SOME NUTRIENT REQUIREMENTS OF JAPANESE QUAIL (*COTURNIX COTURNIX JAPONICA*)

by

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TABLE OF CONTENTS

TABLE OF CONTENTS--*Continued*

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF ILLUSTRATIONS

ABSTRACT

Since 1965, the Poultry Science Department at the University of Arizona has conducted a number of experiments in order to evaluate the usefulness of the Coturnix quail in physiological and nutritional research. This study includes results of nine recent experiments, which represent an attempt to determine some basic nutrient requirements of the Coturnix. When appropriate, reference and comparisons have been made to previously established nutrient requirements of the domestic chicken and the turkey and of two species closely related to the Coturnix--the bobwhite quail and the ringnecked pheasant. In general, dietary requirements of the Coturnix have been found to approximate those of the aforementioned birds, although the Coturnix has also been shown to be unique in many ways. Under experimental conditions described herein, the amount of total protein required in the diets of growing Coturnix and of mature, laying Coturnix hens was found to be 28 and 20%, respectively. Optimum levels of the amino acids methionine plus cystine and glycine for growth of the young bird were observed to be 0.775 and 1.277%, respectively, of the diet. Supplementation of a practical corn-soybean ration with DL-methionine was found to be unnecessary for optimum performance of Coturnix breeders. Vitamin A and pyridoxine were shown to be required at levels of 500 I.U. per pound and 1.2 mg per pound, respectively, for optimum growth of the young bird.

CHAPTER I

INTRODUCTION

The first written reports of domesticated quail in Japan appear in the twelfth century, when they were developed for song. It is believed that birds of the genus Coturnix were either domesticated in Japan in the previous century or that domesticated Coturnix quail were brought from China to Japan at about this time. For centuries these birds served as a source of food in countries of Asia and Europe, but it was not until the twentieth century that the Coturnix gained commercial status in Japan as a source of meat and eggs for human consumption. Today, because of its highly efficient production of animal protein, the Coturnix serves as an increasingly important source of eggs and meat, particularly for the populations of Japan, Hong Kong and Taiwan. In some parts of the United States the dark flesh of the Coturnix breast and leg are treated as delicacies, while the eggs are hard-cooked, colored and pickled.

The Coturnix, native to all continents but the Americas, was introduced into this country by game bird enthusiasts toward the end of the nineteenth century. Attempts by state game commissions in the 1950's to establish permanent colonies of Coturnix as game birds, however, met with little success, primarily because of the semi-migratory character of the bird.

By far the most important role of the Coturnix in this country has come with the recognition of its value as an experimental laboratory animal. Biological research has often been handicapped by limitations of time, space and expense, and it is in the partial alleviation of these problems that the Coturnix excels. Since 1955, studies in virology, oncology, embryology, experimental psychology, toxicology and agricultural and veterinary sciences have made increasing use of the Coturnix. In addition, the similarity of its physiological characteristics to those of the domestic fowl and to the turkey make the Coturnix invaluable as a pilot animal for avian research.

The development of young Coturnix is extremely rapid. During the first week they more than triple in body weight from about seven grams at hatching. At two weeks, strong flight is possible, and at three weeks, the sexes are easily identifiable. Females begin laying eggs at about five and a half weeks and are in full production by seven. Males attain an adult body weight of about 110 grams at seven weeks, and females reach an adult size of about 140 grams at eight weeks. It is possible for females to sustain egg production for as long as eighteen months and to produce as many as 400 eggs in this time. The average egg from a mature female weighs approximately ten grams, representing about seven percent of the body weight of the bird. This compares with an average of three percent for the chicken and one percent for the turkey. The short life cycle of the Coturnix, particularly in comparison to that of the domestic chicken and to that of the turkey, and its ability to produce three to four generations a year greatly enhance its importance as a research animal, particularly for the geneticist.

In addition to its advantage in the economy of time, the Coturnix is economical with regard to space and resources. Eight to ten adult quail can occupy to same amount of space as one large chicken, and feed consumption for the adult Coturnix averages about twenty grams per day, as compared with about 115 grams per day for the chicken. The Coturnix is therefore particularly valuable in studies involving diets composed of costly ingredients, as in the feeding of chemically pure amino acids rather than intact protein.

With these obvious advantages in mind, in 1965 the Poultry Science Department at the University of Arizona established a colony of Coturnix quail in order to evaluate their usefulness as experimental animals for physiological and nutritional research. To date, much of the work involving Coturnix has been in the areas of physiology and genetics, with little effort as yet having been directed toward the establishment of definite nutritional requirements. Before the Coturnix can attain its full value as a research tool, these must be determined. This study is an attempt to establish some of the nutrient requirements of the Coturnix, particularly in the areas of total protein and some amino acids and vitamins. This work is preliminary and is intended to provide direction and guidance for more sophisticated and detailed work in this area.

CHAPTER II

REVIEW OF LITERATURE

A limited amount of published data is available concerning specific nutrient requirements of the growing and adult Coturnix. It has been necessary, therefore, to turn to the rather vast compilation of literature which exists concerning two more or less near relatives of the Coturnix--the bobwhite quail and the ring-necked pheasant, both of which are members of the same family Phasianidae as the Coturnix--in order to establish some reference points for the investigation of the dietary requirements of the Coturnix.

Almost no research was conducted on the nutrition of quail before the 1930's. In 1934 an early study of the protein requirements of young bobwhite quail was published by Norris (1) in which he reported that most rapid growth of the young bird was observed at a dietary protein level of 27%, although the difference in rate of growth at this level and at a level of 24% was not great. Two years later, Norris *et al.* (2) reported that maximum growth for ringnecked pheasants was obtained on a 30% protein diet, although excellent growth was also shown on diets of 21, 24 and 27% protein. Norris, therefore, recommended a practical diet of 24% protein for young ringnecked pheasants.

In subsequent years, the majority of researchers in the field has occurred with Norris and has reported the protein requirement for both young, growing bobwhite quail and ringnecked pheasants to be between 24 and 30% of a practical corn-soybean diet. Nestler (3), on the basis of three criteria--growth, livability and efficiency of feed utilization--in 1949 established a protein level of 28% as optimum for growth of bobwhite quail during the first ten weeks after hatching. But after 2/3 mature weight was reached, he found the difference in efficiency between 28 and 22% protein to be small enough to justify the feeding of the lower level. Also in 1949, Scott and Reynolds (4) suggested a 29.1% protein, 1.7% glycine diet which produced uniform growth, freedom from bone deformities and freedom from perosis in young ringnecked pheasants. Baldini *et al*. (5) in 1950 reported best growth and livability for young bobwhite quail at a protein level of 28%, and four years later Scott *et al*. (6) reported the same requirement for young ringnecked pheasants, but with a subsequent reduction of protein content to 24% of the diet at three weeks of age. A later study reported in 1963 by Scott *et al*. (7) established a protein requirement of 26.5% for both young bobwhite quail and ringnecked pheasants when the diets were adequately supplemented with the amino acid methionine. Maximum growth and efficiency of feed utilization and marked improvement in feathering were shown when 0.1% methionine was added to the diet, raising the total sulfur amino acid content to 3.66% of the protein. Scott, therefore, believed the sulfur amino acid requirement of young ringnecked pheasants and bobwhite quail to be approximately the same as that of the young domestic chicken when expressed as a percentage of protein in the diet.

One notable exception to the above findings was suggested by Baldini et al. (8) in 1953 when they reported the protein requirement for young bobwhite quail to be no more than 20% of the diet, provided the amino acid lysine was supplied in adequate amount. He suggested a lysine requirement of 1.3% of the diet when the protein level is 20-24%.

By far the greatest volume of work on the protein requirements of the birds under consideration has been concerned with the young growing bird, with a resultant scarcity of published data concerning the protein requirements of the adult bird, with particular reference to the laying hen.

As early as 1932 Callenbach et al. (9), working with ringnecked pheasants, reported better early growth on a 24% protein diet than on an 18.50% protein chick starter diet. This advantage was maintained by both sexes until eight weeks of age, but by twelve weeks, differences in body weights for both males and females were not significant.

In 1949, Nestler (3) published data from ten years of experimentation with bobwhite quail breeders. Using protein levels in 2% increments from 13 to 29% of the diet, he reported no statistically significant differences in length of survival, fertility or hatchability. Maximum egg production was obtained at the 23% protein level, and there was a tendency for egg weight to increase as the protein level was raised from 13 to 23%, but there was no significant increase about 24% protein.

Recently a considerable amount of research into the protein requirements of Coturnix quail breeders has been conducted and reported by J. R. Howes of Auburn University at Auburn, Alabama (10). He found improved growth and egg production when the protein level of the diet was increased from 18 to 23%, thus establishing the protein requirements at about 23% for the laying Coturnix hen. Supplementation of the diet with the amino acids glycine, lysine and methionine, individually and collectively, resulted in improved egg production only with the addition of methionine.

By the early 1950's, the vitamin A requirement of both young bobwhite quail and ringnecked pheasants had been fairly well established by several workers. In 1949, Nestler et al. (3) reported that both survival and growth were optimum with bobwhites receiving 3000 I.U. of vitamin A per pound of feed during the growing period. In the same year, Woodward (12) similarly reported good growth of young bobwhites on diets containing 3000 I.U. of vitamin A per pound. Also in 1949, Scott and Reynolds (4) indicated a requirement of 9500 I.U. of vitamin A per pound of diet for pheasant chicks. Good growth and livability of bobwhite quail to sixteen weeks of age was obtained by Harper et al. (13) with a diet containing 3000-4000 I.U. of vitamin A per pound, although a reasonably high level of storage of the vitamin in the liver was not obtained until the vitamin A concentration in the diet was increased to 5000 or 6000 I.U. per pound.

In 1966, Shellenberger and Lee (14) reported effects on growth and viability of young Japanese quail as related to dietary vitamin A and energy levels. Using low energy diets (1890 kcal productive energy per kg), with vitamin A levels ranging from zero to 4400 U.S.P. units per kg of diet, they obtained no demonstrable effect of vitamin A supplementation on growth, although a direct relationship between vitamin A level and survival was seen. At levels of 0, 550 and 1100 U.S.P. units of vitamin A per kg of diet mortality was high and deficiency symptoms including weakness and mild to moderate swelling of the eyes, accompanied in some cases by mild infection and "cheesy" exudates, were readily apparent. At levels of 1650 U.S.P. units and higher, viability was considered normal, and deficiency symptoms were not apparent. No marked differences in growth response were shown as a result of varying vitamin A levels in the diet when a high energy diet (2240 kcal productive energy per kg) was employed, and viability was normal at levels of 1100 U.S.P. units of vitamin A and above.

A pyridoxine requirement has not been established for either the young bobwhite quail, the young ringnecked pheasant or the young Coturnix.

CHAPTER III

PROTEIN AND AMINO ACID STUDIES--YOUNG BIRDS

Introduction. To date, there is no published data known to this author concerning the protein and/or amino acid requirements of the young Coturnix quail. A rather large amount of literature is available, however, on two close relatives of the Coturnix--the young bobwhite quail and the young ringnecked pheasant. Norris (1), Nestler (3), Baldini *et al*. (5) and Scott *et al*. (7) reported protein requirements of 27%, 28%, 28% and 26.5%, respectively, for the young bobwhite quail. The following workers reported similar requirements for the young ringnecked pheasant: Norris *et al*. (2), 24%; Scott and Reynolds (4), 29.1%; Scott *et al*. (6), 28%; and Scott *et al*. (7), 26.5%. In addition, Baldini *et al*. (8) reported a lysine requirement of 1.3% of the diet for young bobwhite quail, and Scott *et al*. (7) suggested a sulfur amino acid level of 3.66% of the protein for both young bobwhite quail and ringnecked pheasants.

Using the above work as a guide, four experiments were designed in an attempt to establish some optimum levels of total protein and, individually, the amino acids methionine plus cystine, glycine and lysine for the young Coturnix. The following four criteria were employed when determining levels of optimum performance: (1) body weight, (2) livability, (3) feed consumption and (4) freedom from recognized deficiency symptoms.

General Experimental Proceedure for Young Birds. Young quail were randomized into experimental groups at hatching and were housed in an electrically heated battery with raised wire floors. Coturnix chicks are quite hardy and can be successfully brooded in modified commercial chick battery brooders maintained at a temperature of 100°F to compensate for the chicks' initial inability to maintain body temperature, particularly during the critical first four or five days. After three weeks, supplemental battery heat was discontinued, and the chicks were maintained at a constant room temperature of 75-80°F. Continuous lighting was in effect for the duration of all experiments. Feed and water were supplied *ad libitum* throughout all studies, each of which lasted for a period of five weeks, at which time quail chicks have completed their period of most rapid growth. Birds and feed were weighed at weekly intervals, and when fecal collections were taken this was done on each of the last three days of the fifth week. Each dietary treatment consisted of either three or four replicate groups of approximately fifteen birds (mixed sexes) per group.

Protein was analyzed in the laboratories of the Poultry Science Department of the University of Arizona, using the official method of the Association of Official Agricultural Chemists (19).

Experiment Q-19: Total Protein

Procedure.. Unpublished work at the University of Arizona suggested that the protein requirement of young Coturnix quail is similar to that of young bobwhite quail and ringnecked pheasants. Experiment Q-19 was instituted in order to substantiate the findings of this preliminary work. Five isocaloric diets, ranging in total protein content from 18.2 to 30.6% were formulated, with calcium, available phosphorous, zinc and manganese levels held constant. Calculated protein levels were as follows: 18.2, 21.3, 24.4, 27.5 and 30.6%. To prevent the effects that varying amino acid patterns may have on the total protein requirement, a protein premix consisting of five protein sources and DL-methionine was first formulated. When supplied at levels of 40.0, 47.5, 55.0, 62.5 and 70.0% of the diet, this provided the total protein content of each ration, resulting in identical amino acid patterns for all experimental diets, but at varying levels of total protein. Percent ingredient compositions of the protein premix and of the Q-19 experimental diets are presented in Tables 1 and 2, respectively. Table 3 shows a calculated analysis of each Q-19 diet, and Table 4 contains calculated analyses of the amino acid compositions.

Results and Discussion. Body weight at five weeks of age was considered to be the most important single criterion in the establishment of an optimum level of total protein in the diet. A summary of the effects of dietary protein level on body weight is

Table 1. Percent ingredient composition of protein premix (Q-10 and Q-19).

Ingredient		%
Soybean meal, solvent		69.50
Fish meal, sardine		10.00
Meat and bone scraps		5.00
Dehydrated alfalfa meal		5.00
Whey, dried whole cheese		5.00
Animal fat		5.00
DL-methionine		0.50
	Total	100.00

Table 2. Percent ingredient compositions of experimental diets (Q-19).

Ingredient	18%	21%	24%	27%	30%
Protein premix[1]	40.00	47.50	55.00	62.50	70.00
Glucose monohydrate	52.30	43.55	34.05	24.85	14.80
Dicalcium phosphate	2.00	1.75	1.25	0.75	0.50
Animal fat	-	1.50	4.00	6.20	9.00
Vitamin premix[2]	5.00				
Salt	0.50		Same		
Trace mineral premix[3]	0.20				
Total	100.00	100.00	100.00	100.00	100.00

[1] See Table 1.

[2] Supplied the following per kg of diet: 19,850 I.U. vitamin A, 3,075 I.C.U. vitamin D_3, 11 I.U. d-alpha-tocopheryl acetate, 27 mcg vitamin B_{12}, 4.4 mg 2-methyl-napthoquinone, 8.9 mg riboflavin, 56.0 mg niacin, 22.5 mg d-calcium pantothenate, 1,860 mg choline chloride and 250 mg ethoxyquin (as a preservative).

[3] Supplied the following per kg of diet: 40 mg Fe, 120 mg Zn, 2 mg Mo, 120 mg Mn, 336 mg Ca, 8 mg Cu, 3 mg I and 3 mg Co.

Table 3. Calculated analyses of experimental diets (Q-19).

Ingredient	18%	21%	24%	27%	30%
Protein, %	18.20	21.31	24.41	27.50	30.60
Fat, %	2.49	4.46	7.42	10.08	13.34
Fiber, %	2.82	3.30	3.77	4.25	4.73
Productive energy, kcal/lb	1036.17	1022.41	1027.66	1028.33	1035.00
Metabolizable energy, kcal/lb	1271.72	1277.22	1306.46	1329.86	1361.39
P.E./Protein ratio	56.93	47.99	42.11	37.39	33.83
M.E./Protein ratio	69.87	59.95	53.53	48.35	44.49
Xanthophylls, mg/lb	1.56	1.86	2.15	2.44	2.73
Calcium, %	1.06	1.09	1.05	1.01	1.04
Phosphorus, %	0.79	0.82	0.80	0.79	0.81
Available phosphorus, %	0.63	0.63	0.59	0.55	0.55
Zinc, PPM	134.76	137.29	139.81	142.35	144.87
Manganese, PPM	140.74	142.57	144.39	146.22	148.05

Table 4. Calculated amino acid compositions of experimental diets (Q-19).

Amino Acid	% Amino Acid/1000 kcal Productive Energy				
	18%	21%	24%	27%	30%
Arginine	1.28	1.52	1.73	1.95	2.16
Lysine	1.17	1.38	1.58	1.78	1.97
Methionine	0.48	0.57	0.66	0.73	0.82
Cystine	0.25	0.29	0.33	0.38	0.41
Cystine plus methionine	0.72	0.86	0.99	1.10	1.23
Tryptophan	0.28	0.34	0.38	0.43	0.48
Glycine	1.08	1.28	1.45	1.64	1.82
Phenylalanine	0.84	0.99	1.13	1.28	1.41
Tyrosine	0.68	0.81	0.92	1.04	1.15
Phenylalanine plus tyrosine	1.52	1.80	2.06	2.32	2.56
Valine	0.98	1.17	1.33	1.50	1.65
Leucine	1.37	1.63	1.86	2.09	2.31
Isoleucine	0.96	1.13	1.29	1.46	1.61
Threonine	0.73	0.87	0.99	1.12	1.24
Histidine	0.44	0.52	0.59	0.67	0.74

shown in Table 5. Feed conversions calculated for the entire five week period of the study are also included. A progressive increase in body weight was noted as dietary protein increased from a level of 18 to 27%. A leveling off occurred between the 27 and 30% protein diets, indicating that the total protein needs of the young Coturnix had been adequately met at about the 27% level of protein. When fifth week body weight was plotted graphically as a function of percent dietary protein (Figure 1), a total protein requirement of about 28% was indicated.

At these levels of dietary protein there appeared to be some correlation between dietary treatment and feed conversions as related to body weight gain. Grams of feed consumed per gram of body weight gain was improved significantly at 24% dietary protein. Productive energy consumption per gram of body weight gain showed decreases at the higher levels of dietary protein, but these differences were not shown to be statistically significant. Grams of protein consumed per gram of body weight gain was approximately the same for all five treatments.

Table 5. Effect of dietary protein level on body weight and feed conversions of young Japanese quail.

Dietary protein level, %	Fifth week body weight (gms)	Gms feed consumed/gm body weight gain	Gms protein consumed/gm body weight gain	Kcal P.E. consumed/gm body weight gain
18	94.55	5.29[a][1]	0.95[a]	11.83[a]
21	96.38	5.52[a]	1.16[a]	12.17[a]
24	106.70	4.26[b]	0.89[a]	9.44[a]
27	112.40	4.59[b]	0.96[a]	10.19[a]
30	114.35	4.58[b]	0.96[a]	10.16[a]

[1] Means having different letter superscripts are significantly different at the 0.05 level of probability (Duncan, 15).

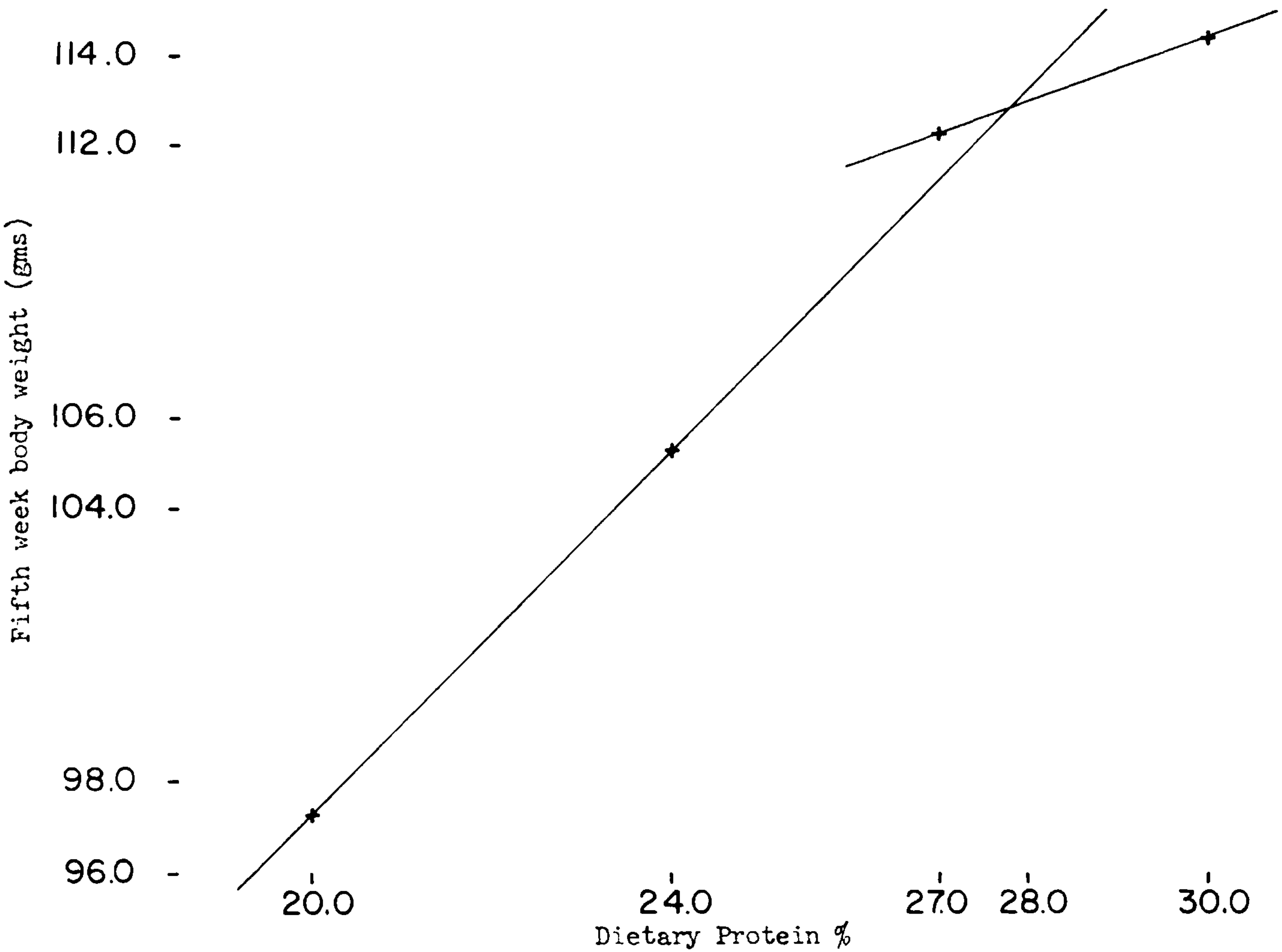

Figure 1. Effect of dietary protein level on fifth week body weight of Japanese quail.

Experiments Q-21, Q-23 and Q-27: Sulfur Amino Acids, Glycine and Lysine.

Procedure. Experiments Q-21, Q-23 and Q-27 were conducted in an attempt to establish some optimum levels of the amino acids methionine and cystine, glycine and lysine, respectively, for growth of the young Coturnix. Baldini et al. (8) reported a lysine requirement of 1.3% of the diet for young bobwhite quail, and Scott et al. (7) a sulfur amino acid requirement of 3.66% of the protein for both young bobwhite quail and ringnecked pheasants, but to date, no requirements for specific amino acids have been established for the young Coturnix.

Three basal diets were formulated, each low in the respective amino acid to be studied. Practical diets were utilized in Q-21 and Q-27, but it was necessary to employ a purified isolated soybean protein-glucose diet in Q-23 to obtain a minimum level of dietary glycine. Percent ingredient compositions of the basal diets are shown in Table 6, and a calculated analysis of each appears in Table 7. Calculated total protein levels were 24.7, 29.0 and 25.2% respectively. Productive energy/protein ratios approximated those at the highest levels of performance in experiment Q-19.

Experiment Q-21 consisted of six treatments, all of which were identical except for the amount of sulfur amino acid supplied by the diet. A calculated analysis of the basal showed a combined methionine and cystine level of 0.718%, to which graded amounts

Table 6. Percent ingredient compositions of basal diets (Q-21, Q-23 and Q-27).

Ingredient	Q-21 (%)	Q-23 (%)	Q-27 (%)
Ground yellow corn	-	-	38.55
Ground milo	43.00	-	-
Soybean meal, solvent	42.50	-	35.00
Cottonseed meal	-	-	10.00
Dehydrated alfalfa meal	3.00	-	3.00
Glucose monohydrate	-	43.17	-
Isolated soybean protein	-	35.00	-
Cellulose	-	3.00	-
Corn Oil	-	8.00	-
Animal fat	3.00	-	5.00
DL-methionine	-	0.57	0.20
Vitamin premix[1]	5.00	-	5.00
Purified vitamin premix[2]	-	4.00	-
Calcium carbonate	1.00	0.05	1.25
Dicalcium phosphate	2.00	4.21	1.00
Purified mineral premix[3]	-	2.00	-
Trace mineral premix[4]	-	-	0.20
Salt	0.50	-	0.50
Antibiotic	-	-	0.10
Chromium oxide	-	-	0.20
Total	100.00	100.00	100.00

Table 6--Continued.

[1] Supplied the following per kg of diet: 19,850 I.U. vitamin A, 3,075 I.C.U. vitamin D_3, 11 I.U. d-alpha-tocopheryl acetate, 27 mcg vitamin B_{12}, 4.4 mg 2-methyl-napthoquinone, 8.9 mg riboflavin, 56.0 mg niacin, 22.5 mg d-calcium pantothenate, 1,860 mg choline chloride and 250 mg ethoxyquin (as a preservative).

[2] Supplied the following per kg of diet: 10,012 I.U. vitamin A, 961 I.C.U. vitamin D_3, 8.7 I.U. d-alpha-tocopheryl acetate, 30 mcg vitamin B_{12}, 6.6 mg 2-methyl-napthoquinone, 12 mg riboflavin, 88 mg niacin, 15 mg d-calcium pantothenate, 4.0 mg thiamine hydrochloride, 0.9 mg folic acid, 91 mcg biotin, 2.2 gm choline chloride, 1.8 mg pyridoxine and 50 mg ethoxyquin (as a preservative).

[3] Supplied the following per kg of diet: 139 mg Mn, 385 mg Fe, 55 mg Cu, 103 mg Zn, 1.6 mg Co, 749 mg Mg, 4.3 mg Mo and 4.1 mg I.

[4] Supplied the following per kg of diet: 40 mg Fe, 120 mg Zn, 2 mg Mo, 120 mg Mn, 336 mg Ca, 8 mg Cu, 3 mg I and 3 mg Co.

Table 7. Calculated analyses of basal diets (Q-21, Q-23 and Q-27).

Ingredient	Q-21	Q-23	Q-27
Protein, %	24.71	29.04	25.19
Fat, %	4.37	8.18	6.87
Fiber, %	5.09	3.04	5.75
Productive energy, kcal/lb	883.35	1153.16	924.45
Metabolizable energy, kcal/lb	1197.46	1411.17	1257.91
P.E./Protein ratio	35.75	39.72	36.70
M.E./Protein ratio	48.46	48.60	49.93
Xanthophylls, mg/lb	2.34	-	5.04
Calcium, %	1.07	1.12	0.92
Phosphorus, %	0.82	1.05	0.66
Available phosphorus, %	0.49	0.86	0.33
Zinc, PPM	18.15	27.29	144.26
Manganese, PPM	36.15	43.66	151.96

of DL-methionine were added. Similar experimental plans were used for experiments Q-23 and Q-27. Glycine levels in the Q-23 diets ranged from 1.177% in the basal to 1.777% in treatment #6, and lysine levels in Q-27 ranged from a low of 1.35% to a high of 1.60%. The calculated amounts of methionine plus cystine, glycine and lysine present in the experimental diets of Q-21, Q-23 and Q-27, respectively, appear in Table 8.

Results and Discussion. Summaries of the results of these experiments are presented in Tables 9, and 10 and Figures 2 and 3. As in experiment Q-19, body weight at five weeks of age was considered to be of prime importance in the establishment of optimum amino acid levels in the diet.

At three weeks of age there appeared to be no correlation between percent sulfur amino acid level in the diet and body weight, while at five weeks there was a tendency for body weight to increase with an increase in sulfur amino acids from 0.718 to 0.768% of the diet, although this increase was not statistically significant (Table 9). This is an indication that the sulfur amino acid needs of the young Coturnix were adequately met at about the 0.718% level (basal level) of methionine plus cystine. When fifth week body weight was plotted graphically as a function of percent sulfur amino acid in the diet (Figure 2), a total methionine plus cystine requirement of about 0.775% of the diet was indicated. At these levels of dietary sulfur amino acids, no correlation between

Table 8. Calculated amounts of methionine plus cystine, glycine and lysine present in experimental diets Q-21, Q-23 and Q-27, respectively.

Dietary treatment	% Amino Acid		
	Q-21 Methionine + Cystine[1]	Q-23 Glycine[2]	Q-27 Lysine[3]
1	0.718(Basal)	1.177(Basal)	1.35(Basal)
2	0.768	1.227	1.45
3	0.818	1.277	1.50
4	0.868	1.427	1.55
5	0.918	1.577	1.60
6	1.018	1.777	-

[1] Supplied as DL-methionine.

[2] Supplied as glycine.

[3] Supplied as L-lysine hydrochloride.

Table 9. Effect of dietary sulfur amino acid level on body weight and feed conversion of young Japanese quail.

Dietary sulfur amino acid level, %	Third week body weight (gms)	Fifth week body weight (gms)	Gms feed consumed/gm body weight gain[1]
0.718	58.9	96.6	5.37
0.768	59.9	102.0	4.76
0.818	59.4	102.3	4.95
0.868	57.2	102.7	5.50
0.918	63.7	103.7	5.70
1.018	60.8	100.4	5.45

[1] For final two weeks of experiment only.

Table 10. Effect of dietary glycine level on body weight and feed conversion of young Japanese quail.

Dietary glycine level, %	Third week body weight (gms)	Fourth week body weight (gms)	Fifth week body weight (gms)	Gms feed consumed/gm body weight gain
1.177(Basal)	59.8	80.3	93.6	3.77[a1]
1.227	60.7	80.4	96.0	3.30[b]
1.277	61.9	81.0	100.0	3.13[b]
1.427	61.7	83.3	100.2	3.27[b]
1.577	60.3	79.1	96.6	3.33[b]
1.777	62.5	82.4	99.3	3.27[b]

[1] Means having different letter superscripts are significantly different at the 0.05 level of probability (Duncan, 15).

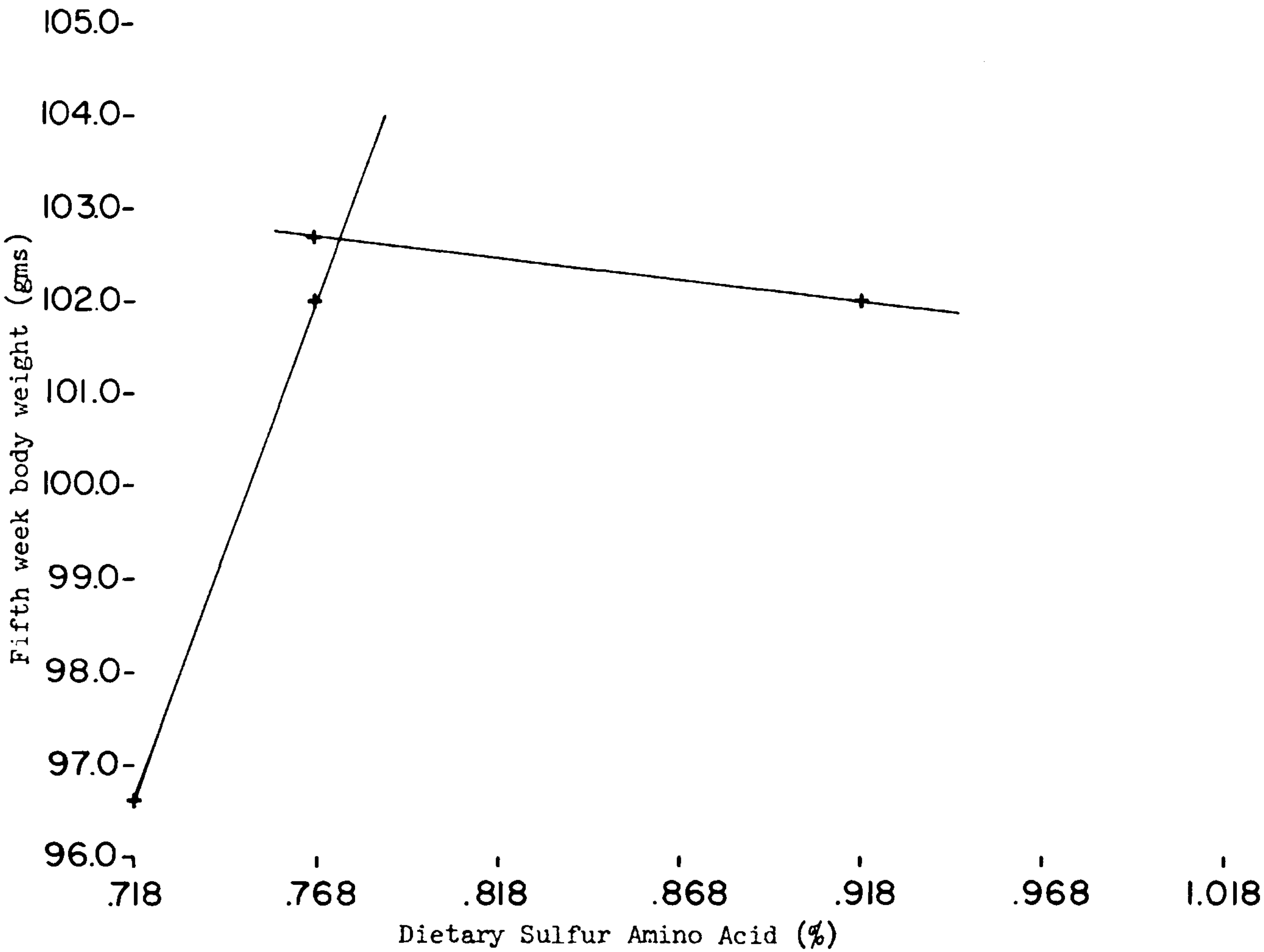

Figure 2. Effect of dietary sulfur amino acid level on fifth week body weight of Japanese quail.

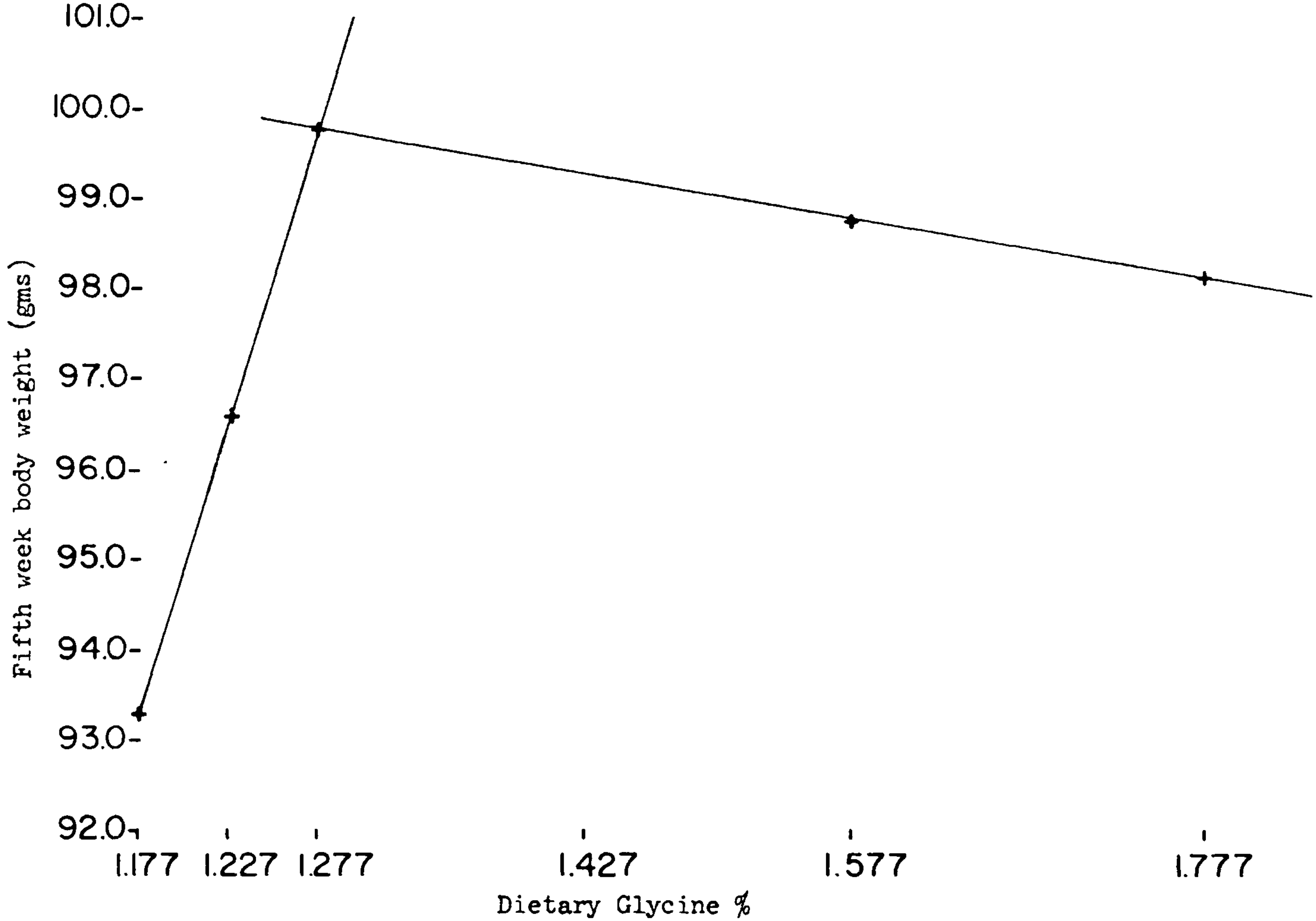

Figure 3. Effect of dietary glycine level on fifth week body weight of Japanese quail.

dietary sulfur amino acid and grams of feed consumed per gram of body weight gain was apparent.

Body weights at three, four and five weeks after hatching were relatively constant at all dietary glycine levels, although feed conversion, measured as grams of feed consumed per gram of body weight gain, was significantly higher at the basal glycine level (Table 10). When fifth week body weight was plotted graphically as a function of dietary glycine, a level of 1.277% glycine in the diet was indicated as optimum for growth of the young Coturnix (Figure 3).

At three weeks of age, birds on lysine supplemented diets showed no differences in body weight as a result of dietary treatment. At the end of five weeks, still no differences in body weight, viability or feed consumption were apparent, indicating that the lysine requirement of Coturnix chicks was adequately met by the basal level of 1.35% of the diet.

CHAPTER IV

PROTEIN AND AMINO ACID STUDIES--MATURE BIRDS

Introduction. Howes (10) recently reported optimum growth and egg production for the Coturnix laying hen fed a protein level of 23% in a practical corn-soybean diet. Supplementation with the amino acid methionine resulted in a further improvement in egg production. Likewise, Callenbach (9) reported a protein level of 24% for satisfactory growth of mature ringnecked pheasants, and Nestler (3) reported maximum egg production in bobwhite quail breeders at a 23% protein level.

In an attempt to substantiate the findings of the foregoing workers, three experiments utilizing mature Coturnix quail were conducted at the University of Arizona during the years 1966 and 1967. Two were specifically concerned with the establishment of a protein level at which optimum performance by laying Coturnix hens could be obtained, and one involved the establishment of a sulfur amino acid requirement for the Coturnix breeder. Optimum performance, or requirement, for these studies was defined by the following criteria: (1) body weight, (2) livability, (3) feed consumption, (4) freedom from recognized deficiency symptoms, (5) retention of dietary nutrients, (6) egg production and (7) fertility and hatchability of eggs.

General Experimental Procedure for Mature Birds. At five to six weeks of age, young quail were sexed, wingbanded, debeaked and transferred from the battery brooder into wire-floored colony mating cages, 24" X 24" X 15" in size. Each dietary treatment consisted of two replicate cages, each containing ten females and five males. A room temperature of 70°F was maintained, and a lighting schedule of sixteen hours light, eight hours darkness was followed for the duration of all experiments. Feed and water were supplied *ad libitum* throughout each study. Birds and feed were weighed at twenty-eight day intervals and fecal samples were collected once each day for three days during each twenty-eight day period.

All analyses were carried out in the laboratories of the Poultry Science Department at the University of Arizona. Calcium was determined by the Coleman Method (16), with modifications according to Reid in unpublished data. Phosphorous was analyzed by the method of Koenig and Johnson (17) and fatty acids by the method of Metcalfe and Schmitz (18). Protein and chromic oxide were determined using A.O.A.C. official methods of analysis (19).

Experiment Q-6: Total Protein

Procedure. Four diets, approximately isocaloric and with nearly equivalent levels of fat, fiber, calcium, available phosphorus, zinc and manganese, were formulated, with calculated protein levels of 20.2, 22.2, 24.8 and 30.0%. Determined average protein levels of 20.7, 22.5, 25.6 and 31.1% closely approximated the calculated values. For convenience and ease of comparison, the four diets have been designated according to their approximate protein levels of 20, 22.5, 25 and 30% and are henceforth referred to in this manner. Their percent ingredient compositions and a calculated analysis of each are presented in Tables 11 and 12, respectively. In addition, Table 13 shows the calculated percent amino acid composition per therm productive energy for each diet, compared with the amino acid requirements of the laying hen as recommended by the National Research Council in 1964 (11). In every instance where data were available, the concentration of each amino acid in the experimental Q-6 diets, on the basis of percent per therm productive energy, exceeded that established by the National Research Council for optimum performance of the domestic laying hen.

Results and Discussion. Percent egg production was considered to be of prime importance as a criterion of the performance of the laying Coturnix. On the basis of similar studies with the laying hen, it was assumed that percent egg production would increase with increasing dietary protein level to some optimum percentage of protein

Table 11. Percent ingredient compositions of experimental diets (Q-6).

Ingredient	20%	22.5%	25%	30%
Ground milo	36.78	34.13	30.23	21.13
Soybean meal, solvent	16.50	16.50	16.50	17.50
Fish meal, sardine	5.50	9.00	13.50	22.00
Animal fat	3.00	2.50	2.75	3.75
Calcium carbonate	4.10	4.24	3.90	3.50
Dicalcium phosphate	2.00	1.50	1.00	-
Ground yellow corn	15.00			
Meat and bone scraps	4.00			
Dehydrated alfalfa meal	3.00			
Whey, dried whole cheese	4.00			
DL-methionine	0.20		Same	
Vitamin premix[1]	5.00			
Salt	0.40			
Trace mineral premix[2]	0.20			
Manganese sulfate	0.02			
Chromium oxide	0.30			
Total	100.00	100.00	100.00	100.00

[1] Supplied the following per kg of diet: 19,850 I.U. vitamin A, 3,075 I.C.U. vitamin D_3, 11 I.U. d-alpha-tocopheryl acetate, 27 mcg vitamin B_{12}, 4.4 mg 2-methyl-napthoquinone, 8.9 mg riboflavin, 56.0 mg niacin, 22.5 mg d-calcium pantothenate, 1,860 mg choline chloride and 250 mg ethoxyquin (as a preservative).

[2] Supplied the following per kg of diet: 40 mg Fe, 120 mg Zn, 2 mg Mo, 120 mg Mn, 336 mg Ca, 8 mg Cu, 3 mg I and 3 mg Co.

Table 12. Calculated analyses of experimental diets (Q-6).

Ingredient	20%	22.5%	25%	30%
Protein, %	20.21	22.25	24.83	29.98
Fat, %	5.13	4.71	5.04	6.16
Fiber, %	3.64	3.61	3.56	3.49
Productive energy, kcal/lb	915.56	903.14	907.60	918.89
Metabolizable energy, kcal/lb	1209.06	1199.69	1211.95	1239.34
P.E./Protein ratio	45.31	40.60	36.56	30.65
M.E./Protein ratio	59.83	53.93	48.82	41.34
Xanthophylls, mg/lb	3.39	3.39	3.39	3.39
Calcium, %	2.90	2.98	2.92	2.89
Phosphorus, %	1.03	1.02	1.03	1.03
Available phosphorus, %	0.80	0.79	0.81	0.83
Zinc, PPM	145.26	148.71	153.05	161.21
Manganese, PPM	189.93	190.58	189.58	188.48

Table 13. Calculated amino acid compositions of experimental diets (Q-6) as compared with the amino acid requirements of the laying hen.

Amino acid	% Amino acid/1000 kcal productive energy				
	laying hen requirement[1]	20%	22.5%	25%	30%
Arginine	-	1.428	1.600	1.785	2.153
Lysine	0.598	1.298	1.535	1.808	2.333
Methionine	0.304	0.598	0.681	0.774	0.947
Cystine	-	0.327	0.358	0.390	0.451
Cystine plus methionine	0.543	0.925	1.040	1.163	1.398
Tryptophan	0.163	0.303	0.339	0.378	0.456
Glycine	0.652	1.398	1.580	1.778	2.159
Phenylalanine	0.543	1.053	1.166	1.283	1.511
Tyrosine	-	0.857	0.938	1.021	1.184
Phenylalanine plus tyrosine	0.924	1.910	2.104	2.304	2.695
Valine	0.652	1.230	1.390	1.563	1.896
Leucine	0.870	2.001	2.197	2.394	2.767
Isoleucine	0.598	1.135	1.272	1.418	1.704
Threonine	0.435	0.904	1.025	1.156	1.409
Histidine	0.217	0.518	0.590	0.669	0.822

[1] As established by the National Research Council (11).

in the diet. Howes (10), working with Coturnix, reported an increase in percent egg production when dietary protein was raised from 18 to 23%. Preliminary, unpublished work at the University of Arizona noted a similar increase as dietary protein was raised from 15 to 30%.

A summary of the results of egg production data for Coturnix fed dietary protein levels of 20, 22.5, 25 and 30% appears in Table 14. Of particular interest is the high level of performance at the lowest protein level and the failure of percent production to change significantly with an increase in protein level from 20 to 25%. In addition, Table 14 shows no significant differences in feed consumption per bird per day or in fertility and hatchability of eggs as related to dietary protein level. The number of pounds of feed consumed per dozen eggs produced was constant for comparable production levels, and rose significantly with a decrease in percent production, as would be expected when feed consumption was maintained at a constant level and the total number of eggs produced dropped.

Intake of protein, in grams per bird per day, increased with an increase in dietary protein, as would be expected when total feed consumption was constant for all treatments (Table 15). Percent protein retained was not significantly different at the levels of dietary protein employed, resulting in a rather large variation in grams of protein retained per bird per day, particularly between the 20% and 30% levels of dietary protein. There are,

Table 14. Effect of dietary protein level on the performance of mature Japanese quail.

Dietary protein level, %	% egg production	Lbs feed consumed/ dozen eggs	Feed consumption (gms/bird/day)	% Fertility	% Hatchability
20	82.10[a][1]	1.13[b]	34.4[a]	65.16[a]	79.40[a]
22.5	77.19[ab]	1.13[b]	32.9[a]	67.13[a]	79.25[a]
25	77.23[ab]	1.14[b]	33.3[a]	70.04[a]	78.07[a]
30	68.19[b]	1.29[a]	32.8[a]	69.30[a]	67.87[a]

[1] Means having different letter superscripts are significantly different at the 0.05 level of probability (Duncan, 15).

Table 15. Effect of dietary protein level on protein intake and retention by mature Japanese quail.

Dietary protein level, %	Protein intake (gms/bird/day)	Protein retained (%)	Protein retained (gms/bird/day)	Protein retained (gms/egg)
20	6.88	24.19	1.66	1.03
22.5	7.40	29.14	2.16	1.25
25	8.33	24.59	2.05	1.06
30	9.84	31.76	3.13	1.55

however, no significant differences in grams of protein retained per egg or in egg weights, which averaged about 11.3 grams. Average body weights for all treatments showed no significant differences.

On the basis of these results, it appears that the 20% protein diet employed in experiment Q-6 adequately supplied the total dietary protein needs of the laying Coturnix, as no further improvement in performance was seen above this protein level. It is conceivable that a good protein source which supplies essential amino acids in a pattern balanced to meet the specific needs of the Coturnix may lower the total dietary protein requirement from the heretofore suggested 23 or 24% of the diet. The existence of such a balance in the Q-6 diets may provide a partial explanation for the foregoing results.

Calculation of calcium and phosphorus retentions by the mature Coturnix (Table 16) and analyses of the fatty acid compositions, as percent of total lipid, of Q-6 diets and corresponding eggs (Table 17 and Figure 4) were also made during the course of experiment Q-6. Although these data are not of immediate relevancy to the topic in question, they are included here as a reference for further work in this area.

Table 16. Calcium and phosphorus retention by mature Japanese quail.

Dietary protein level, %	Calcium retained (%)	Calcium retained (gms/egg)	Phosphorus retained (%)	Phosphorus retained (gms/egg)
20	30.02	1.28	12.67	0.54
22.5	35.04	1.50	18.50	0.79
25	32.13	1.38	21.15	0.91
30	35.31	1.73	14.13	0.69

Table 17. Fatty acid compositions of feed and eggs (Q-6).

Fatty acid	Fatty acid, % of total lipid							
	20% Protein diet	20% Protein eggs	22.5% Protein diet	22.5% Protein eggs	25% Protein diet	25% Protein eggs	30% Protein diet	30% Protein eggs
C14:0	1.74	0.73	1.75	0.68	2.83	0.96	2.85	0.68
C16:0	24.21	27.60	19.93	25.76	23.88	26.78	25.08	27.20
C16:1	3.70	5.30	4.34	5.98	6.66	5.90	5.03	5.69
C16:2	0.40	-	1.60	-	1.26	-	1.64	-
C18:0	16.36	8.52	10.79	9.78	11.54	8.23	11.49	9.78
C18:1	35.55	51.74	34.16	51.71	37.57	51.26	38.30	49.91
C18:2	16.20	6.13	18.71	6.10	15.17	6.90	10.51	6.74
C18:3	1.85	-	8.90	-	1.08	-	5.11	-

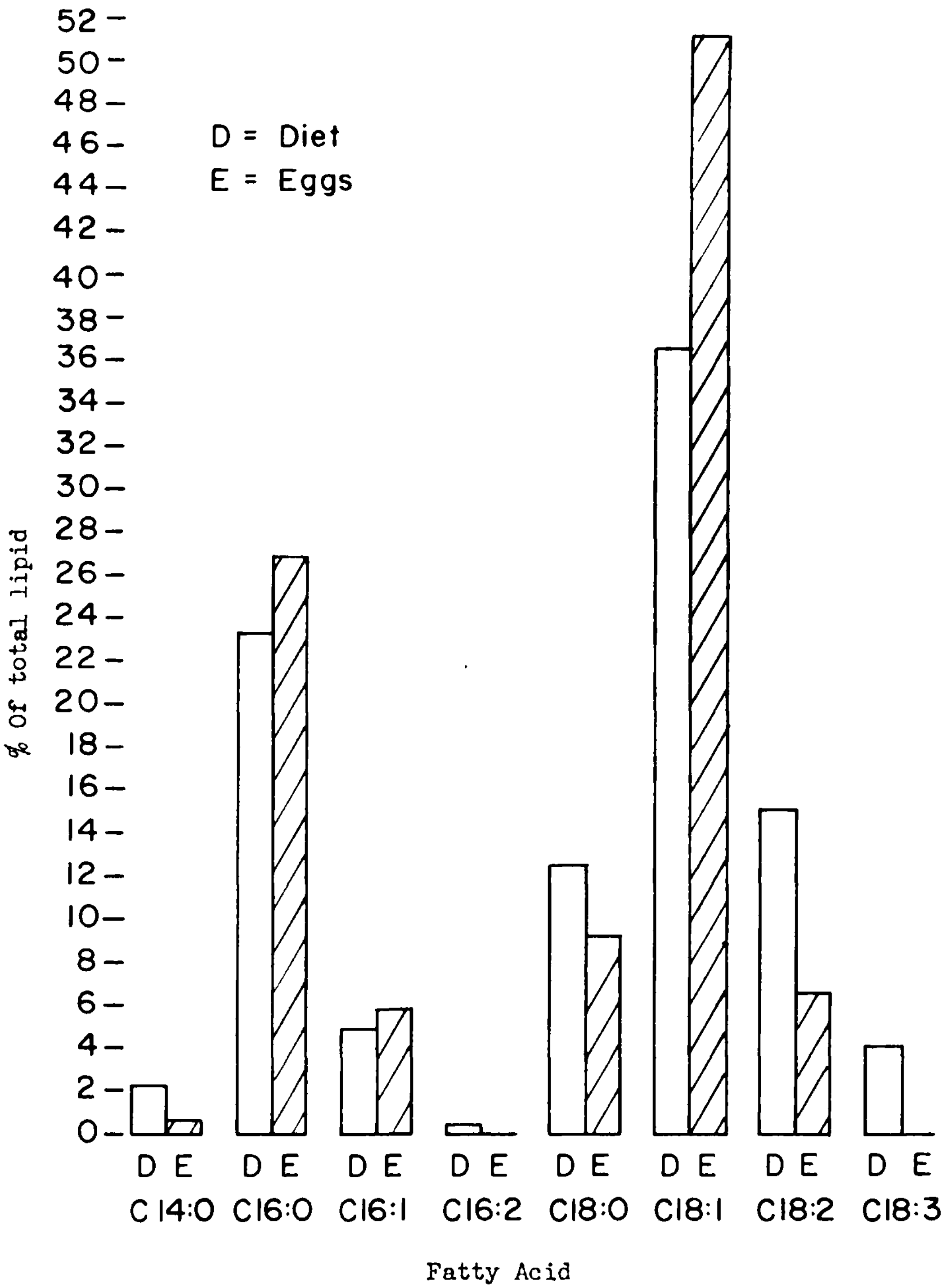

Figure 4. Fatty acid compositions of Q-6 diets and eggs.

Experiment Q-10: Total Protein.

Procedure. Experiment Q-10 was instituted in an attempt to further clarify the findings of experiment Q-6. Six isocaloric diets, ranging in total protein content from 12.4 to 22.8%, were formulated, with calcium and available phosphorus levels held constant. Calculated protein levels were as follows: 12.4, 14.5, 16.5, 18.6, 20.7 and 22.8%. In order to exercise a greater amount of control over the amino acid composition of each diet, a protein premix consisting of five protein sources and DL-methionine was first formulated. When supplied at levels of 26, 31, 36, 41, 46 and 51% of the diet, this provided the total protein content of each ration, resulting in identical amino acid patterns for all experimental diets, but at varying levels of total protein. Percent ingredient compositions of the protein premix and of the Q-10 experimental diets are presented in Tables 1 and 18, respectively. Table 19 shows a calculated analysis of each Q-10 diet, and Table 20 contains calculated analyses of their amino acid compositions. As in experiment Q-6, the concentration of each amino acid, on the basis of percent per therm productive energy, for all Q-10 diets exceeded that established by the National Research Council (11) for optimum performance of the domestic laying hen.

Table 18. Percent ingredient compositions of experimental diets (Q-10).

Ingredient	12%	14%	16%	18%	20%	22%
Soybean meal, solvent	18.07	21.55	25.02	28.50	31.97	35.45
Fish meal, sardine	2.60	3.10	3.60	4.10	4.60	5.10
Meat and bone scraps	1.30	1.55	1.80	2.05	2.30	2.55
Dehydrated alfalfa meal	1.30	1.55	1.80	2.05	2.30	2.55
Whey, dried whole cheese	1.30	1.55	1.80	2.05	2.30	2.55
DL-methionine	0.13	0.16	0.18	0.21	0.23	0.26
Glucose monohydrate	50.85	47.90	44.85	41.90	38.95	35.19
Dicalcium phosphate	4.00	3.70	3.50	3.20	2.90	2.65
Animal fat	1.30	1.55	1.80	2.05	2.30	2.55
Bentonite	8.00	6.24	4.50	2.74	1.00	-
Calcium carbonate	4.50					
Chromium oxide	0.20					
Vitamin premix[1]	5.00					
Trace mineral premix[2]	0.20			Same		
Antibiotic	0.25					
Salt	0.50					
Potassium chloride	0.50					
Total	100.00	100.00	100.00	100.00	100.00	100.00

[1] Supplied the following per kg of diet: 19,850 I.U. vitamin A, 3,075 I.C.U. vitamin D_3, 11 I.U. d-alpha-tocopheryl acetate, 27 mcg vitamin B_{12}, 4.4 mg 2-methyl-napthoquinone, 8.9 mg riboflavin, 56.0 mg niacin, 22.5 mg d-calcium pantothenate, 1,860 mg choline chloride and 250 mg ethoxyquin (as a preservative).

[2] Supplied the following per kg of diet: 40 mg Fe, 120 mg Zn, 2 mg Mo, 120 mg Mn, 336 mg Ca, 8 mg Cu, 3 mg I and 3 mg Co.

Table 19. Calculated analyses of experimental diets (Q-10).

Ingredient	12%	14%	16%	18%	20%	22%
Protein, %	12.42	14.49	16.55	18.62	20.68	22.75
Fat, %	1.63	1.93	2.24	2.55	2.86	3.17
Fiber, %	1.92	2.24	2.56	2.88	3.20	3.52
Productive energy, kcal/lb	905.73	906.09	905.05	905.41	905.70	895.26
Metabolizable energy, kcal/lb	1092.62	1104.62	1115.01	1127.01	1138.90	1138.75
P.E./Protein ratio	72.95	62.54	54.69	48.63	43.79	39.35
M.E./Protein ratio	88.00	76.25	67.38	60.53	55.07	50.05
Xanthophylls, mg/lb	1.01	1.21	1.40	1.60	1.79	1.99
Calcium, %	3.12	3.10	3.11	3.44	3.08	3.07
Phosphorus, %	1.02	1.02	1.03	1.03	1.02	1.02
Available phosphorus, %	0.91	0.89	0.89	0.86	0.84	0.82
Zinc, PPM	130.24	131.93	133.61	135.33	136.98	138.66
Manganese, PPM	151.73	152.95	154.17	158.27	156.60	157.82

Table 20. Calculated amino acid compositions of experimental diets (Q-10).

Amino acid	% Amino acid/1000 kcal productive energy					
	12.4%	14.5%	16.5%	18.6%	20.7%	22.8%
Arginine	1.00	1.17	1.34	1.50	1.67	1.86
Lysine	0.91	1.06	1.21	1.36	1.52	1.69
Methionine	0.36	0.43	0.49	0.56	0.62	0.70
Cystine	0.19	0.22	0.26	0.29	0.32	0.36
Cystine plus methionine	0.56	0.66	0.75	0.85	0.94	1.06
Tryptophan	0.22	0.26	0.30	0.33	0.37	0.41
Glycine	0.83	0.98	1.12	1.26	1.40	1.56
Phenylalanine	0.66	0.76	0.87	0.98	1.09	1.21
Tyrosine	0.53	0.62	0.71	0.80	0.89	0.99
Phenylalanine plus tyrosine	1.19	1.39	1.58	1.78	1.98	2.20
Valine	0.77	0.89	1.02	1.15	1.28	1.42
Leucine	1.07	1.25	1.43	1.61	1.79	1.99
Isoleucine	0.75	0.87	1.00	1.12	1.24	1.38
Threonine	0.57	0.67	0.76	0.87	0.95	1.06
Histidine	0.34	0.40	0.46	0.51	0.57	0.63

Results and Discussion. A rather significant increase in egg production was seen as the protein level of the diet was increased from 12 to 14%, although no further increase in production occurred above this protein level (Table 21). On the basis of egg production alone, then, it appeared that a dietary protein level of 14% satisfactorily met the total protein requirement of the bird. However, when fertility and hatchability of eggs were considered, significant increases were seen not only at the 14% protein level, but at the 20% level as well. These results, however, were obtained over a relatively short experimental period of only four weeks.

Combining these data with the results of experiment Q-6, it appears that the total protein requirement of the mature Coturnix for egg production can be satisfactorily met at rather low dietary protein levels, providing the protein source is one which adequately meets the specific needs of the bird. In this instance, a diversified protein source was utilized, with rather high concentrations of all the amino acids, when taken as percent per therm of productive energy in the diet and when compared with the requirements of the laying hen on the same basis. Fertility and hatchability, however, while adequate at the 14% level, don't attain maximum values until the protein level of the diet reaches approximately 20%.

Table 21. Effect of dietary protein level on egg production and fertility and hatchability of eggs.

Dietary protein level, %	% Egg production	% Fertility	% Hatchability
12	31.53	39.29	18.34
14	64.69	62.05	60.52
16	66.37	67.41	62.79
18	51.04	57.38	64.29
20	69.88	81.46	79.40
22	66.42	73.16	67.34

Experiment Q-8: Sulfur Amino Acids.

Procedure.. A basal diet, similar to the Q-6 diets but lower in the sulfur amino acids methionine and cystine, was formulated as shown in Table 22. A calculated analysis showed a total protein level of 22.5% and a combined methionine and cystine content of 0.769% (Table 23). An analysis of the amino acid pattern showed all amino acids to be in excess of the National Research Council's requirements for the laying hen (Table 24). Supplemental DL-methionine was supplied at levels of 0.1, 0.2 and 0.4% of the diet, resulting in four rations with total sulfur amino acid levels of 0.769 (basal), 0.869, 0.969 and 1.169%.

Results and Discussion. A rather high level of performance was obtained at the basal sulfur amino acid level, with no significant change in percent production with increasing methionine levels (Table 25). In addition, no significant differences in grams of feed consumed per bird per day or in hatchability of eggs, as related to dietary sulfur amino acid level were noted. However, supplementation with methionine did appear to affect the fertility of eggs. A rather large increase of 14% was noted when the methionine level was increased from 0.769 to 1.169% of the diet. As would be expected when both feed consumption and egg production were constant, there were no significant differences in the number of pounds of feed consumed per dozen eggs at different sulfur amino acid levels.

Table 22. Percent ingredient composition of basal diet (Q-8).

Ingredient	%
Ground yellow corn	15.00
Ground milo	31.18
Soybean meal, solvent	16.50
Fish meal, sardine	10.00
Meat and bone scraps	4.00
Dehydrated alfalfa meal	3.00
Whey, dried whole cheese	4.00
Animal fat	5.50
Vitamin premix[1]	5.00
Calcium carbonate	3.50
Dicalcium phosphate	1.50
Salt	0.40
Trace mineral premix[2]	0.20
Manganese sulfate	0.02
Chromium oxide	0.20
Total	100.00

[1] Supplied the following per kg of diet: 19,850 I.U. vitamin A, 3,075 I.C.U. vitamin D_3, 11 I.U. d-alpha-tocopheryl acetate, 27 mcg vitamin B_{12}, 4.4 mg 2-methyl-napthoquinone, 8.9 mg riboflavin, 56.0 mg niacin, 22.5 mg d-calcium pantothenate, 1,860 mg choline chloride and 250 mg ethoxyquin (as a preservative).

[2] Supplied the following per kg of diet: 40 mg Fe, 120 mg Zn, 2 mg Mo, 120 mg Mn, 336 mg Ca, 8 mg Cu, 3 mg I and 3 mg Co.

Table 23. Calculated analysis of basal diet (Q-8).

Ingredient	Amount
Protein, %	22.52
Methionine plus cystine, %	0.77
Fat, %	7.67
Fiber, %	3.55
Productive energy, kcal/lb	966.40
Metabolizable energy, kcal/lb	1276.10
P.E./protein ratio	42.92
M.E./protein ratio	56.67
Xanthophylls, mg/lb	3.39
Calcium, %	2.74
Phosphorus, %	1.03
Available phosphorus, %	0.81
Zinc, PPM	149.33
Manganese, PPM	187.79

Table 24. Calculated amino acid composition of basal diet (Q-8) as compared with the amino acid requirements of the laying hen.

Amino acid	% Amino acid/1000 kcal productive energy	
	Laying hen requirement[1]	Q-8 Basal diet
Arginine	-	1.528
Lysine	0.598	1.488
Methionine	0.304	0.457
Cystine	-	0.339
Cystine plus methionine	0.543	0.796
Tryptophan	0.163	0.324
Glycine	0.652	1.511
Phenylalanine	0.543	1.104
Tyrosine	-	0.887
Phenylalanine plus tyrosine	0.924	1.991
Valine	0.652	1.325
Leucine	0.870	2.068
Isoleucine	0.598	1.211
Threonine	0.435	0.979
Histidine	0.217	0.565

[1] As established by the National Research Council in 1964 (11).

Table 25. Effect of dietary sulfur amino acid level on the performance of mature Japanese quail.

Dietary sulfur amino acid level, %	% Egg production	Lbs feed consumed/ dozen eggs	Feed consumption (gms/bird/day)	% Fertility	% Hatchability
0.769	70.54	1.18	29.8	60.18[b1]	79.66
0.869	68.86	1.10	27.1	66.79[ab]	78.85
0.969	63.31	1.29	29.2	64.08[ab]	72.84
1.169	76.36	1.04	29.3	74.10[a]	78.37

[1] Means having different letter superscripts are significantly different at the 0.05 level of probability (Duncan, 15).

Protein intake, in grams per bird per day, was constant at all dietary sulfur amino acid levels, as expected, as all diets contained equal amounts of protein (Table 26). There appeared to be no correlation between dietary sulfur amino acid level and protein retention, with retention considered either as percentage, grams per bird per day or grams per egg. In addition, neither body weights nor egg weights showed significant differences as a result of dietary treatment.

On the basis of these results, it appears that the Q-8 basal diet containing 0.769% methionine and cystine adequately met the sulfur amino acid requirement of the laying Coturnix, as no further improvement in performance, except in fertility, was seen above this level of sulfur amino acids in the diet. Supplementation of a practical corn-soybean diet of the Q-8 type with DL-methionine therefore appears to be unnecessary.

Table 27 presents data on calcium and phosphorus retention by Q-8 birds, and Table 28 shows the fatty acid composition, as percent of total lipid, of eggs collected from Q-8 birds during the course of this experiment. While not directly related to the question under consideration, these data are included here as a reference for further work in this area.

Table 26. Effect of dietary sulfur amino acid level on protein intake and retention by mature Japanese quail.

Dietary sulfur amino acid level, %	Protein intake (gms/bird/day)	Protein retained (%)	Protein retained (gms/bird/day)	Protein retained (gms/egg)
0.769	6.71	25.56	1.72	1.14
0.869	6.10	37.17	2.26	1.55
0.969	6.57	27.90	1.83	1.37
1.169	6.59	30.28	2.00	1.19

Table 27. Calcium and phosphorus retention by mature Japanese quail.

Dietary sulfur amino acid level, %	Calcium retained (%)	Calcium retained (gms/egg)	Phosphorus retained (%)	Phosphorus retained (gms/egg)
0.769	38.86	1.73	12.22	0.55
0.869	39.64	1.65	21.30	0.89
0.969	27.98	1.37	8.19	0.40
1.169	39.37	1.55	19.87	0.78

Table 28. Fatty acid composition of eggs (Q-10).

Fatty acid	Fatty acid/% of total lipid			
	0.769% Methionine	0.869% Methionine	0.969% Methionine	1.169% Methionine
C14:0	0.89	0.71	0.69	0.65
C16:0	27.07	26.52	25.61	27.30
C16:1	9.45	5.50	6.20	5.71
C18:0	8.27	8.87	9.36	9.35
C18:1	48.14	51.93	50.77	50.11
C18:2	6.20	6.49	7.39	6.89

CHAPTER V

VITAMIN STUDIES--YOUNG BIRDS

Introduction. The vitamin A requirement for optimum growth and viability of young bobwhite quail was reported by Nestler et al. (3), Harper et al. (13) and Woodward (12) to be approximately 3000 I.U. of vitamin A per pound of feed. However, high liver storage of the vitamin was not encountered until dietary levels reached 5000-6000 I.U. per pound. Scott and Reynolds (4) suggested a somewhat higher level of 9500 I.U. of vitamin A per pound of diet for young ringnecked pheasants.

Shellenberger and Lee (14) fed vitamin A depletion diets to young Japanese quail for one week after hatching, followed by experimental diets containing concentrations of vitamin A ranging from zero to 4400 U.S.P. units per kg. No demonstrable effects of vitamin A supplementation on growth were seen on either low or high energy diets, although viability was poor when less than 1650 U.S.P. units of vitamin A per kg. were supplied in the low energy diet and less than 1100 in the high.

The two experiments reported in this chapter include a further investigation of the vitamin A needs of the young Coturnix (Q-11) and a study of pyridoxine requirements (Q-25). General experimental proceedures for vitamin studies were the same as those employed for protein and amino acid studies with young birds (See Chapter III).

Experiment Q-11: Vitamin A

Procedure. Experiment Q-11 was designed and carried out in order to establish an optimum level of dietary vitamin A for growth of the young Coturnix. A practical milo-soybean meal basal diet, low in vitamin A, was formulated, to which the vitamin was added in the following amounts: 0, 250, 500, 1000, 5000, 10,000 and 20,000 I.U. per pound. The percent ingredient composition and a calculated analysis of the basal diet appear in Tables 29 and 30, respectively.

Liver vitamin A was determined in the laboratories of the Poultry Science Department of the University of Arizona by the official method of analysis of the Association of Official Agricultural Chemists (19).

Results and Discussion. Body weight at five weeks of age was fairly consistent for all treatments except at the lowest and highest levels of vitamin A, where growth was somewhat depressed (Table 31). When the logarithms of fifth week body weights were plotted graphically as functions of dietary vitamin A levels, 500 I.U. of vitamin A per pound of diet were shown to be optimum for growth of the young Coturnix (Figure 5). Increases in dietary vitamin A concentrations above this level did not result in additional increases in body weight, and at the highest level, growth was somewhat inhibited.

Table 29. Percent ingredient composition of basal diet (Q-11).

Ingredient	%
Ground milo	40.60
Soybean meal, solvent	47.00
Animal fat	3.00
DL-methionine	0.20
Vitamin premix[1]	5.00
Calcium carbonate	1.00
Dicalcium phosphate	2.50
Salt	0.50
Trace mineral premix[2]	0.20
Total	100.00

[1] Supplied the following per kg of diet: 19,850 I.U. vitamin A, 3,075 I.C.U. vitamin D_3, 11 I.U. d-alpha-tocopheryl acetate, 27 mcg vitamin B_{12}, 4.4 mg 2-methyl-napthoquinone, 8.9 mg riboflavin, 56.0 mg niacin, 22.5 mg d-calcium pantothenate, 1,860 mg choline chloride and 250 mg ethoxyquin (as a preservative).

[2] Supplied the following per kg of diet: 40 mg Fe, 120 mg Zn, 2 mg Mo, 120 mg Mn, 336 mg Ca, 8 mg Cu, 3 mg I and 3 mg Co.

Table 30. Calculated analysis of basal diet (Q-11).

Ingredient	Amount
Protein, %	26.08
Fat, %	4.27
Fiber, %	4.56
Productive energy, kcal/lb	878.31
Metabolizable energy, kcal/lb	1194.52
P.E./Protein ratio	33.67
M.E./Protein ratio	45.80
Xanthophylls, mg/lb	-
Calcium, %	1.20
Phosphorus, %	00.93
Available phosphorus, %	0.58
Zinc, PPM	137.94
Manganese, PPM	156.42

Table 31. Effect of dietary vitamin A level on body weight and liver storage of vitamin A in young Japanese quail.

Dietary vitamin A (I.U./lb)	Fifth week body weight (gms)	Liver storage (I.U. vitamin A/liver)
Basal	85.3	60.
250	99.3	34.
500	97.4	162.
1000	100.9	275.
5000	99.6	1306.
10,000	97.2	1724.
20,000	91.9	2475.

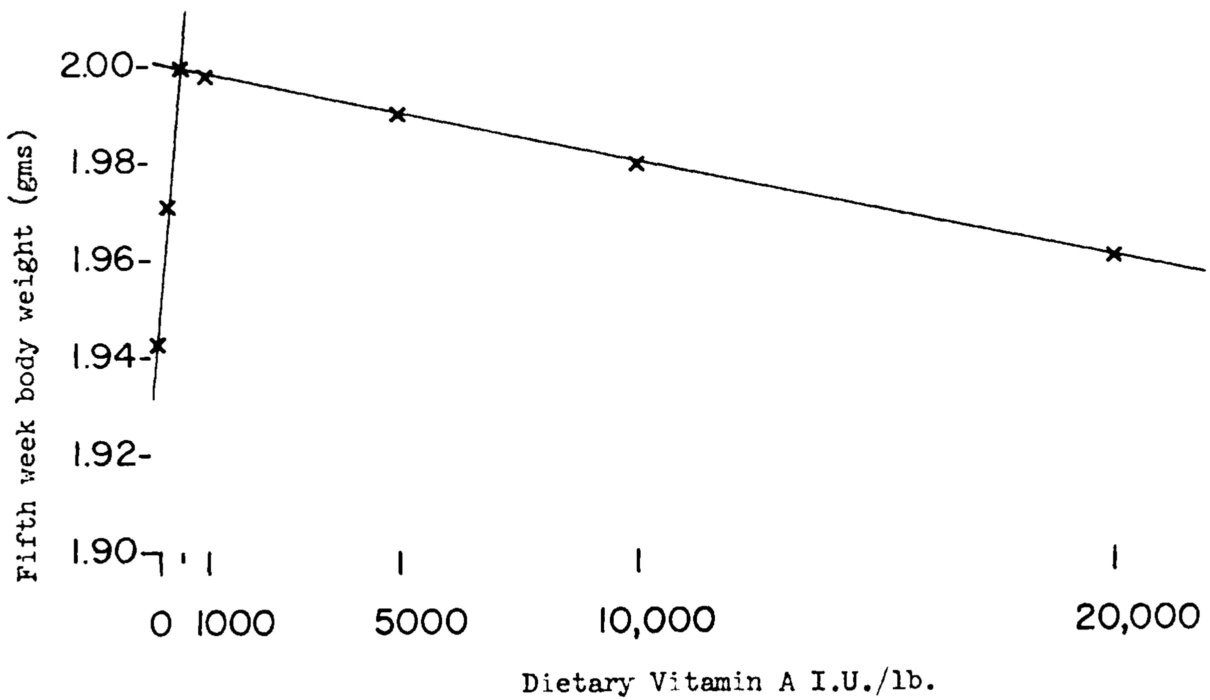

Figure 5. Effect of dietary vitamin A level on fifth week body weight of Japanese quail.

With the exception of the 250 I.U. per pound level, storage of vitamin A in the liver was shown to increase with increasing levels of vitamin A in the diet. When the logarithm of liver storage (I.U. of vitamin A per liver) was plotted versus dietary vitamin A level, a dietary level of 1000 I.U. of vitamin A per pound was indicated as the most advantageous for optimizing liver storage (Figure 6).

Traditionally, vitamin A requirements of the domestic chicken and the turkey have been established employing both body weight and liver storage of the vitamin as criteria for its optimum utilization. It appears from Q-11 data, however, that the extent of liver stores actually bears little direct relationship to either mortality or the promotion of growth in young Coturnix, and that growth data alone, as represented by body weight gain, is entirely adequate as an indication of the dietary vitamin level at which optimum performance is obtained.

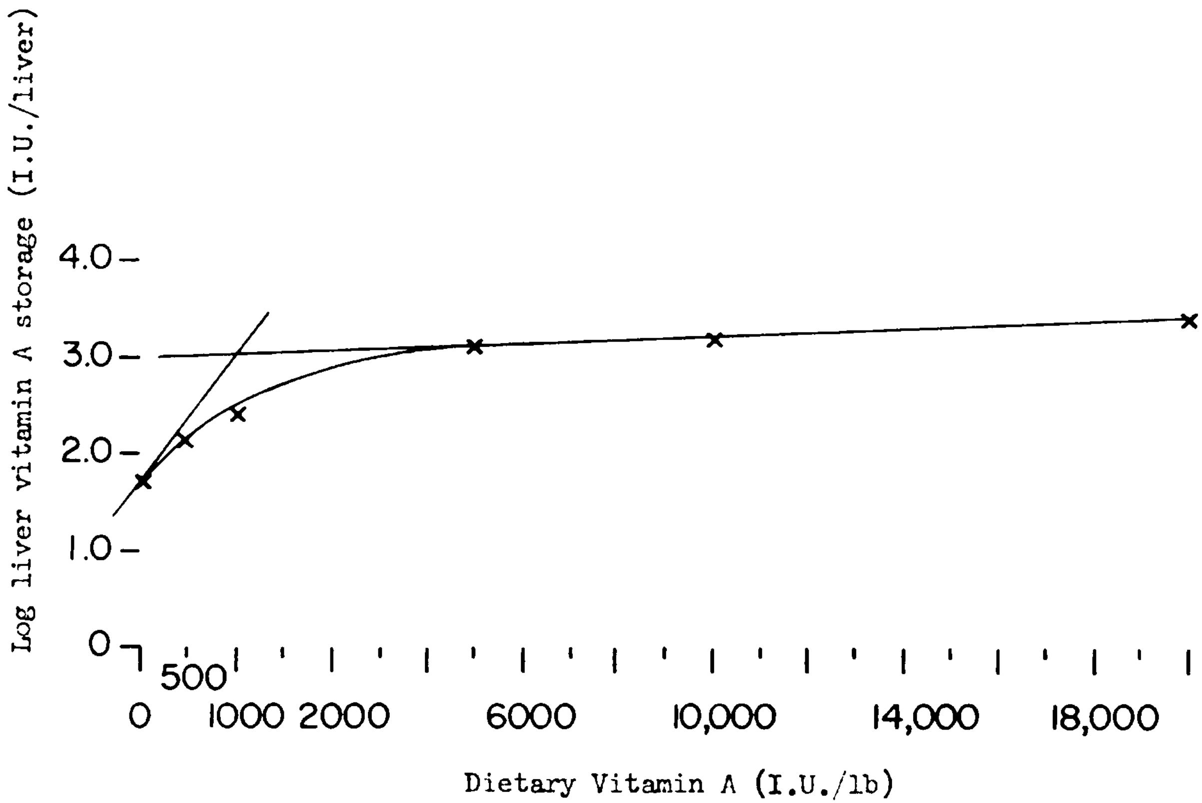

Figure 6. Effect of dietary vitamin A level on liver storage of vitamin A in young Japanese quail.

Experiment Q-25: Pyridoxine

Procedure. The percent ingredient composition of the pyridoxine-deficient Q-25 basal diet appears in Table 32, and a calculated analysis of its ingredients is shown in Table 33. In order to minize the amount of pyridoxine present, a purified glucose-isolated soybean protein ration, with a calculated protein content of 29%, was utilized. Pyridoxine was added at concentrations of 0, 0.2, 0.4, 0.8 and 1.6 mg. per pound, resulting in five diets with total calculated pyridoxine levels of 0.7 (Basal), 0.9, 1.1, 1.5 and 2.3 mg. of pyridoxine per pound.

Results and Discussion. Body weights at three, four and five weeks were shown to increase as dietary pyridoxine level was increased from 0.9 to 1.5 mg of pyridoxine per pound of diet. Either a leveling off or a slight decrease in weights was seen at levels higher than 1.5 mg per pound. None of the birds on the basal treatment (0.7 mg pyridoxine per pound) survived until the third week. When fifth week body weight was plotted graphically as a function of dietary pyridoxine concentration, a pyridoxine level of 1.2 mg per pound of diet was indicated as optimum for growth of the young Coturnix.

Table 32. Percent ingredient composition of basal diet (Q-25).

Ingredient	%
Glucose monohydrate	43.17
Isolated soybean protein	35.00
Cellulose	2.55
Corn oil	8.00
DL-methionine	0.57
Purified vitamin premix[1]	4.00
Calcium carbonate	0.05
Dicalcium phosphate	4.21
Purified mineral premix[2]	1.50
Chromium oxide	0.20
Glycine	0.25
Salt	0.50
Total	100.00

[1] Supplied the following per kg of diet: 10,012 I.U. vitamin A, 961 I.C.U. vitamin D_3, 8.7 I.U. d-alpha-tocopheryl acetate, 30 mcg vitamin B_{12}, 6.6 mg 2-methyl napthoquinone, 12 mg riboflavin, 88 mg niacin, 15 mg d-calcium pantothenate, 4.0 mg thiamine hydrochloride, 0.9 mg folic acid, 91 mcg biotin, 2.2 gm choline chloride, 1.8 mg pyridoxine and 50 mg ethoxyquin (as a preservative).

[2] Supplied the following per kg of diet: 139 mg Mn, 385 mg Fe, 55 mg Cu, 103 mg Zn, 1.6 mg Co, 749 mg Mg, 4.3 mg Mo and 4.1 mg I.

Table 33. Calculated analysis of basal diet (Q-25).

Ingredient	Amount
Protein, %	29.04
Fat, %	8.18
Fiber, %	2.59
Productive energy, kcal/lb	1153.16
Metabolizable energy, kcal/lb	1411.17
P.E./Protein ratio	39.72
M.E./Protein ratio	48.60
Xanthophylls	-

Table 34. Effect of dietary pyridoxine level on body weight of young Japanese quail.

Dietary pyridoxine level, mg/lb	Third week body weight (gms)	Fourth week body weight (gms)	Fifth week body weight (gms)
0.7 (Basal)	-	-	-
0.9	32.0	52.9	65.9
1.1	49.3	70.4	89.8
1.5	55.6	82.1	98.8
2.3	56.7	80.6	95.8

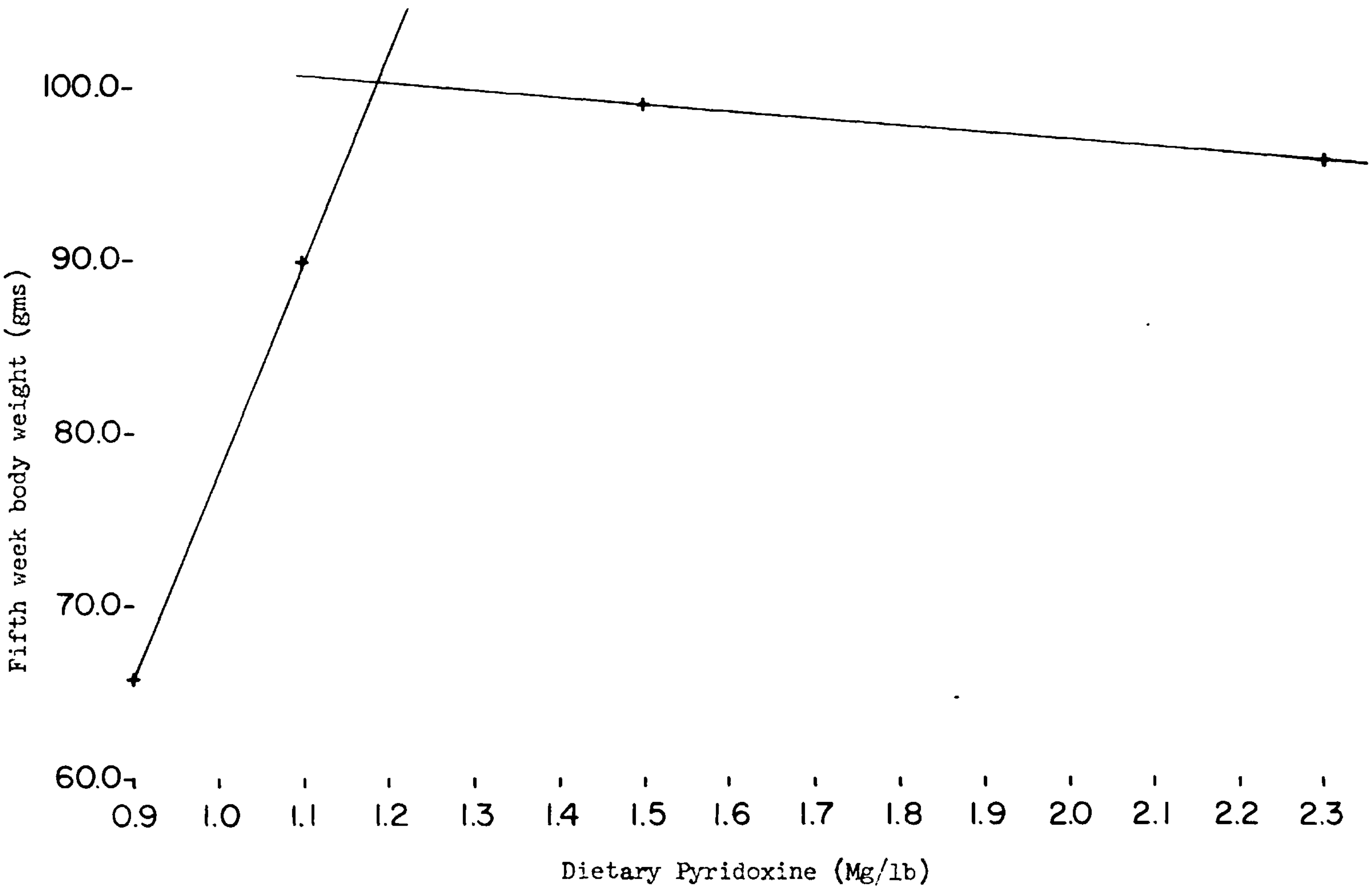

Figure 7. Effect of dietary pyridoxine level on fifth week body weight of Japanese quail.

SUMMARY

In 1965 the Poultry Science Department at the University of Arizona established a colony of Coturnix quail in order to evaluate their usefulness as experimental laboratory animals in physiological and nutritional research. Included here are the results of nine recent experiments involving the determination of some nutrient requirements for both young, growing birds and mature laying hens.

Under experimental conditions described herein, the amount of total protein required in the diets of growing Coturnix (hatching to five weeks of age) was found to be 28%. Optimum levels of the amino acids methionine plus cystine and glycine for growth of the young bird were observed to be 0.775 and 1.277%, respectively, of the diet. Vitamin A and pyridoxine were shown to be required at levels of 500 I.U. per pound and 1.2 mg per pound, respectively, for optimum growth of the Coturnix chick.

The amount of total protein required in the diet of mature, laying Coturnix hens was found to be approximately 20%. Supplementation of a practical corn-soybean ration with DL-methionine was found to be unnecessary for optimum performance of Coturnix breeders.

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