrient composition of turkey and other meats.

TABLE 2

COMPARISON OF NUTRIENT COMPOSITION OF TURKEY AND OTHER MEATS (1)

Meat	Protein %	Calories per 100 gm.	Fat %	Riboflavin mg./100 gm.	Niacin mg./100 gm.
Turkey, *roasted and boned					
Breast	33.5	194	6.7	0.42	9.4
Leg	30.8	224	11.2	0.94	4.1
Chicken, roasted and boned					
Breast	31.5	138	1.3	0.30	10.5
Leg	25.4	168	7.3	0.60	5.6
Beef, cooked and boned					
Round steak	27.0	233	13.0	0.22	5.5
Hamburger	22.0	364	30.0	0.19	4.8
Pork, cooked and boned					
Ham	24.0	400	33.0	0.24	4.7
Loin chops	23.0	333	26.0	0.24	5.0

*Data for mature turkeys. Younger turkeys would have less fat and more protein (1).

CHAPTER III

PROCEDURE

Basis for the Experimental Diets

The dietary level of a protein that will yield maximum efficiency will vary for each individual protein. Sure (11) illustrated in his studies that the protein efficiency ratio (PER) of wheat tended to improve with increasing protein level in the diet. Wheat fed at a 9.0 percent level had a PER value of 1.05 while a diet containing a 5.0 percent level had a PER value of 0.90. Rolled oats gave the same PER value at 7 to 12 percent protein levels. Egg and milk proteins had a lower PER value when fed at 12 percent levels than when fed at a 5 percent level. Due to their amino acid composition (21, 22), it would be expected that peanut flour would have a higher maximum efficiency at a lower dietary level than would corn gluten meal.

The test animals in this study were fed diets containing 12 percent protein which it is recognized is not the dietary level for maximum efficiency of either peanut flour or corn gluten meal. Albanese (5) recommends a 10-15 percent protein level when determining PER in rat growth experiments, for the purpose of comparing various sources of protein for human consumption.

The ratio for supplementation was planned without regard to the amino acid content of the plant proteins. The one-fourth to three-fourths ratio allows the plant protein to constitute the major portion of the diet. This was done for the purpose of testing a diet that might be inexpensive and would utilize for human consumption the available resources of the underdeveloped areas.

Diets A, B, and C, were control diets used for the purpose of comparing the growth of the animals with those fed the supplemented diets, D and E. Table 3 illustrates the experimental design of the diets.

TABLE 3

EXPERIMENTAL DESIGN OF DIETS

Diet Designation	Turkey Meat %	Corn Gluten %	Peanut Flour %
A	12		
B		12	
C			12
D	3	9	
E	3		9

Selection of Animals

Thirty male weanling albino rats were purchased from a stock laboratory.[1] The weights of the animals were between 37 and

[1] Dublin Laboratory Animals, Dublin, Virginia

46 gms. at the start of the experiment. The rats were assigned according to weight distribution to the five diets, with six to each diet. The rats were housed singly in wire cages.

Composition of the Experimental Diets

There were five isocaloric diets used. The two plant proteins utilized in this study were corn gluten meal and peanut flour. Corn gluten meal, an animal feed, consists chiefly of the corn gluten separated in the wet milling process of starch manufacture. The composition of corn gluten meal (21) is 40 percent protein; it has on the average 2.0 percent fat and is low in fiber. Peanut flour is a product obtained by compression of the peanut to remove the oil. The nutrients in the resulting flour (22) are protein 61.94 percent, fat 0.40 percent, fiber 3.43 percent, and ash 4.40 percent.

The turkey meat was obtained from the breasts of Beltsville turkeys, approximately 26 weeks old. The meat was freed as completely as possible from tendons and visible fat, then dried in a Virtis macro freeze-dryer. After lyophylizing, the meat was stored at -20° C. The analyzed value of the protein content of the lyophylized turkey meat was 92.1 percent.

The protein value of the sources of protein used was determined by the Kjeldahl Method (23) and calculated as nitrogen x 6.25. Fat content of the diets was determined by ether extraction (24), using the Goldfisch Fat Extractor.

TABLE 4

DIET COMPOSITION IN PERCENTAGE

Components	Diet				
	A	B	C	D	E
Sucrose	69.97	53.73	62.83	57.79	64.62
Corn oil	10.0	10.0	10.0	10.0	10.0
Jones and Foster Salt	4.0	4.0	4.0	4.0	4.0
Non-nutritive fiber[1]	2.0	2.0	2.0	2.0	2.0
Vitamin-dextrose mixture	1.0	1.0	1.0	1.0	1.0
Turkey breast meat	13.03	-	-	3.26	3.26
Corn gluten meal	-	29.27	-	21.95	-
Peanut flour, defatted	-	-	20.17	-	15.12
Total	100.0	100.0	100.0	100.0	100.0

[1]Alpha Cel, Nutritional Biochemicals Co., Cleveland, Ohio

Administration of Food and Daily Care of Animals

Food was given ad libitum for a period of 28 days. Spilled or left-over food was weighed and the actual food intake was recorded. Tap water was given ad libitum. Each rat was weighed every other day and the weight recorded.

CHAPTER IV

RESULTS AND DISCUSSION

Growth of Rats in the Five Diet Groups

The weight gain of the rats consuming the five different diets has been summarized in Table 5 and Figure 1. Figure 2 illustrates the amino acid composition of each of the diets and relates it to the amino acid requirement of the young growing rat.

There was a distinguishable difference between the growth rates of the animals in the five diet groups. The growth rate of the rats fed Diet A (12 percent turkey protein) was better than that of the other groups. The limiting amino acid in this diet was tryptophan with the remainder of the amino acids being present in an amount near that required for normal rat growth. The mean weight gain of the animals on this diet was 92.33 gms. The growth of the animals receiving Diet C which contained the plant protein, peanut flour, was very close to that of the animals fed Diet A, containing turkey meat. The mean weight gain of rats consuming Diet C was 88.16 gms. Lysine was the first limiting amino acid with tryptophan the second in this diet.

The poorest growth was obtained with Diet B, which contained the plant protein, corn gluten meal. This can be attributed

FIGURE 1 - WEIGHT GAIN OF YOUNG RATS FED THREE DIFFERENT PROTEINS AND TWO COMBINATIONS OF PROTEINS

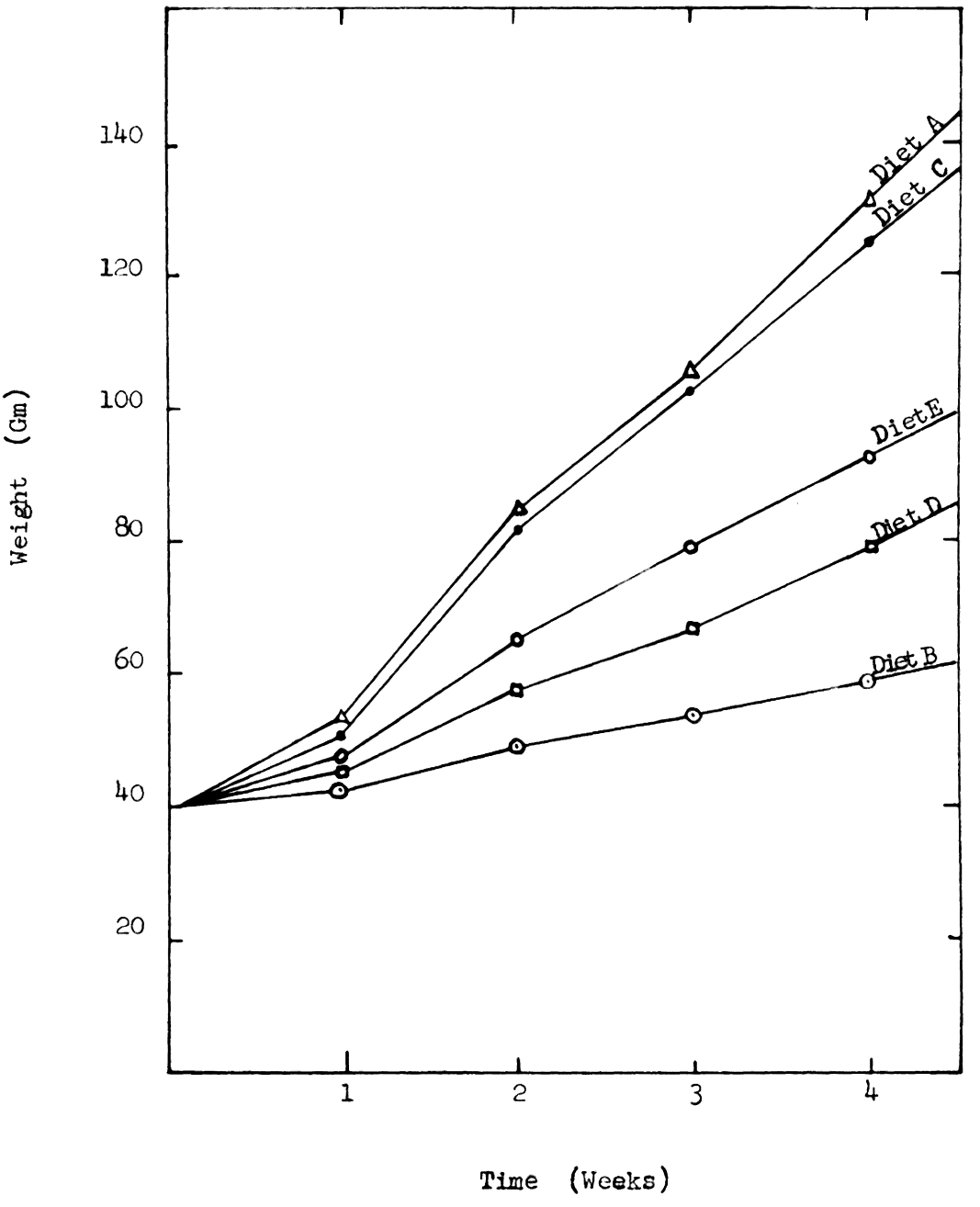
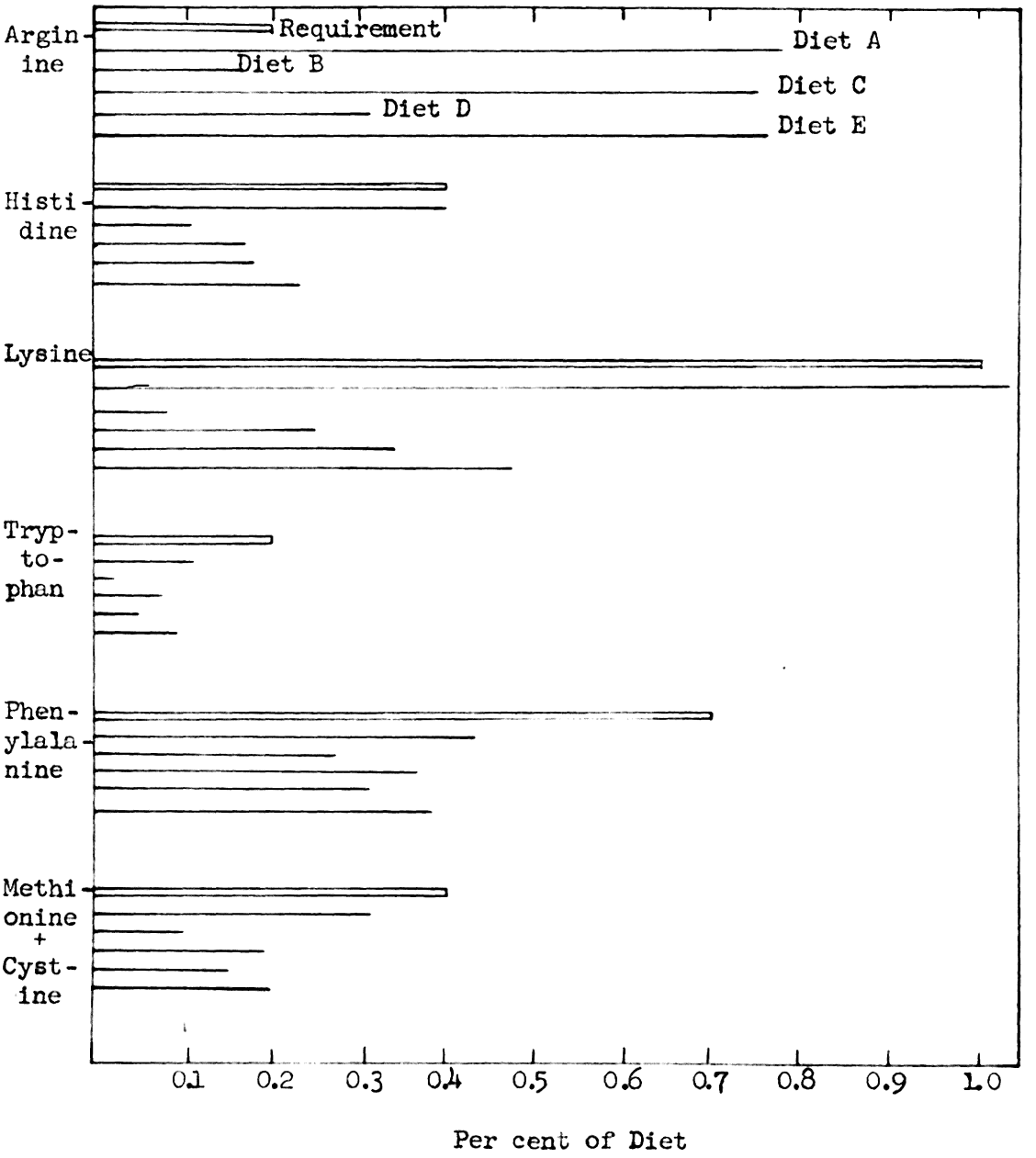
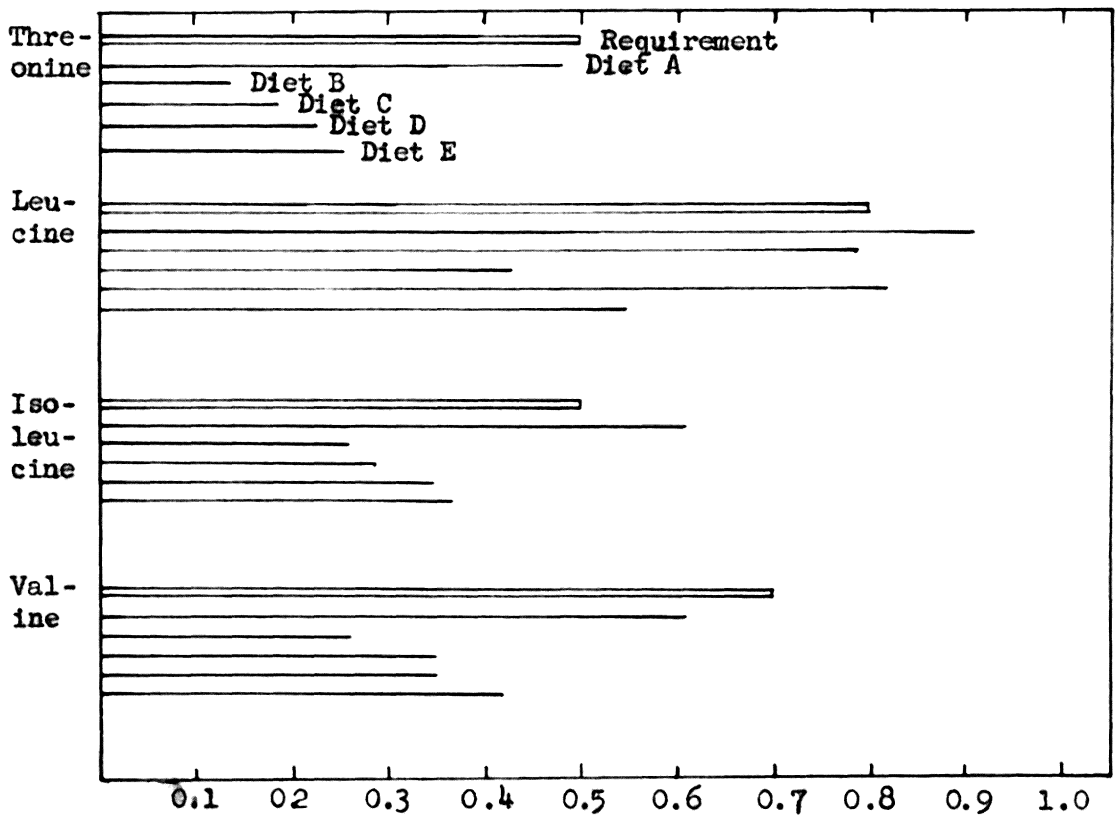


FIGURE 2 - COMPARISON OF AMINO ACID COMPOSITION OF DIETS WITH AMINO ACID REQUIREMENTS OF THE YOUNG RAT (6)



"FIGURE 2 (CONTINUED)"



to its amino acid composition. This protein furnished only 8 percent of the lysine requirement needed by the growing rat and 12 percent of the tryptophan requirement with only leucine being near the requirement. The mean weight gain of these animals was 17.4 gms. Data was not used for one rat in Group B due to an error in recording his growth.

When corn gluten meal was supplemented with turkey meat (Diet D), the mean weight gain was almost 100 percent higher, 33.83 gms. as compared to 17.4 gms. The supplementation with the turkey meat, which provides an ample supply of lysine, improved the 8 percent lysine level in Diet B to 33 percent in Diet D. The effects of the supplementation on the amounts of the individual amino acids in each diet can be seen in Figure 2.

When peanut flour was supplemented with turkey meat (Diet E), the weight gain was less than that obtained when feeding the peanut flour alone in Diet C. An examination of the amino acid patterns of the two diets reveals that the best growth should have been obtained with Diet E. The amino acid composition of Diet E resembled that of the amino acid requirement pattern of the rat more closely than did the composition of Diet C. However, the mean weight gain in Diet E was 50.66 gms. and in Diet C was 88.16 gms. The total food consumption by rats in Diet E was 50 gms. less than that eaten by animals in Diet C, which may account in part for the difference. No explanation is available for these results.

These findings pertaining to growth illustrate that the degree to which a single animal protein will support growth better than will protein from a single plant source depends upon the quality of the protein. It would be expected that plant protein supplemented with turkey protein would support growth as well as animal protein alone if the proper supplementation ratio is used. A poor quality plant protein supplemented with turkey protein will support growth better than the plant protein alone.

TABLE 5

WEIGHT GAIN OF YOUNG RATS FED THREE DIFFERENT PROTEINS AND TWO COMBINATIONS OF PROTEINS

Diet	A	B	C	D	E
No. of animals	6	5	6	6	6
Total gain gm.	90	17	96	38	53
	92	17	104	23	50
	106	17	81	30	50
	90	21	80	36	42
	69	15	79	42	54
	107		89	34	55
Total	554	87	529	203	304
Mean	92.3	17.4	88.2	33.8	50.7

Protein Efficiency Ratios of Experimental Diets

The protein efficiency ratios of the five different diets have been summarized in Table 6. Growth is directly proportional to the amount and quality of the protein in the diet (25). This may be observed from the values in Table 6. The mean weight gain per gram of protein consumed in Diet A was 3.0. Diet A contained the best quality protein as the amino acid composition was nearest the amino acid requirement of the rat. When comparing the PER values of Diets B and D, they are directly proportional to the growth results obtained from those diets. The supplementation of Diet B with turkey meat produced approximately a 100 percent increase in both PER value and the growth rate. However, the supplementation of peanut flour with turkey meat (Diet E) decreased the PER value. The reason for this unexpected lowering of the growth promoting value of the two proteins when combined is not known.

TABLE 6

PROTEIN EFFICIENCY OF THE FIVE DIETS

Diet	A	B	C	D	E
No. of animals	6	5	6	6	6
PER value	2.9	0.9	3.0	1.8	2.2
	3.1	0.8	3.1	1.1	2.1
	3.3	0.9	2.7	1.5	2.1
	3.1	1.0	2.7	1.6	1.7
	2.6	0.7	2.9	1.8	2.1
	3.1	-	3.0	1.5	2.2
Total	18.1	4.3	17.4	9.3	12.5
Mean	3.0	0.9	2.9	1.5	2.1

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ABSTRACT

Five experimental groups of male weanling albino rats were fed adequate diets containing 12 percent protein for a period of 28 days. Peanut flour and corn gluten meal proteins were combined with turkey protein in the ratio of 9 percent to 3 percent, respectively. The supplementary value of turkey protein to intact natural proteins was determined by comparing the growth rates from the different groups of animals.

Best growth, 92.3 gms., was obtained when feeding an adequate diet containing 12 percent turkey meat protein. Corn gluten meal, when fed at the 12 percent level, produced the poorest weight gain, 17.4 gms. Supplementation of the corn gluten meal with turkey meat increased the growth approximately 100 percent to 33.8 gms. Gain in weight obtained when feeding 12 percent peanut flour, 88.2 gms., was close to that obtained for the turkey protein. Supplementation of the peanut flour with turkey protein produced a decrease in growth of the animals. The PER values found were 3.0 for turkey meat, 0.9 for corn gluten meal, 2.9 for peanut flour, 1.5 for corn gluten supplemented with turkey meat, and 2.1 for peanut flour supplemented with turkey meat.