THE EFFECT OF DIFFERENT LEVELS OF DIETARY VITAMIN A ON COTURNIX COTURNIX JAPONICA

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ABSTRACT

THE EFFECT OF DIFFERENT LEVELS OF DIETARY VITAMIN A ON COTURNIX COTURNIX JAPONICA

by Hanna D. Georgis

Three experiments were carried out to estimate the effect of different levels of dietary vitamin A on *Coturnix coturnix japonica* (Japanese quail).

Vitamin A was essential to the coturnix quail for maintaining life, growth, health, vigor, normal function of epithelial tissue, vision, egg production, fertility and hatchability and, also, for survival.

Liver and blood plasma vitamin A values were determined. Body weight, feed efficiency, mortality, feed consumption, egg production, fertility and hatchability were measured.

Vitamin A deficiency symptoms in Japanese quail were characterized by drowsiness, weakness, poor plumage, excessive nasal and eye discharge, corneal opacity, restlessness; followed by incoordination, depression and, finally, death. Egg production, fertility and hatchability were reduced. The renal tubules of the deficient birds were filled with whitish urate deposits.

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A vitamin A depletion diet produced vitamin A deficiency symptoms and eventually resulted in death of the depleted birds. The low vitamin A dietary levels (250, 500, 1,000 IU/lb) caused vitamin A deficiency symptoms and led to some mortality among the birds on these levels.

Liver and blood plasma vitamin A values were simultaneously increased when vitamin A dietary levels were increased from 250 - 500 - 1,000 - 2,000 - 3,000 IU/lb.

On the 3,000 IU level, birds showed the lowest mean body weight, while on the 2,000 IU level, birds showed the highest mean body weight on any of the levels tested. The birds on the 500 and the 1,000 IU vitamin A levels died before losing weight, and surviving birds were strong enough to eat well and to put on weight until they died. On the 2,000 and 3,000 IU levels, the weak birds survived and remained weak and lived for a long time and showed a decrease in mean body weight.

On the 2,000 IU level, birds showed the best feed efficiency ratio both during the growth and egg production periods. They were the best feed converters of any birds on any of the different experimental vitamin A dietary levels.

On the 250 IU level, the female birds never produced any eggs. The highest egg production per hen per day and

the highest average egg weight during the experimental laying period were for the birds on the 2,000 IU level; the lowest were for birds on the 500 IU level.

Feed consumption was always increased when egg production increased.

The percent fertility was highest for eggs produced by birds on the high levels; the highest was on the 3,000 IU level. Eggs from birds on the 2,000 and the 3,000 IU vitamin A levels showed the highest percent hatchability, while those from birds on the 500 IU level showed the lowest percent fertility and hatchability.

The percent mortality was inversely proportional to vitamin A levels. It was 100 percent among the birds on the depletion diet and on the 250 IU level. After birds were put on the experimental diets, the highest percent mortality was recorded during the first week. All the deaths which were recorded during the laying period were among the female birds only. It appears that the female birds were more susceptible to vitamin A deficient diets than were the male Japanese quail. There were no deaths recorded from vitamin A deficiency among birds on the 2,000 IU and the 3,000 IU levels.

In a comparison between the different vitamin A experimental diets tested, the 2,000 IU level was the most efficient in maintaining life and the other biological criteria observed.

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It appears that the vitamin A requirement for the Japanese quail is more than 1,000 IU/lb vitamin A and less than 3,000 IU/lb and, that of the levels tested in these experiments, the 2,000 IU level most closely approaches the requirement.

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INTRODUCTION

Vitamin A has been the subject of more research in the field of animal nutrition and veterinary medicine than has any other vitamin. About fifty years of investigations have provided extensive data on its chemistry, analysis, deficiency symptoms and its requirements.

From a review of literature, it appears that no work has been done on the effects of vitamin A on Coturnix coturnix japonica (Japanese quail) concerning requirements, feed conversion, growth rate, survival, egg production, fertility and hatchability, blood plasma level and liver storage, deficiency symptoms, and other pathological disorders and physiological functions.

Recently, the Japanese quail has been used as a pilot animal for poultry research because of its ease of handling, its early maturity and short reproductive cycle and because it is not susceptible to any of the common diseases of the bobwhite quail (Wilson *et al.*, 1959, 1961; Padgett and Ivey, 1959).

This study was undertaken in an attempt to determine the effect of different levels of dietary vitamin A on the Japanese quail.

OBJECTIVES

The objectives of this experiment were to determine:

1. The effect of different levels of vitamin A on blood plasma level and liver concentration in mature Japanese quail.
2. The effect of different levels of vitamin A on growth rate during the growing period.
3. The effect of different levels of vitamin A on egg production during the egg laying period.
4. The effect of different levels of vitamin A on fertility and hatchability during the egg laying period.
5. The effect of different levels of vitamin A on mortality during the growing and egg laying periods.
6. The effect of low levels of vitamin A on the severity of the deficiency symptoms and the pathological disorders.
7. Vitamin A requirements for Japanese quail.

REVIEW OF LITERATURE

The ancient Greek, Roman and Arab physicians knew the therapeutic value of animal liver for the prevention and cure of night blindness (Moore, 1957).

The first evidence of the existence of vitamin A was presented in 1913 by two independent groups of workers (Osborne and Mendel, and McCollum and Davis) who found that certain natural fats and oils stimulated growth in rats while other fats with similar triglyceride compositions did not. In 1917, McCollum and Simmonds demonstrated that xerophthalmia was due specifically to lack of a fat soluble vitamin.

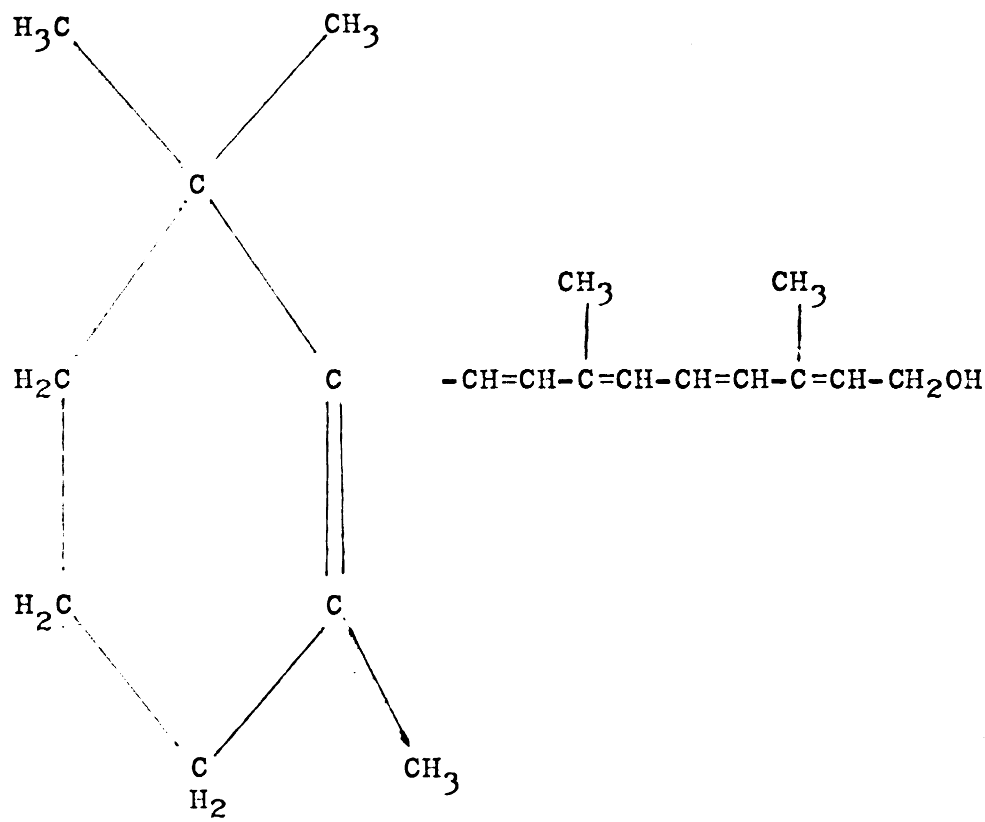
In 1920, Rosenheim and Drummond demonstrated that carotene of plants has a biologic action similar to the fat-soluble A substance. Ten years later it was found that carotene is converted to vitamin A *in vivo* (Moore, 1930).

In 1931, Karrer, Morf and Schopp determined vitamin A structure. In 1937, it was first produced synthetically by Kuhn and Morris in the laboratory.

Vitamin A is colorless and soluble in all fat solvents. It is a highly unsaturated alcohol which is stored in the body as an ester. It is found in the liver almost wholly as an ester. It appears in nature in several forms, the most common of which is found in mammals and salt water

fish and has been designated as vitamin A_1; while that found in fresh water fish is known as vitamin A_2 (Wohl and Goodhart, 1964).

Usually, the term vitamin A refers to vitamin A_1 whose empirical formula is $C_{20}H_{29}OH$. The structural formula is:



containing one beta-ionine ring and a long side chain composed of a series of isoprene units containing conjugated double bonds. Vitamin A_2 has an additional double bond in the beta-ionine ring (West and Todd, 1951).

Beta-carotene is the predominant carotinoid found in green leaves of legumes such as alfalfa and clovers, and

in green grasses and green vegetables. Cryptoxanthin is another vitamin A precursor and is the primary carotenoid present in yellow corn. Both beta-carotene and cryptoxanthin are converted in the animal body to vitamin A. Vitamin A, itself, is almost colorless, whereas the carotenes are intensely colored. They are isomeric hydrocarbons with the formula $C_{40}H_{56}$ and contain no oxygen. They are relatively stable to heat in the absence of oxygen (Wohl and Goodhart, 1964).

Pure vitamin A is readily destroyed by oxidation, it is heat stable when antioxidants are present. The less highly purified preparations are more stable than the pure preparations. The esters of vitamin A are more stable than the free alcohol. Vitamin A is easily oxidized and is decomposed rapidly in the presence of high levels of moisture, in the presence of water-soluble salts, at elevated temperature, during storage in the summer months, and in the presence of light (Moore, 1957).

Vitamin A can be protected by antioxidants, such as butylated hydroxytoluene (BHT) and by enveloping vitamin A in stable fat, gelatin, or wax. Gelatin is superior to fat or wax for this purpose (Pfizer, 1963; Olsen et al., 1959).

Xanthophylls contain a number of vitamin A inactive chemical substances closely related to vitamin A precursors. Xanthophyll and crytoxanthin are largely responsible for

the color in the eyes, beaks, shanks, egg yolks, and in the adipose tissue of some chickens (Moore, 1957).

Vitamin A is produced synthetically on a commercial scale as acetate and palmitate (Kuhn and Morris, 1937). One International Unit (IU) of vitamin A is equivalent to 0.344 micrograms of crystalline vitamin A acetate, or 0.300 micrograms of crystalline vitamin A alcohol. One IU of carotene is the activity of 0.6 micrograms of beta-carotene (Moore, 1957).

The vitamin A requirement of the chick is 1,200 IU/lb., for the laying hen it is 2,000 IU/lb., and for the turkey it is 2,400 IU/lb. (NAS-NRC, 1963). These requirements are influenced by nitrates, proteins, high concentrate ration, phosphorus, antibiotics, thyroid function, diethylstilbestrol, vitamin D, high temperature, and diseases and parasites (Hoffman-LaRoche, 1965).

Most of the carotenes are converted into vitamin A in the intestinal wall during absorption (Olsen et al., 1959). The liver contains about 90 percent of the total vitamin A in the body. The blood and the kidneys contain most of the remainder (Hoffman-LaRoche, 1965).

Orally administered vitamin A is emulsified in the small intestine by bile salts, then it is transformed into the alcohol form in the intestinal wall, then absorbed through the wall of the intestine and transported by the lymph in ester form as a protein complex through

the lymphatic duct, and finally it is stored mainly as esters in the liver (Hoffman-LaRoche, 1965).

Vitamin A is essential for growth, health, vigor, normal function of epithelial tissue, vision, egg production, fertility and hatchability.

Vitamin A deficiency in poultry causes impaired growth and poor feed efficiency, general weakness, emaciation, staggering gait, ataxia, poor plumage, markedly decreased resistance to infections and increased mortality, excessive eye and nasal discharge and excessive secretion from intestinal mucous glands, and finally, corneal cloudiness. Egg production, fertility and hatchability are markedly reduced. Finally, vitamin A deficiency results in total blindness, incoordination, convulsions and death (Scott and Norris, 1959). Vitamin A deficiency in cockerels causes an increase in the number of abnormal sperm and a decrease in the total number of sperm and, thus, male fertility is reduced (Paredes and Garcia, 1959). According to Bearse et al. (1953) the number of blood spots in eggs progressively increased as the levels of vitamin A decreased in the ration.

On post-mortem examination of birds which are suffering from a vitamin A deficiency, creamy, small white pustules are found in the nasal passages and the upper alimentary tract. The renal tubules are filled with white urate deposits. The mucous membrane of the

alimentary and respiratory tracts is replaced by stratified squamous keratinized epithelium, and keratinization of the secretary epithelial tissue is seen (Scott and Norris, 1959).

Absorption of vitamin A is rapid, thus birds respond promptly to high doses of vitamin A if they are not in advanced stages of deficiency. Supplemental vitamin A decreases the incidence and severity of infections and parasitic diseases (Scott and Norris, 1959; Squibb et al., 1955; Erasmus et al., 1960; and Pande and Krishnamurty, 1959).

GENERAL EXPERIMENTAL PROCEDURE

Stock Used

Fertile Japanese quail eggs from the Michigan State University experimental poultry farm stock were randomly selected and hatched in a Jamesway-252 forced draft-type incubator.

Housing and Management

The one-day-old quail chicks were removed from the incubator and placed in raised-wire chick batteries (Petersime Brooder unit with electrical heating unit for each pen) at 95° F. and fed on a basal depletion diet (protein 26.95%), adequate in all known requirements except vitamin A. The chicks were reared on paper for the first seven days, then the paper was removed and the chicks were held in the battery until two weeks of age on the same vitamin A deficient basal ration.

The birds were individually weighed, then placed in equal weight groups, wing-banded, and replications of twenty birds each were randomly distributed into raised-wire chick batteries, each replicate in a separate pen. The birds were placed on different proposed vitamin A experimental dietary levels. Experiment I consisted of three replicates of four different levels, and Experiment II consisted of four replicates of five different levels. Feed and water were kept before the birds at all times.

The heating units were adjusted to 95° F. before the chicks were placed in the batteries, then decreased five degrees per week until the temperature reached 80° F. The temperature in the room was not constant. All the birds received continuous (24-hour) lighting.

Feeding

The basal depletion diet which was used during all the experiments was a modified Michigan State University experimental poultry ration (Table 1). It was designed to determine a suitable depletion period for chicks. It contained all the known requirements of chicks except vitamin A (Harms, Reid & Couch, 1955; and Flegal, 1965).

The vitamin A which was used in the different levels in the experimental rations was a vitamin A palmitate stabilized with gelatin and sugar (Pfizer A 250-P); each gram contained 250,000 USP units. It dissolves readily in digestive fluids for immediate absorption, is highly stable during storage, and does not need to be stored in a refrigerator or in the dark.

Experimental Design

One-day-old Japanese quail chicks were used for each of the three successive experiments, using a new group of birds for each experiment. The previously mentioned basal vitamin A depletion ration was fed to the quail chicks

until they were two weeks of age. Then the birds were placed on different proposed vitamin A experimental diets until the end of each of the experiments.

The basal depletion diet was mixed once for the whole experiment. The different vitamin A experimental rations were mixed once weekly, approximately one-half of the weekly need was fed, and the remainder was stored until used in the second half of the week. Feed was kept before the birds continuously.

Growing Period

The birds were individually weighed at weekly intervals, and feed consumption per lot was measured at the end of each week during the experimental period.

At the end of the fourth week on the experimental diets, blood samples by heart puncture were taken individually; the samples were pooled from each treatment level, and plasma vitamin A determined by the method described by Yudkin (1941). Half of the birds on each test diet were randomly selected and sacrificed. Livers were removed, wrapped in Saran Wrap and aluminum foil, frozen and held at about -14° C. and later assayed for vitamin A content by the basic Carr-Price method (1926).

Egg Laying Period

The remainder of the birds were kept on the same experimental diets to the end of the experiments. Ground limestone was fed free-choice all the time during the egg laying period. A ratio of one male quail to each five females were kept in each experimental pen.

When the females came into production, eggs were gathered twice daily, and egg weight and production were recorded. Eggs were placed in the incubator at the end of each week during the egg laying period until the end of the experiment. On the eighteenth day of incubation, the quail chicks were examined and removed from the incubators, and the eggs which failed to hatch were broken out and examined macroscopically to determine fertility. All egg weights and body weights were measured to the nearest gram. The feed consumption was recorded during the egg laying period, and the average egg rate per quail was recorded for each dietary level.

Mortality was recorded during both the growing and the egg laying period.

The body weights for the different dietary levels were subjected to analysis of variance (Guenther, 1964).

PRELIMINARY EXPERIMENT

On April 24, 1964, sixty one-day-old Japanese quail chicks were placed in a Jamesway backwarmer-type starting

battery at 95° F. with a room temperature of 75° F. and were fed on the previously mentioned vitamin A depletion diet. Another sixty one-day-old Japanese quail chicks from the same stock were placed in the same battery and fed on a quail breeder ration (25.66% protein and 3,100 IU/lb. vitamin A) as a control (Appendix Table 1). Mortality was recorded during the experimental period.

EXPERIMENT I

On May 24, 1964, one-day-old Japanese quail chicks were hatched and placed into raised-wire chick batteries and fed the previously mentioned vitamin A depletion ration.

On June 9, 1964 (16 days of age), the birds were placed in equal weight groups, wing-banded, and three replications of twenty birds each were randomly distributed into the following experimental rations:

Diet								
1	Basal	ration	+ 500 IU/lb	stabilized	vitamin	A	palmitate
2	"	"	+ 1,000 IU/lb	"	"	"	"
3	"	"	+ 2,000 IU/lb	"	"	"	"
4	"	"	+ 3,000 IU/lb	"	"	"	"

All the experimental procedures which were previously mentioned were carried out with exception of the egg laying period procedures.

At the end of the fourth week on the experimental diets, blood samples were taken from all the birds. Half

of the birds from both sexes were randomly selected, sacrificed, and livers were removed. The remainder of the birds were kept on the same experimental diets.

Individual body weight, feed consumption and mortality were recorded. Blood plasma vitamin A concentration and liver vitamin A concentrations were assayed.

At the end of the fourteenth week on the experimental rations, Experiment I was terminated.

EXPERIMENT II

On September 8, 1964, Experiment II was initiated using the same experimental procedures as in Experiment I, except that the birds were randomly distributed when they were 14 days of age in four replications of twenty birds each and were placed on the following experimental rations:

Diet									
1	Basal	ration	+ 250	IU/lb	stabilized	vitamin	A	palmitate
2	"	"	+ 500	"	"	"	"	"
3	"	"	+ 1,000	"	"	"	"	"
4	"	"	+ 2,000	"	"	"	"	"
5	"	"	+ 3,000	"	"	"	"	"

At the end of the fourth week on the experimental diets, blood samples were taken from only a random sample of the male Japanese quail of each experimental level. These same birds were sacrificed, and their livers removed and assayed for vitamin A content. The remainder of the birds were kept on the same experimental diets. The other experimental procedures which were mentioned before were carried out and feed consumption, individual body weight, mortality, egg production and egg weight, fertility and hatchability were recorded. Blood plasma vitamin A concentration and liver vitamin A concentrations were assayed.

At the end of the twenty-second week on experimental diets, Experiment II was terminated.

Table 1. Composition of the Japanese quail basal vitamin A depletion ration

Ingredient	Percent of ration
Ground milo	42.5
Soybean oil meal, 44% protein	50.0
Cottonseed oil	1.5
Steamed bonemeal	2.0
Limestone	1.5
Salt, iodized + 1.5 gms. $MnSO_4$ + 2 gms. $ZnSO_4$	0.5
Vitamin premix	2.0*

* The premix contains the following ingredients per 100 lbs. of ration:

200	mgs.	riboflavin
500	mgs.	dicalcium pantothenate
1,250	mgs.	niacin
2,000	mgs.	choline chloride
0.5	mgs.	vitamin B_{12}
24	mgs.	vitamin K
4,000	ICU	vitamin D_3
200	mgs.	procaine penicillin

Sufficient soybean to make up the 2 percent

Calculated analysis:

Ingredient	Percent	Ingredient	Percent
Protein	26.95	Arginine	1.97
Fat	3.13	Glycine	1.38
Fiber	4.51	Methionine	0.40
Ash	7.25	Cystine	0.41
Calcium	1.25	Lysine	1.68
Phosphorus	0.72	Tryptophan	0.39

Productive energy Cal/lb 910.20

EXPERIMENTAL RESULTS

Preliminary Experiment

Excessive death from vitamin A deficiency started among the birds which were fed a completely deficient ration at the seventeenth day of age before any of the macroscopic vitamin A deficiency symptoms were visible. Most of the deaths occurred between three and four weeks of age, the remainder of the birds died before the end of the fifth week on the deficient diet, and no bird on this diet survived beyond this age (Table 2). Vitamin A deficiency symptoms were observed on the surviving birds after 24 days of age. The symptoms were general weakness and emaciation, poor plumage, excessive nasal and eye discharge, corneal opacity and restlessness. These symptoms were followed by incoordination, depression and finally death.

Some of the birds died from starvation because they could not reach the water to drink and the food to eat. Most of the birds died before their eyes were affected. Some of the birds showed sudden death before any symptoms appeared.

A peculiar pathological sign which was seen on autopsy for the depletion birds was a network of white lines in the renal tubules resulting from their being filled with white urate deposits. The internal organs were pale and emaciated; creamy-white pustules were seen along the nasal passages and the upper alimentary tract.

Experiment I

1. Liver Vitamin A Concentration and Vitamin A Blood Plasma Concentration

Table 3 shows liver vitamin A concentration of quail after four weeks on the different vitamin A level experiment diets.

Table 4 shows vitamin A blood plasma levels after four weeks on the vitamin A experimental diets.

Both liver and blood plasma vitamin A values were simultaneously increased when vitamin A dietary levels were increased from 500 - 1,000 - 2,000 - 3,000 IU/lb in the Japanese quail diets.

2. Body Weight

The statistical analysis of the body weight of the Japanese quail as shown in Table 5 revealed no significant differences between the levels ($P < 0.05$) at two weeks on vitamin A experimental diets. The mean body weights at two weeks on vitamin A experimental diets which were compared in this experiment are shown in Table 6. The mean body weight of the quail receiving the ration containing the 500 IU/lb vitamin A dietary level was 70.4 gms. and was the highest mean body weight, while that of the quail on the 3,000 IU/lb vitamin A dietary level was 65.6 gms. and was the lowest mean body weight.

Table 7 shows the analysis of variance of body weights after four weeks on the vitamin A experimental diets; the differences between the levels were highly significant ($P < 0.01$). The mean body weights of birds after four weeks on the four different levels of vitamin A which were compared in this experiment are shown in Table 8. The highest mean body weight was 98.8 gms. for the 2,000 IU/lb vitamin A dietary level and the lowest was 84.4 gms. for the 3,000 IU/lb vitamin A level.

3. Feed Efficiency

Feed efficiency (gms. feed/gms. gain) of quail for the first four weeks on the vitamin A experimental diets is recorded in Table 9. The average feed efficiency was calculated for all the survival birds in each treatment from the first day until the end of the fourth week on the experimental diets. The lowest ratio was 5.16 for the 2,000 IU/lb. vitamin A level, and the highest ratio was 6.10 for the 3,000 IU/lb. vitamin A level.

4. Mortality

Mortality for the first four weeks on the experimental diets (growing period) is recorded in Table 10. Mortality increased when vitamin A level in the diet was decreased. The lowest mortality was 26.6 percent on the 2,000 and the 3,000 IU/lb. vitamin A levels, and the highest was 46.6 percent on the 500 IU/lb. level.

5. General Data

Average feed consumption per Coturnix quail per day for the first four weeks on the different vitamin A dietary levels is recorded in Appendix Table 2.

The body weight per male and female Japanese quail during the growing period is recorded in Appendix Table 3.

The data from Experiment I is summarized in Appendix Table 4.

Table 2. Preliminary Experiment -- Summary of mortality on vitamin A depletion diet (Basal ration)

Age/day	No. Mortality
1 - 16	10*
17	3
18	3
19	3
20	2
21	3
22	3
23	2
24	3
25	5
26	4
27	4
28	3
29	3
30	2
31	1
33	2
34	1
35	2
36	1
Total	60
% Mortality	100 percent

* The ten birds died in the first few days and showed no vitamin A deficiency symptoms.

Table 3. Experiment I -- Liver vitamin A concentrations of quail after four weeks on vitamin A experimental diets*

Vitamin A level (IU/lb)	Mean Vitamin A Liver Concentrations (mcg/gm., fresh basis)
500	1.24
1,000	2.85
2,000	18.17
3,000	38.81

* The samples were pooled from each treatment level.

Table 4. Experiment I -- Vitamin A blood plasma concentration of quail after four weeks on vitamin A experimental diets*

Vitamin A level (IU/lb.)	Mean vitamin A blood plasma concentration (mcg/100 ml. blood plasma)
500	20.31
1,000	38.75
2,000	69.16
3,000	82.08

* The samples were pooled from each treatment level.

Table 5. Experiment I -- Analysis of variance of body weights of quail after two weeks on the vitamin A experimental diets

Source		Sum square	Degrees of freedom	Mean square	F value
Treatment (row, level)	SS_A	528	3	176	2.11
Replicate (column)	SS_B	1391.4	2	695.7	
Interaction	SS_{AB}	1846	6	307.7	
Subclass	SS_{Tr}	3765.4	11	324.3	
Error (within)	SS_E	12834.2	154	83.34	
Total	SS_T	16599.6	165		

Table 6. Experiment I -- Mean body weight of quail after two weeks on vitamin A experimental diets

Vitamin A level (IU/lb.)	Mean body wt. (gms.)
500	70.4
1,000	67.1
2,000	69.1
3,000	65.6

Table 7. Experiment I -- Analysis of variance of body weights of quail after four weeks on the experimental diets

Source	Sum square		Degrees of freedom	Mean square	F value
Treatment (row)	SS_A	4914	3	1638	8.06
Replicate (column)	SS_B	3783	2	1891.5	
Interaction	SS_{AB}	3626	6	604.3	
Subclass	SS_{Tr}	12323	11	1120.27	
Error (within)	SS_E	30275	149	203.20	
Total	SS_T	42598	160		

Table 8. Experiment I -- Mean body weights of quail after four weeks on vitamin A experimental diets

Vitamin A level (IU/lb.)	Mean body wt. (gms.)
500	98.7
1,000	93.0
2,000	98.8
3,000	84.4

Table 9. Experiment I -- Feed efficiency of quail for the first four weeks on vitamin A experimental diets (gms. feed/gms. gain)*

Weeks	Vitamin A level (IU/lb.) 500	1,000	2.000	3,000
1	4.24	4.55	4.22	4.52
2	3.94	4.08	3.96	4.48
3	5.82	5.50	5.99	7.26
4	8.52	3.40	7.52	11.54
Overall av.	5.29	5.33	5.16	6.10

*The average was calculated for all the survival birds in each treatment from the first day until the end of the fourth week on the experimental diets (growing period).

Table 10. Experiment I -- Summary of mortality for the first four weeks on vitamin A experimental diets during the growing period

	Vitamin A levels (IU/lb.)*							
	500		1,000		2,000		3,000	
Week	No.mort.	% mort.	No.mort.	% mort.	No.mort.	% mort.	No.mort.	% mort.
1	23	38.3	18	30.0	15	25.0	14	23.3
2	3	5.0	0	0	0	0	1	1.6
3	2	3.3	0	0	1	1.6	1	1.6
4	0	0	1	1.6	0	0	0	0
Total	28	46.6	19	31.6	16	26.6	16	26.6

* Sixty birds started at each treatment level.

Experiment II

1. Liver Vitamin A Concentration and Vitamin A Blood Plasma Concentration

The liver vitamin A concentration in Japanese quail on the different vitamin A levels after four weeks on the experimental diets are recorded in Table 11.

Table 12 shows vitamin A blood plasma concentration after four weeks on vitamin A experimental diets.

The liver vitamin A concentration and the blood plasma vitamin A values were raised when vitamin A dietary levels were increased. The lowest value was for quail on the 500 IU level and the highest for birds on the 3,000 IU level.

2. Body Weight

The statistical analysis of the body weights of the Japanese quail on the different diets showed no significant differences at the end of two weeks on the experimental diets (Table 13). The mean body weights are shown in Table 14.

Body weights of quail at the end of four weeks on the different vitamin A experimental diets (Table 15) were significantly different ($P < 0.05$). The mean body weights of quail after four weeks on the vitamin A experimental diets which were compared in Experiment II are shown in Table 16.

3. Feed Efficiency

Table 17 shows the feed efficiency of quail for the first four weeks on the different vitamin A level experimental diets. The 500 IU/lb. vitamin A dietary level produced the lowest ratio of any of the treatments while the 3,000 IU level produced the highest ratio.

Feed efficiency during the egg laying period from the sixth week to the end of the seventeenth week on the vitamin A experimental diets is recorded in Table 18. Birds on the 2,000 IU/lb. vitamin A level ration showed the best feed conversion rate while birds on the 500 IU/lb. level ration showed the poorest feed conversion.

4. Egg Production

Table 19 gives a summary of egg production data during the egg laying period from the sixth week to the seventeenth week on the vitamin A experimental diets. Recorded in this table for each vitamin A treatment level are the number of Coturnix quail females, number of eggs laid and their weight, average egg weight, and the percent egg production per hen per day. Quail on the 2,000 IU/lb. vitamin A level diet showed the highest egg production while birds on the 500 IU level diet showed the lowest. Birds on the 250 IU level did not produce any eggs.

The females came into egg production during the fifth week on the vitamin A experimental diets (7 weeks of age), except those on the 500 IU/lb. level which began to lay eggs one week later. The highest production level from birds on the vitamin A experimental diets was reached between the ninth and eleventh weeks on the diets.

5. Fertility and Hatchability

The percent of fertile eggs produced by birds on the different vitamin A level diets and the percent of fertile eggs which hatched are shown in Table 20. The summary of data for each week during the egg laying period is recorded in Appendix Table 5. The highest percentage fertility and hatchability was secured at the 2,000 and the 3,000 IU/lb. vitamin A level.

6. Mortality

The percent of mortality of quail during the growing period and egg laying period is shown in Table 21. The summary of mortality data from Experiment II is shown in Appendix Table 6. Mortality was highest on the 250 and the 500 IU/lb. vitamin A levels during both the growing and egg laying periods.

7. General Data

Feed consumption per Japanese quail per day is recorded in Appendix Table 7.

The body weight per male and per female Japanese quail is recorded in Appendix Table 8.

The females came into egg production during the fifth week on the vitamin A experimental diets (7 weeks of age), except those on the 500 IU/lb. level which began to lay eggs one week later. The highest production level from birds on the vitamin A experimental diets was reached between the ninth and eleventh weeks on the diets.

5. Fertility and Hatchability

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6. Mortality

The percent of mortality of quail during the growing period and egg laying period is shown in Table 21. The summary of mortality data from Experiment II is shown in Appendix Table 6. Mortality was highest on the 250 and the 500 IU/lb. vitamin A levels during both the growing and egg laying periods.

7. General Data

Feed consumption per Japanese quail per day is recorded in Appendix Table 7.

The body weight per male and per female Japanese quail is recorded in Appendix Table 8.

Summary of data from Experiment II is shown in Appendix Table 9.

8. Vitamin A Deficiency Symptoms

Excessive mortality was observed among the birds which were fed the low levels of vitamin A.

On the 250 IU/lb. vitamin A level, mortality started among the birds during the first week on the experimental diet, and the highest mortalities were recorded during the second week on the experimental diet. Deficiency symptoms were seen in the surviving birds during the third week on the experimental diet. The symptoms were the same as described previously (Scott and Norris, 1959) with the exception that the deficient birds were abnormally quiet and depressed. They continued to eat well and put on weight until they died without losing weight. Four male birds remained alive on the 250 IU/lb. level although showing vitamin A deficiency symptoms. These birds were placed on a high concentrate vitamin A diet (100,000 IU/lb.). In a few days they returned back to normal and grew well. A few virgin Japanese quail females were placed with them and fed the same high vitamin A ration and, when they came into egg production, fertility and hatchability were recorded. Fertility and hatchability were rather low when compared with birds on the 2,000 IU/lb. level (table 22).

On the 500 IU/lb. vitamin A diet, deficiency symptoms started to appear during the third week on the experimental diet. The highest mortalities were recorded during the first four weeks on this experimental diet. Egg production, fertility and hatchability were markedly reduced. Eye troubles and lameness appeared in some of the hatched chicks.

Vitamin A deficiency symptoms appeared among a few birds on the 1,000 IU/lb. vitamin A level diet after twelve weeks on the experimental diets. The symptoms took a slow chronic course and ended in death. Fertility and hatchability were low among birds on the 1,000 IU/lb. level.

On the 2,000 IU/lb. level the birds were normal during the experiment but on the 3,000 IU/lb. level the birds were nervous. Average body weight was the lowest for birds on the 3,000 IU/lb. level.

Table 11. Experiment II -- Liver vitamin A concentration of quail after four weeks on vitamin A experimental diets*

Vitamin A level (IU/lb.)	Mean vitamin A liver concentration (mcg/gm., fresh basis)
500	1.73
1,000	3.45
2,000	18.52
3,000	43.87

* The samples were pooled from each treatment.

Table 12. Experiment II -- Vitamin A blood plasma concentration of quail after four weeks on vitamin A experimental diets*

Vitamin A level (IU/lb.)	Mean vitamin A blood plasma concentration (mcg/100 ml. blood plasma)
500	20.00
1,000	36.28
2,000	63.25
3,000	78.75

* The samples were pooled from each treatment.

Table 13. Experiment II -- Analysis of variance of two-week body weights of quail on vitamin A experimental diets

Source	Sum square		Degrees of freedom	Mean square	F value
Treatment (row, level)	SS_A	314	4	78.50	0.71
Replicate (column)	SS_B	352	3	117.33	
Interaction	SS_{AB}	932	12	77.66	
Subclass	SS_{Tr}	1598	19	84.10	
Error (within)	SS_E	26182	239	109.54	
Total	SS_T	27780	258		

Table 14. Experiment II -- Mean body weights of quail after two weeks on vitamin A experimental diets

Vitamin A level (IU/lb.)	Mean body wt. (gms.)
250	53.7
500	56.4
1,000	56.6
2,000	55.1
3,000	57.2

Table 15. Experiment II -- Analysis of variance of body weight of quail after four weeks on the experimental diets

Source	Sum square		Degrees of freedom	Mean square	F value
Treatment (row, level)	SS_A	4316	4	1079	2.76
Replicate (column)	SS_B	3823	3	1274.3	
Interaction	SS_{AB}	7377	12	614.7	
Subclass	SS_{Tr}	15516	19	816.6	
Error (within)	SS_E	79551	204	389.9	
Total	SS_T	95067	223		

Table 16. Experiment II -- Mean body weight of quail after four weeks on vitamin A experimental diets

Vitamin A level (IU/lb.)	Mean body wt. (gms.)
250	79.9
500	84.7
1,000	80.0
2,000	81.0
3,000	72.1

Table 17. Experiment II -- Feed efficiency of quail for the first four weeks on vitamin A experimental diets (gms.feed/gms. gain)*

	Vitamin A levels (IU/lb.)				
Week	250	500	1,000	2,000	3,000
1	2.82	2.85	2.54	2.54	2.54
2	5.00	3.64	3.07	4.10	3.01
3	6.72	5.62	5.25	5.46	6.48
4	8.83	7.63	10.17	7.63	17.46
Overall av.	4.15	4.36	4.24	4.42	4.67

* The average was calculated for all the survival birds in each treatment from the first day until the end of the fourth week on the experimental diets (growing period).

Table 18. Experiment II -- Feed efficiency (gms. feed/gms. egg produced) of quail during egg production from the sixth week to the seventeenth week on vitamin A experimental diets*

	Vitamin A level (IU/lb.)			
Week	500	1,000	2,000	3,000
6	21.01	12.78	10.61	14.49
7	20.99	10.99	6.57	9.19
8	18.75	4.06	5.89	5.89
9	31.02	3.33	4.27	6.11
10	19.79	4.55	3.92	7.15
11	12.44	5.05	4.47	6.30
12	53.66	7.23	4.99	10.05
13	39.22	6.61	5.62	7.39
14	156.95	8.31	7.40	15.32
15	17.43	9.00	5.49	10.58
16	90.04	10.44	6.31	11.66
17	26.19	10.26	6.53	10.02
Overall average	24.45	6.20	5.64	8.50

* The average was calculated for all the survival birds in each treatment from the beginning of the sixth week until the end of the seventeenth week on the experimental diets (egg laying period).

Table 19. Experiment II -- Summary of egg production data of quail from the sixth week to the seventeenth week on vitamin A experimental diets

	Vitamin A levels (IU/lb.)																			
	500					1000					2000					3000				
Week	No. female	No. eggs	Wt. eggs	Av. egg wt.	% egg prod /hen	No. female	No. eggs	Wt. eggs	Av. egg wt.	% egg prod /hen	No. female	No. eggs	Wt. eggs	Av. egg wt.	% egg prod /hen	No. female	No. eggs	Wt. eggs	Av. egg wt.	% egg prod /hen
6	16	10	78	7.8	8.9	22	31	251	8.1	20.1	25	34	304	9.0	19.4	27	27	212	7.8	14.3
7	16	10	77	7.7	8.9	22	51	434	8.5	33.1	24	49	452	9.2	29.2	27	38	329	8.7	20.1
8	15	13	92	7.1	12.3	22	86	776	9.0	55.8	23	57	537	9.4	35.4	27	65	582	8.9	34.4
9	13	8	60	7.5	8.8	21	104	948	9.1	70.7	21	71	687	9.7	48.2	26	63	601	9.5	34.6
10	12	10	86	8.6	11.9	21	75	684	9.1	51.0	21	87	854	9.8	59.2	26	64	595	9.3	35.2
11	11	16	135	8.4	20.8	20	64	604	9.4	45.7	20	73	712	9.7	52.1	23	64	605	9.4	39.8
12	10	5	28	5.6	7.1	20	45	407	9.1	32.1	20	67	643	9.6	47.9	23	37	362	9.8	23.0
13	8	5	36	7.2	8.9	19	48	433	9.0	36.1	19	57	542	9.5	42.9	23	50	492	9.8	31.1
14	8	1	7	7.0	1.8	19	38	361	9.5	30.1	19	41	404	9.8	30.8	23	21	216	10.2	13.0
15	6	8	63	7.9	19.0	18	35	315	9.0	27.8	19	60	576	9.6	45.1	23	31	314	10.1	19.3
16	6	2	12	6.0	4.7	18	30	276	9.2	23.8	19	52	486	9.3	39.1	23	34	285	8.4	21.1
17	6	5	39	7.8	11.9	17	28	250	8.9	23.5	19	51	470	9.2	38.3	22	38	374	9.8	24.7
Total		97	713				635	5739				699	6668				532	4967		
Overall egg wt.				7.7					9.0					9.5					9.3	
% egg prod.,hen day					10.4					37.9					40.2					25.9

Table 20. Experiment II -- Fertility and hatchability of eggs produced by quail from the sixth week to the seventeenth week on the vitamin A experimental diets

Vitamin A level (IU/lb.)	No. eggs	Hatch.	Fert.	Infert.	% H.	% F.	% I.
500	43	5	11	27	31	37	63
1,000	302	76	109	117	41	61	39
2,000	348	140	116	92	54	74	26
3,000	301	132	110	59	54	80	20

Table 21. Experiment II -- Mortality of quail during the growing period and egg laying period on vitamin A experimental diets

	Vitamin A levels (IU/lb.)				
	250	500	1,000	2,000	3,000
Growth period (1-4 wks.) %	83.7	48.7	27.5	30.0	30.0
Egg laying period* (5-22 wks.) %	100.0	56.5	31.0	28.1	27.0

* Four male Japanese quail on the 250 IU level were saved and placed on a high concentrated vitamin A diet (100,000 IU/lb).

Table 22. Experiment II -- Fertility and hatchability of eggs produced by quail on high vitamin A dietary level (100,000 IU/lb.)

Week	No.eggs	Hatch.	Fert.	Infert.	% Hatch.	% Fert.
1	11	3	4	4	42.9	63.6
2	4	-	1	3	0	25.0
3	9	2	2	5	50.	44.4
4	6	-	4	2	0	66.7
5	8	1	2	5	33.3	37.5
Total	38	6	13	19	31.0	50.0

DISCUSSION

1. Liver Vitamin A Concentration and Vitamin A Blood Plasma Concentration

From a review of literature, it appears that no work has been done on the values of liver vitamin A concentrations or blood plasma vitamin A concentrations on the Japanese quail. A comparison with that of the chicken is valuable for the study.

The liver and blood plasma concentrations of Coturnix quail in this experiment were lower than those reported by Castano *et al*. (1951) for the chicken and were about the same concentrations which were reported by Flegal (1965), also for the chicken.

It appears that liver vitamin A concentrations and blood plasma concentrations were dependent on the length of time the bird was on the experimental diet, level of dietary supplementation and, based on other researchers' results, the amount which is passed from egg to the offspring.

The liver and blood plasma concentration of quail on the 250 IU level was not recorded because so few birds were left alive that there was not a sufficient number from which liver and blood samples could be secured to make the assay.

In Experiment I, blood samples were taken from all the birds and livers from half of them. Many of the birds

from which blood samples had been taken by heart puncture died from internal hemorrhage, thrombosis, anemia, shock and from injuries; so few birds remained that there were not enough to continue the second half of the experiment (egg laying period).

In Experiment II, blood samples were taken only from the extra males which were sacrificed and their livers removed and assayed. The remainder of the birds were kept on the same experimental vitamin A dietary levels until the end of the experiment.

The liver vitamin A values were higher in Experiment II than in Experiment I when the two similar levels were compared, possibly due to the length of the depletion period which was 16 days in Experiment I and 14 days in Experiment II. Both liver and blood plasma vitamin A values were simultaneously increased when vitamin A dietary levels were increased in the Japanese quail diets.

2. Body Weight

The analysis of variance of body weights of quail at the end of two weeks on vitamin A experimental diets in both Experiments I and II showed no significant differences between the treatments. At the end of four weeks, body weights were significantly different ($P < 0.05$).

In both Exeriments I and II the mean body weights of quail on the 3,000 IU vitamin A level were the lowest.

The deficient birds on the low vitamin A levels (250, 500, 1,000) died before losing weight; the survivors were evidently strong enough to eat well and to put on weight until they died, while the weak birds on the high vitamin A levels, especially the 3,000 IU level, survived and remained weak and lived for a long time and showed a decrease in mean body weight.

Harms et al. (1955) reported that increasing the vitamin A content of the diet from 500 - 10,000 IU/lb had no effect on the average weight of chickens. Hill et al. (1961), Olsen et al. (1964) and Flegal (1965) reported that within certain levels the average body weight of the chicken was increased as the vitamin A activity of the diet was increased. The same results were recorded in the turkey (Stoewsand and Scott, 1961). In Coturnix quail, those on the 3,000 IU level had the lowest mean body weight, while those on the 500 IU level had the highest.

It appears that the vitamin A activity has no influence on the average body weight of the Japanese quail.

3. Feed Efficiency

Birds on the 3,000 IU vitamin A dietary level showed the poorest feed efficiency for growth rate among all levels in both Experiments I and II; while feed efficiency was quite similar for birds on the other levels. The average feed efficiency was calculated for the survival

birds in each treatment from the first day until the fourth week on the experimental diet. It was previously mentioned that birds on the lower vitamin A dietary levels died before losing weight and the survivors were strong enough to eat well and to put on weight until they died, while the weak birds on the high levels lived for a long time and showed a decrease in body weight and poor growth rate.

Feed efficiency in the chicken (Olsen *et al.*, 1964; Flegal, 1965) and in the turkey (Stoewsand and Scott, 1961) was closely associated with rate of gain; the faster rate of gain producing the best feed efficiency and the higher vitamin A levels in the diet producing the better feed efficiency.

During the egg production period, birds on the 2,000 IU level showed the best feed conversion. They were closely followed by birds on the 1,000 IU level. The poorest conversion was for the birds on the 500 IU level.

4. Egg Production

Birds on the 250 IU level never produced any eggs. The lowest percent egg production per hen per day was for birds on the 500 IU level, and the highest percent was for birds on the 2,000 IU level.

The highest average egg weight during the experimental laying period was for birds on the 2,000 IU level, and the lowest average egg weight was for birds on the 500 IU level.

Egg production was generally low for birds on the low levels of vitamin A.

Total feed consumption was simultaneously increased when egg production was increased.

According to Sherwood and Fraps (1932) a marked decrease in egg production was noted and the length of time between clutches increased greatly when chickens were fed a vitamin A deficient diet. Hill *et al*. (1961) in the chicken and Stoewsand and Scott (1961) in the turkey, reported a decrease in egg production among birds when vitamin A in the diet was decreased.

5. Fertility and Hatchability

The percent of fertile eggs and the percent of fertile eggs which hatched were simultaneously high for birds on the high vitamin A levels and low for birds on the low vitamin A levels. The highest percent fertility was for birds on the 3,000 IU level and the highest percent hatchability was for birds on the 2,000 and the 3,000 IU levels. Birds on the 500 IU level produced eggs showing the lowest percent fertility and hatchability recorded in the experiment.

Hatchability in chickens and turkeys was decreased when vitamin A activity in the diet was lowered (Hill *et al*., 1961 and Stoewsand and Scott, 1961).

6. Mortality

Mortality was observed among birds on the vitamin A depletion diet at the seventeenth day of age, and all the birds died before the end of the fifth week. The differences in survival time were probably due to differences in the quantity of vitamin A stored in the egg and which was passed to the Japanese quail chick, as well as to the general condition of the birds and to hereditary factors.

The percent mortality on the different vitamin A dietary levels in Experiments I and II during the growing period and the egg laying period was inversely proportional to vitamin A levels.

Mortality was 100 percent among birds on the vitamin A depletion diet and among birds on the 250 IU level with the exception of four male birds which were eventually placed on a high vitamin A concentrated diet. The highest percent mortality among the birds was seen during the first week on the experimental diets, and mortality began to decrease as the birds continued to receive vitamin A in the diet. The birds on the low levels continued to die.

All the deaths during the egg laying period were among the female Japanese quail only, while during the growing period, the sexes could not be differentiated. It appeared that the female Japanese quail were more susceptible to vitamin A deficient diets than were the male birds.

Mortality in the chicken (Scott and Norris, 1959) and in the turkey (Stoewsand and Scott, 1961) started in the depleted birds at the end of the second week of age and was dependent upon the quantity of vitamin A stored in the egg and which was passed from the egg to the progeny. There was also a trend toward longer survival time of growing chicks as the vitamin A activity of the diet increased (Flegal, 1965).

7. Vitamin A Deficiency Symptoms

Vitamin A deficiency symptoms were observed among the birds on the depletion diet after 24 days of age, while mortality among the depletion birds greatly increased beginning at the seventeenth day of age.

Deficiency symptoms were seen among birds on the 250 IU level during the third week on the experimental diet (five weeks of age), and mortality started during the first week on the experimental diet.

Deficiency symptoms started to appear among the birds on the 500 IU level during the third week on the experimental diet and ended in death.

Vitamin A deficiency symptoms appeared among a few birds on the 1,000 IU level after twelve weeks on the experimental diet; the symptoms took a slow chronic course and ended in death.

It appears that the 250, the 500 and the 1,000 IU levels were not high enough in vitamin A to prevent deficiency symptoms.

No growth deficiency symptoms were observed among the birds on the 2,000 and the 3,000 IU levels during the experiments. The birds on the 3,000 IU level appeared to be more nervous than birds on the other vitamin A levels.

There was a trend toward longer survival time as the vitamin A activity of the diet increased.

Deficiency symptoms in Japanese quail were the same as described previously by Scott and Norris (1959) with the exception that the deficient birds were abnormally quiet and depressed. Some of them continued to eat well and to put on weight until they died; sudden death was observed among the deficient birds before any symptoms appeared.

In the chicken and turkey, continuous weight loss, general weakness and emaciation in addition to the previously mentioned symptoms were observed among the deficient birds (Scott and Norris, 1959 and Stoewsand and Scott, 1961).

The female quail were more susceptible to vitamin A deficient diets than were the male birds.

Vitamin A deficient birds responded promptly to high doses of vitamin A in the diet, and the supplemental vitamin A corrected the deficiency symptoms in the deficient birds.

A comparison of the performance of all quail in these experiments with that of normal Japanese quail would probably not be legitimate. Body weight, feed efficiency, mortality, maturity, egg production, and to a certain extent fertility and hatchability may have been affected by the two weeks vitamin A depletion period and by the effect of population density (crowdedness), lighting, room temperature and by the ratio of males to females.

A comparison of data between birds on the 2,000 IU and that of normal birds reported by Wilson et al. (1961) and by Ernst (1963) is possibly most nearly applicable for the study.

The mean body weight at six weeks of age was lower than that reported by Ernst (1963). Average adult male and female body weight was also lower than that reported by Wilson et al. (1961) and by Ernst (1963).

Feed efficiency at three weeks of age was about the same as that reported by Ernst (1963) while feed efficiency during maximum egg production was the same as reported by Wilson et al. (1961).

Egg weight and percent egg weight to body weight were higher than those reported by Wilson et al. (1961).

Percent egg production per day per hen during maximum egg production was in the range of that which was reported by Wilson et al. (1961) but was lower than that reported by Ernst (1963).

Percentages of fertility and hatchability were slightly lower than those reported by Wilson et al. (1961) and Ernst (1963).

Mortality, as previously mentioned, was high during the first week on the experimental diets (three weeks of age); this was possibly due to the vitamin A depletion diet which was used during the first two weeks of age, so a comparison with birds on a standard diet is probably not valid.

From the general data which were discussed above, it appears that performance of the birds on the 2,000 IU vitamin A dietary level closely resembled that of birds fed standard diets.

SUMMARY AND CONCLUSIONS

1. Vitamin A is essential to the Japanese quail for maintaining life, growth, vigor, normal function of epithelial tissue, vision, egg production, fertility and hatchability, and also for survival.

2. Liver vitamin A concentration and blood plasma concentration were simultaneously increased when vitamin A dietary levels were increased.

3. Birds on the 3,000 IU vitamin A dietary level had the lowest mean body weight, while those on the 2,000 and the 500 IU level had the highest. The survivors on the low levels (250, 500, 1,000 IU) were evidently strong enough to eat well and to put on weight until they died as they showed an increase in mean body weight to that time.

4. During the growing period, birds on the 3,000 IU level showed the poorest feed efficiency. During egg laying period, birds on the 2,000 level showed the best feed conversion.

5. Birds on the 250 IU level never produced any eggs. The highest percent egg production per hen per day and the highest average egg weight were for the birds on the 2,000 IU level, and the lowest were for birds on the 500 IU level.

Total feed consumption was simultaneously increased when egg production was increased.

6. Fertility and hatchability were simultaneously raised when vitamin A dietary levels were increased.

7. Mortality was 100 percent among the vitamin A depleted birds and the birds on the 250 IU vitamin A level with the exception of four male birds which were placed on a high vitamin A concentrated diet before they died. They survived until the termination of the experiment.

The percent mortality was inversely proportional to vitamin A dietary levels. The highest percent mortality was seen during the first week on the experimental diets; however, mortality began to decrease as the birds continued to receive vitamin A in the diets.

All the deaths during the egg laying period were among the female quail only. It appeared that the female Japanese quail were more susceptible to vitamin A deficient diets than were the male birds.

Excessive mortality started among the birds on the depletion diet at the seventeenth day of age, and no bird survived more than the fifth week of age. On the 250 IU level, mortality started among the birds during the third week of age.

8. Mortality started among the birds on the depletion diet and on the 250 IU level before vitamin A deficiency symptoms were observed.

Vitamin A deficiency symptoms appeared among the birds on the depletion diet at 24 days of age, and among birds on the 250 IU and the 500 IU levels during the third week on the experimental diets (five weeks of age) while birds on the 1,000 IU level showed no symptoms until after twelve weeks on the experimental diet. Sudden death was observed among the birds on all three of these vitamin A levels. The deficient quail were abnormally quiet and depressed; they continued to eat well and to put on weight until they died.

It appeared that the 250, the 500, and the 1,000 IU vitamin A levels were less than the need of Japanese quail as they produced vitamin A deficiency symptoms which ended in death.

Vitamin A deficient birds responded promptly to a high supplemental dose of vitamin A in the diet.

9. In a comparison of the different vitamin A dietary levels tested, the 2,000 IU/lb. level produced the best results in feed efficiency, body weight, egg production, fertility and hatchability, and survival.

10. It appears that the vitamin A requirement for the Japanese quail is more than 1,000 IU vitamin A/lb. and less than 3,000 IU/lb. and that of all levels tested in these experiments, the 2,000 IU/lb. vitamin A level most closely approaches the requirement.

11. Body weight gain, in this experiment, was a poor index to use in determining the vitamin A requirement of the Japanese quail.

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Appendix Table 1. Quail breeder control ration

Ingredients	Percent
Ground yellow corn	41.25
Soybean oil meal, dehulled 50% prot.	37.00
Alfalfa meal, 17% prot.	5.00
Dried whey	2.50
Meat and bone scraps, 50% prot.	2.50
Fish meal, menhaden, 60% prot.	2.50
Ground limestone ($CaCO_3$)	5.00
Dicalcium phosphate	1.50
Salt, iodized	0.50
Vitamin premix, Nopco M-4	0.25
Fat	2.00

Calculated analysis:

Ingredient		%	Ingredient		%
Protein	%	25.66	Glycine	%	1.39
Fat	%	4.27	Methionine	%	0.50
Fiber	%	3.47	Cystine	%	0.37
Ash	%	4.68	Lysine	%	1.46
Calcium	%	3.03	Tryptophan	%	0.298
Phosphorus	%	0.83	Metab. energy		
Arginine	%	1.55	Cal/lb		835.63

Appendix Table 2. Experiment I -- Average feed consumption per quail per day in grams for the first four weeks on vitamin A experimental diets.

Weeks	Vitamin A levels IU/lb			
	500	1,000	2,000	3,000
1	10.166	11.194	11.387	11.133
2	11.219	10.547	10.161	10.146
3	13.964	11.763	12.691	10.701
4	14.963	12.956	12.750	13.191

Appendix Table 3. Experiment I -- Average body weight per male and female quail for the first four weeks on vitamin A experimental diets

	Vitamin A levels IU/lb.							
	500		1,000		2,000		3,000	
Weeks	M	F	M	F	M	F	M	F
Init. wt.	32.94	32.38	33.06	31.38	30.35	34.23	31.23	33.26
1	45.61	44.31	50.50	47.96	48.35	54.14	47.35	53.32
2	69.67	71.25	67.50	66.83	65.22	73.23	61.54	71.37
3	85.41	86.00	80.28	83.21	80.82	89.09	71.32	83.16
4	95.71	102.13	85.67	98.74	87.23	106.41	75.52	95.63

Appendix Table 4. Experiment I -- Summary of data on different vitamin A levels

	Vitamin A levels IU/lb.			
	500	1,000	2,000	3,000
Liver vitamin A concentration, 4 wks. (Mcg/gm)	1.24	2.85	18.17	38.81
Vitamin A blood plasma concentration, 4 wks. (Mcg/100 ml)	20.31	38.75	69.16	82.08
Mean body wt. 2 wks. on test diets (gms)	70.4	67.1	69.1	65.6
Mean body wt. 4 wks. on test diets (gms)	98.7	93.0	98.8	84.4
Feed efficiency (gms feed/gms gain)	5.29	5.33	5.16	6.10
Mortality, growing period (%)	46.6	31.6	26.6	26.6

Appendix Table 5. Experiment II -- Fertility and hatchability of eggs produced by quail from the 6th to the 17th week on vitamin A experimental diets

	Vitamin A levels IU/lb															
	500				1,000				2,000				3,000			
Wks.	No.	H	F	I	No.	H	F	I	No.	H	F	I	No.	H	F	I
6	6	-	-	6	19	5	2	12	23	8	2	13	19	5	7	7
7	6	1	1	4	40	14	12	14	42	19	13	10	29	12	9	8
8	8	3	2	3	29	9	10	10	36	18	11	7	35	16	13	6
9	-				38	15	14	9	37	17	11	9	33	17	13	3
10	8	1	4	3	33	8	18	7	33	16	14	3	32	14	15	3
11	9	-	3	6	26	8	8	10	26	9	13	4	26	14	8	4
12	Defect in the incubator															
13	-				36	6	14	16	35	17	10	8	33	15	7	11
14	-				27	4	9	14	23	6	8	9	16	5	10	1
15	5	-	1	4	17	4	8	5	36	7	19	10	27	13	7	7
16	-				21	3	7	11	27	12	8	7	24	9	10	5
17	1	-	-	1	16	-	7	9	30	11	7	12	27	12	11	4
Total	43	5	11	27	302	76	109	117	348	140	116	92	301	132	110	59
%		31	37	63		41	61	39		54	74	26		54	80	20

No. - Number of eggs
H - hatched eggs
F - fertile eggs
I - infertile eggs

Appendix Table 6. Experiment II - Summary of quail mortality data during the growing and laying periods on vitamin A experimental diets

	Vitamin A levels IU/lb														
	250			500			1,000			2,000			3,000		
Wk.	No. live birds	No died	% mort.	No. live birds	No. died	% mort.	No. live birds	No. died	% mort.	No. live birds	No. died	% mort.	No. live birds	No. died	% mort.
1	80	23	28.7	80	24	30.0	80	14	17.5	80	17	21.2	80	22	27.5
2		30	37.5		6	7.5		1	1.2		3	3.7		1	1.2
3		9	11.3		4	5.0		6	7.5		2	2.5		0	0
4		5	6.2		5	6.2		1	1.2		2	2.5		1	1.2
Total		67	83.7		39	48.7		22	27.5		24	30.0		24	30.0
5	13	1	7.7	21	1	4.7	29	0	0	32	1	3.1	37	1	2.7
6		6	46.1		0	0		1	3.4		0	0		1	2.7
7		2	15.4		0	0		0	0		1	3.1		0	0
8		4	30.8		1	4.7		0	0		1	3.1		0	0
9					2	9.5		1	3.4		2	6.2		1	2.7
10					1	4.7		0	0		0	0		0	0
11					1	4.7		1	3.4		1	3.1		3	8.1
12					1	4.7		0	0		0	0		0	0
13					2	9.5		1	3.4		1	3.1		0	0
14					0	0		0	0		0	0		0	0
15					2	9.5		1	3.4		0	0		0	0
16					0	0		0	0		0	0		0	0
17					0	0		1	3.4		0	0		1	2.7
Total	0	13	100	10	11	52.3	23	6	20.6	25	7	21.8	30	7	18.9
Total for 22 wks.			100	8	13	56.5	20	9	31.0	23	9	28.1	27	10	27.0

Appendix Table 7. Experiment II -- Average feed consumption per Japanese quail per day (gms) on vitamin A experimental diets

Weeks	Vitamin A levels IU/lb. 250	500	1,000	2,000	3,000
1	6.419	7.737	6.840	7.380	6.987
2	10.979	9.209	7.842	9.026	7.679
3	9.873	10.279	10.123	10.509	9.260
4	--	12.258	11.222	11.490	12.268
5		14.429	14.695	13.935	12.901
6		11.707	16.378	14.778	12.547
7	--	11.543	14.291	14.162	12.343
8		12.970	16.097	15.586	14.008
9		15.638	16.719	15.540	15.433
10	--	15.205	16.503	17.730	17.894
11		16.000	16.764	17.511	17.576
12		15.337	16.187	17.659	16.779
13	--	16.809	16.371	17.406	16.760
14		13.083	17.149	17.097	15.253
15		15.700	16.893	18.080	15.313
16	--	15.442	17.161	17.537	15.313
17		14.600	15.932	17.566	17.857

Appendix Table 8. Experiment II - Average body weight per Japanese quail on vitamin A experimental diets

	250 IU		500 IU		1,000 IU		2,000 IU		3,000 IU	
Weeks	M	F	M	F	M	F	M	F	M	F
Init. wt.	18.80	--	18.5	--	18.81	--	18.67	- -	19.30	--
1	46.10	36.63	38.96	38.48	38.47	41.41	38.18	42.27	38.13	40.0
2	62.30	40.75	58.44	56.58	55.16	62.55	52.85	59.04	55.74	58.24
3	74.30	59.00	70.67	70.68	67.73	78.05	66.91	72.88	66.43	67.85
4	78.55	83.00	82.00	88.65	74.54	88.26	76.37	86.23	69.49	74.79
5	90.00	88.50	107.50	102.94	93.50	106.52	96.00	99.04	90.75	92.14
6	95.50	84.00	105.75	107.56	96.33	111.59	96.00	102.48	91.75	96.85
7	90.20	--	108.25	104.94	98.33	118.68	97.16	106.46	92.12	103.48
15	100.75	--	119.50	117.33	107.00	123.67	103.33	119.63	98.25	107.57

Appendix Table 9. Experiment II - Summary of data from quail on vitamin A experimental diets

	Vitamin A levels (IU/lb.)				
	250	500	1,000	2,000	3,000
Liver vitamin A storage, 4 wks. (Mcg/gm)	--	1.73	3.45	18.52	43.87
Vitamin A blood level, 4 wks (mcg/100 ml)	--	20	36.38	63.25	78.75
Body wt. 2 wks. on test diets (gms.)	53.7	56.4	56.6	55.1	57.2
Body wt. 4 wks. on test diets (gms)	79.9	84.7	80.0	81.0	72.1
Feed efficiency (growing period)(gms feed/gms gain)	4.15	4.36	4.24	4.42	4.67
Feed efficiency (egg production period)(gms feed/gms eggs)	--	24.45	6.20	5.64	8.50
Egg production, hen day %	--	10.46	37.95	40.26	25.93
Egg wt. (gms.)	--	7.66	9.04	9.54	9.33
Fertility (%)	--	37.0	61.0	74.0	80.0
Hatchability (%)	--	31.0	41.0	54.0	54.0
Mortality, growing period(%)	83.3	48.7	27.5	30.0	30.0
" laying period (%)	100.0	56.5	31.0	28.1	27.0