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EFFECT OF THREONINE SUPPLEMENTATION ON JAPANESE QUAIL FED VARIOUS LEVELS OF PROTEIN AND SULFUR AMINO ACIDS.

2. LAYING PERIOD

By

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Abstract*:**This study was conducted using 378 six-week old Japanese quail birds which were equally divided into 7 groups of 3 replicates each. The experiment was done to explore the extent to which dietary crude protein (CP) level can be reduced in diets through sulfur amino acids (SAA) and threonine (Thr) supplementation while maintaining adequate performance. Seven experimental isocaloric (2900 kcal ME/kg diet) layer diets were formulated. One positive control diet (A) was formulated to cover or exceed NRC (1994) recommendations of CP, SAA and Thr. Two negative control diets (B & C)were formulated to contain lower CP (18 and 16% CP, respectively) than NRC (1994) recommended level but SAA and Thr were held at a constant ratio to CP for obtaining the same ratio in the two diets. Two amino acid-supplemented diets (B_1 & C_1) were formulated to be similar in composition to diets B and C, respectively but still supplying the same SAA and Thr as in diet A. Two other amino acid-supplemented diets (B_2 & C_2) were formulated in a similar manner as in diets B_1 and C_1, respectively but supplemented with additional Thr at levels of 0.2 and 0.4%, respectively to ensure that it contained higher Thr levels than the NRC (1994) recommended level. Body weight, body weight change, mortality rate, egg production traits, feed intake, feed conversion, hatching parameters, egg quality traits and economical efficiency were determined. From the nutritional and economical point of view, it could be concluded that Japanese quail fed low-protein diet (18% CP) supplemented with SAA as NRC (1994) recommendations plus additional Thr at 0.2% over NRC (1994) recommendations gave better performance and higher economical efficiency value as compared to those achieved with birds fed the high-protein diet (20% CP).*

INTRODUCTION

Diet formulation for Japanese quail (*Coturnix coturnix Japonica*) is commonly based on foreign nutrient requirement tables such as **NRC (1994)** from other countries, which are not ideal for Egypt climatic conditions. Moreover, there are not enough studies with laying Japanese quail. In addition, no new reports on quail nutrient requirements have been described since 1984 **(NRC, 1994)**, evidencing that new information is needed.

Formulating poultry diets based on crude protein (CP) requirements, frequently results in diets containing high amino acid (AA) levels, above the real bird's requirements. An excess of AA is deaminated and excreted as uric acid. **Firman *et al.*, (1999)** reported that overfeeding CP results in higher feed costs and excess nitrogen levels being excreted into the litter. Moreover, feeding cost still represents around 65-70% of the total poultry production cost and protein cost represents around 15% of the total feeding cost **(Banerjee, 1992 and Singh, 1990)**. Satisfying AA needs while maintaining a minimum CP may decrease diet cost. **Firman *et al.*, (1999)** reported that a 1% decrease in CP level could yield savings of 5 $ per ton of feed. Also, low-protein diets are favored to reduce the polluting effect on soil and water by reducing nitrogen dropping content **(Holsheimer and Jensen, 1992)**. Amino nitrogen, needed for dispensable amino acid synthesis, is a limiting factor in low-protein diets (**Han *et al.*, 1992)**. Satisfying amino acid needs while maintaining a minimum CP may decrease diet cost. Moreover, broilers fed amino acid-supplemented diets had higher protein utilization and lower nitrogen excretion **(DeSchepper and DeGroote, 1995)**.

The greater commercial availability of the 2 most important limiting amino acids for birds [methionine (Met) and threonine (Thr)] have drawn interest to diet formulation based on reduced CP levels with adequate amino acid supplementation. The importance of Met is indicated by its 3 major functions in poultry: as a methyl donor, in protein synthesis, and as a precursor of cysteine **(Graber and Baker, 1971)**. The importance of Thr has been well recognized for its maintenance characteristics associated with the digestive tract **(Specian and Oliver, 1991; Stoll *et al.*, 1998 and Van Der Schoor *et al.*, 2002)** and virtues towards maximizing productivity **(Kidd and Kerr, 1997; Penz *et al.*, 1997; Kidd *et al.*, 1999; Dozier *et al.*, 2000; Kidd *et al.*, 2003a and Kidd *et al.*, 2003$_b$)**. It also serves as a body protein component, as a feather protein component, a precursor of glycine and serine, involved in immune responses and needed in gastrointestinal mucin production **(Lemme, 2001)**.

Therefore, the objective of this study was to explore the extent to which overall dietary CP can be reduced in laying Japanese quail diet by sulfur amino acids (SAA) and Thr supplementation while maintaining adequate performance.

MATERIALS AND METHODS

Experimental Birds, Housing and Management:

A total number of 378 six-week old Japanese quail birds were used in a 90-days laying trial. Birds were individually wing-banded, weighed, and randomly distributed into 7 equal groups of similar body weight of 3 replicates each (6 ♂&12 ♀/replicate) and reared in battery laying cages. Birds were reared under similar management conditions and exposed to a 16-h photoperiod. Mash feed and fresh clean tap water were available *ad liblitum*.

Experimental Diets and Treatments:

Seven experimental isocaloric (2900 kcal ME/kg diet) layer diets were formulated. One positive control diet (A) was formulated to cover or exceed NRC (1994) recommendations of CP, SAA and Thr. Two negative control diets (B & C)were formulated to contain lower CP (18 and 16% CP, respectively) than NRC (1994) recommended level but SAA and Thr were held at a constant ratio to CP for obtaining the same ratio in the two diets. Two amino acid-supplemented diets (B_1 & C_1) were formulated to be similar in composition to diets B and C, respectively but still supplying the same SAA and Thr as in diet A. Two other amino acid-supplemented diets (B_2 & C_2) were formulated in a similar manner as in diets B_1 and C_1, respectively but supplemented with additional Thr at levels of 0.2 and 0.4%, respectively to ensure that it contained higher Thr levels than the NRC (1994) recommended level. The composition and calculated analysis of the experimental diets is shown in Table 1.

Measurements and Data Collection

Body Weight, Body Weight Change and Mortality Rate:

Individual body weight (BW, g) was recorded at the start and end of the trial to determine body weight change (BWC, g). Mortality rate (MR) % was calculated on weekly basis.

Egg Production Traits:

Eggs were daily collected and weighed. Weekly egg production (EP, %), egg number (EN), egg weight (EW, g) and egg mass (EM, g) were calculated per each replicate for 90-day laying period.

Feed Intake and Conversion:

Feed intake (FI, g/bird) was weekly recorded to determine weekly feed conversion ratio (FCR, g feed/g egg) and protein conversion ratio (PCR, g protein/g egg) per each replicate for 90-day laying period.

Hatching Parameters:

During the last week of the experiment, eggs were collected and incubated. At hatching time, hatched chicks were weighed and infertile eggs were examined to determine fertility % (fertile eggs/total eggs x 100) and hatchability % (hatched chicks/fertile eggs x 100).

Egg Quality Traits:

Egg quality was assessed in 9 eggs/treatment (3 eggs/replicate) during the last 2 d of the experimental period. Egg shape index (ESI) was determined according to **Stadleman (1977)**. Percentages of egg yolk (Y, %), albumen (Alb, %) and shell (S, %) were determined. Shell thickness (ST, μ) was measured by a micrometer as an average of 3 points (top, medial and base).

Chemical and Statistical Analysis:

Experimental diets were analyzed following procedures detailed by the Association of Official Analytical Chemists **(AOAC, 1990)** for dry matter (DM), crude protein (CP), crude fiber (CF) and ether extract (EE). The nitrogen free extract (NFE) was calculated by difference. Metabolizable energy (ME) of experimental diets was calculated considering the ME values of different feed ingredients according to the **Feed Composition Tables for Animal and Poultry Feedstuffs Used in Egypt (2001).**

Obtained data were expressed as means ± standard error and statistically analyzed by one-way analysis of variance according to **Steel and Torrie (1980)**. Also, the General Linear Model (GLM) procedure of **SPSS (1993)** computer statistical program for MS Windows release 6.0 was used. The significant means were ranked using Duncan's Multiple Range Test **(Duncan, 1955)** as outlined by **Obi (1990)**. Statistical significance level was tested at probability of $p \leq 0.05$.

protein, methionine, threonine, performance, eggs, quails, layers

RESULTS AND DISCUSSION

Body Weight, Body Weight Change and Mortality Rate:

The mean BW, BWC and MR values of birds during the overall experimental period are given in Table 2.

Initially, the initial BW of 6-week old birds was similar for all treatments. It was also observed that the highest BW and BWC values were obtained with feeding A, B_1, C_1, B_2 or C_2-diet.Moreover, feeding C-diet caused the lowest values; while, feeding B-diet caused medium values.

The results also revealed that feeding B or C-diet caused the highest MR %. Such finding may be attributed to the shortage of amino acids in these diets. Whereas, feeding A, or B_2-diet caused the lowest values. While, feeding B_1, C_1 or C_2-diet caused medium values.

Egg Production Traits:

The mean EP %, EN, EW and EM values of birds during the overall experimental period are shown in Table 3.

The results showed that feeding either A-diet or B_2-diet caused the highest EP %, EN, EW and EM values. Whereas, feeding B, C or C_1-diet caused the lowest values. On the other hand, feeding B_1, C_2-diet caused medium values in this respect.

The improvement in EW observed in the current study may be due to the fact that egg size depends greatly on daily CP intake, since layers do not store large amounts of protein; thus, dietary CP level is important to control PI as a function of EP **(Murakami and Furlan, 2002)**.

Feed Intake and Conversion:

The mean FI, PI, FCR and PCR values of birds during the overall experimental period are given in Table 4.

It was found that feeding A-diet caused the highest PI value. On the other hand, feeding either A or B_2-diet gave the best FCR values. Furthermore, feeding either A, B_2 or C_2-diet gave the best FCR and PCR values.

These results disagree with those of **Garcia *et al.* (2005)** who found that Japanese quails fed 20 or 18% CP-diets had higher FI than those fed 16% CP-diet.

Hatching Parameters:

The results obtained for fertility %, hatchability %, hatch weight values and abnormal chicks % at the end of the experimental period are presented in Table 5.

It was observed that feeding A or B_2-diet caused the highest fertility %, hatchability % and hatch weight as well as the lowest abnormal chicks %. The difference in chick weight at hatching is due to egg size, since egg volume is a limiting factor to embryo development (**Luquetti et al., 2004)**

Egg Quality Traits:

Data regarding egg quality in terms of ESI, ST, S%, Y% and Alb% are tabulated in Table 6.

It was noticed that feeding A or B_2-diet caused the highest ESI, ST and S %. Also, feeding A-diet caused the lowest Alb value.

The present results are not in agreement with those of **Bello (1997)** who reported that egg characteristics were not affected and ST was poorer with higher methionine levels.

Economical efficiency:

Economical evaluation parameters in terms of feeding cost, net revenue, economical efficiency (EE_f) and relative economical efficiency (REE_f %) of egg production are listed in Table 7.

Results showed that the highest REE_f % was obtained with feeding B_2-diet followed by those obtained with feeding A-diet.

The present findings suggest that CP levels of 16% might reduce nitrogen availability to be used in the synthesis of nonessential amino acids. According to **Keshavarz and Jackson (1992)**, essential amino acids might be converted to non-essential amino acids, reducing the availability of the former and, consequently, reducing bird performance.

Briefly, from the nutritional and economical point of view, it could be concluded that Japanese quail fed low-protein diet (18% CP) supplemented with SAA as NRC (1994) recommendations plus additional Thr at 0.2% over NRC (1994) recommendations gave better performance and higher economical efficiency value as compared to those achieved with birds fed the high-protein diet (20% CP).

Table (1) Composition and calculated analysis of the experimental diets.

Item, %	A	B	C	B1	C1	B2	C2
Yellow Corn, ground	53.32	60.37	67.44	60.20	66.59	59.80	65.80
Soybean meal (44% CP)	35.20	29.30	23.40	29.30	23.50	29.35	23.65
Dicalcium phosphate	1.11	1.18	1.22	1.18	1.23	1.18	1.23
Limestone	5.63	5.63	5.65	5.63	5.65	5.63	5.65
Common salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Vegetable oil	3.90	2.70	1.50	2.70	1.74	2.85	1.98
Vitamins minerals premix*	0.30	0.30	0.30	0.30	0.30	0.30	0.30
DL-Methionine	0.14	0.12	0.09	0.16	0.19	0.16	0.19
L-Lysine	0.00	0.00	0.00	0.07	0.26	0.07	0.26
L-Threonine	0.00	0.00	0.00	0.06	0.14	0.26	0.54
Total	100	100	100	100	100	100	100
Price (L.E./Kg)**	2.31	2.21	2.11	2.24	2.20	2.28	2.28
Calculated analysis***							
ME, kcal/kg	2902	2905	2908	2905	2902	2900	2900
CP	20.02	18.02	16.03	18.02	16.00	18.00	16.00
Ca %	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Avail. P %	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Met	0.45	0.41	0.36	0.45	0.45	0.45	0.45
Met+Cys	0.78	0.71	0.63	0.75	0.73	0.75	0.73
Lys	1.02	0.95	0.80	1.02	1.02	1.02	1.02
Arg	1.31	1.15	0.99	1.15	0.99	1.15	0.99
His	0.53	0.48	0.43	0.48	0.43	0.48	0.43
Ile	0.84	0.75	0.65	0.75	0.65	0.75	0.65
Leu	1.73	1.60	1.47	1.60	1.46	1.59	1.46
Phe-Ala (Phenylalanine)	0.96	0.86	0.76	0.86	0.76	0.86	0.76
Phy-Ala+Tyr	1.80	1.60	1.41	1.60	1.41	1.60	1.41
Thr	0.74	0.68	0.60	0.74	0.74	0.94	1.14
Tryp	0.29	0.25	0.21	0.25	0.21	0.25	0.21
Val	0.94	0.85	0.75	0.85	0.75	0.85	0.75
Gly+Ser	1.85	1.65	1.45	1.65	1.45	1.65	1.45

*Vitamins minerals premix provides per kilogram of diet: 10000 IU vitamin A, 11.0 IU vitamin E, 1.1 mg vitamin K , 1100 ICU vitamin D3, 5 mg riboflavin, 12 mg Ca pantothenate, 12.1 µg vitamin B12, 2.2 mg vitamin B6, 2.2 mg thiamin, 44 mg nicotinic acid, 250 mg choline chloride, 1.55 mg folic acid, 0 .11 mg d-biotin. 60 mg Mn, 50 mg Zn, 0.3mg I, 0. 1 mg Co, 30 mg Fe, 5 mg Cu and 1 mg Se.

****** Prices per Egyptian pound (L.E) where 1 US $ = 5.55 L.E

*******According to Feed Composition Tables for Animal & Poultry Feedstuffs Used in Egypt (2001).

Table (2): Performance of laying Japanese quail fed the experimental diets at 8-20 wks of age.

Treatments				Initial BW (g/bird)	Final BW (g/bird)	BWC (g/bird)	MR (%)
Diet	**CP (%)**	**SAA**	**Thr**				
A	**20**	**NRC**	**NRC**	204.03±2.10	227.00±2.10^{a}	22.97±1.12^{a}	2.86±0.01^{c}
B	**18**	**% of CP**	**% of CP**	200.90±2.00	211.00±2.02^{b}	10.10±0.20^{b}	9.09±0.03^{a}
C	**16**			198.11±2.01	200.00±2.00^{c}	1.89±0.21^{c}	9.09±0.02^{a}
B_1	**18**	**NRC**	**NRC**	204.06±2.15	223.26±2.10^{a}	19.20±1.00^{a}	5.88±0.02^{b}
C_1	**16**			203.10±2.06	223.00±2.18^{a}	19.90±1.01^{a}	5.88±0.04^{b}
B_2	**18**	**NRC**	**Over NRC**	205.08±2.11	226.48±2.21^{a}	21.40±1.05^{a}	2.86±0.02^{c}
C_2	**16**			201.13±2.05	224.33±2.00^{a}	23.20±1.11^{a}	5.88±0.03^{b}

Means in the same column having different letters are significantly different at $p \leq 0.05$

BW: body weight BWC: body weight change MR: mortality rate

Table (3): Egg production of laying Japanese quail fed the experimental diets at 8-20 wks of age.

Treatments				EP (%)	EN (No./hen/day)	EW (g)	EM (g/hen/day)
Diet	**CP (%)**	**SAA**	**Thr**				
A	**20**	**NRC**	**NRC**	81.91±1.12^{a}	0.82±0.03^{a}	11.62±0.02^{a}	9.52±0.01^{a}
B	**18**	**% of CP**	**% of CP**	73.05±1.10^{c}	0.73±0.01^{c}	9.41±0.04^{c}	6.87±0.03^{c}
C	**16**			72.08±1.11^{c}	0.72±0.02^{c}	9.33±0.03^{c}	6.73±0.01^{c}
B_1	**18**	**NRC**	**NRC**	76.02±1.13^{b}	0.76±0.04^{b}	10.25±0.02^{b}	7.79±0.02^{b}
C_1	**16**			72.89±1.10^{c}	0.73±0.01^{c}	9.31±0.01^{c}	6.79±0.04^{c}
B_2	**18**	**NRC**	**Over NRC**	80.58±1.12^{a}	0.81±0.02^{a}	11.41±0.04^{a}	9.19±0.02^{a}
C_2	**16**			77.08±1.11^{b}	0.77±0.03^{b}	10.66±0.3^{b}	8.22±0.01^{b}

Means in the same column having different letters are significantly different at $p \leq 0.05$.

EP: egg production **EN**: egg number **EW**: egg weight **EM**: egg mass

Table (4): Feed utilization of laying Japanese quail fed the experimental diets at 8-20 wks of age.

Treatments				FI (g/hen/day)	PI (g/hen/day)	FCR (g feed/g egg)	PCR (g protein/g egg)
Diet	**CP (%)**	**SAA**	**Thr**				
A	**20**	**NRC**	**NRC**	19.95±0.13	3.99±0.03[a]	2.10±0.02[c]	0.42±0.01[b]
B	**18**	**% of CP**	**% of CP**	20.33±0.10	3.66±0.02[b]	2.96±0.01[a]	0.53±0.03[a]
C	**16**			20.46±0.14	3.28±0.04[c]	3.04±0.01[a]	0.49±0.02[a]
B_1	**18**	**NRC**	**NRC**	20.24±0.10	3.65±0.05[b]	2.60±0.06[b]	0.47±0.02[a]
C_1	**16**			20.71±0.16	3.31±0.03[c]	3.05±0.03[a]	0.49±0.03[a]
B_2	**18**	**NRC**	**Over NRC**	20.04±0.13	3.61±0.04[b]	2.18±0.07[c]	0.39±0.01[b]
C_2	**16**			20.41±0.17	3.27±0.03[c]	2.48±0.05[b]	0.40±0.02[b]

Means in the same column having different letters are significantly different at $p \leq 0.05$

FI: feed intake PI: protein intake

FCR: feed conversion ratio PCR: protein conversion ratio

Table(5): Hatching parameters of laying Japanese quail fed the experimental diets at 8-20 wks of age.

Treatments				Fertility (%)	Hatchability (%)	Hatch weight (g)	Abnormal chicks (%)
Diet	**CP (%)**	**SAA**	**Thr**				
A	**20**	**NRC**	**NRC**	82.16±0.17[a]	79.72±0.15[a]	8.23±0.02[a]	1.27±0.09[d]
B	**18**	**% of CP**	**% of CP**	79.00±0.15[b]	77.16±0.19[b]	7.14±0.01[b]	3.90±0.01[c]
C	**16**			77.12±0.19[c]	74.27±0.16[c]	7.00±0.01[b]	6.11±0.04[b]
B_1	**18**	**NRC**	**NRC**	79.94±0.14[b]	77.68±0.14[b]	7.19±0.03[b]	7.79±0.03[a]
C_1	**16**			77.92±0.12[c]	74.98±0.13[c]	7.05±0.01[b]	8.11±0.01[a]
B_2	**18**	**NRC**	**Over NRC**	81.73±0.16[a]	79.03±0.19[a]	8.10±0.02[a]	1.27±0.02[d]
C_2	**16**			79.01±0.10[b]	77.00±0.13[b]	7.12±0.01[b]	3.90±0.02[b]

Means in the same column having different letters are significantly different at $p \leq 0.05$

Table (6): Egg quality of laying Japanese quail fed the experimental diets at 8-20 wks of age.

Treatments				ESI	ST (µ)	% of EW		
Diet	**CP (%)**	**SAA**	**Thr**			**S**	**Y**	**Alb**
A	**20**	**NRC**	**NRC**	80.10±0.11[a]	321.30±0.02[a]	10.52±0.04[a]	33.09±0.07[a]	56.39±0.12[d]
B	**18**	**% of CP**	**% of CP**	71.03±0.18[c]	237.37±0.04[c]	9.11±0.07[c]	31.12±0.04[b]	59.77±0.19[b]
C	**16**			69.06±0.21[c]	200.10±0.02[c]	9.00±0.05[c]	30.14±0.08[c]	60.86±0.14[a]
B_1	**18**	**NRC**	**NRC**	75.74±0.20[b]	284.63±0.03[b]	9.60±0.03[b]	31.26±0.06[b]	59.14±0.11[b]
C_1	**16**			72.11±0.14[c]	221.56±0.03[c]	9.15±0.07[c]	30.21±0.05[c]	60.64±0.15[a]
B_2	**18**	**NRC**	**Over NRC**	78.31±0.17[a]	307.37±0.02[a]	10.36±0.06[a]	31.81±0.09[b]	57.83±0.13[c]
C_2	**16**			69.50±0.24[c]	272.70±0.04[b]	9.71±0.05[b]	31.22±0.04[b]	59.07±0.17[b]

Means in the same column having different letters are significantly different at $p \leq 0.05$.
ESI: egg shape index ST: shell thickness
S: shell percentage Y: yolk percentage Alb: albumen percentage

Table (7): Economical efficiency ratio of quail fed the experimental diets during the whole period.

Treatments				FI (g/hen/day)	Feed price (PT/kg)	Feed cost* (PT/hen/day)	EN (No./hen/day)	Egg price** (PT/hen/day)	Net revenue*** (PT/hen/day)	EE_f ****	REE_f ***** (%)
Diet	CP (%)	SAA	Thr								
A	20	NRC	NRC	19.95	230.86	4.61	0.82	20.50	15.89	3.45	100
B	18	% of CP	% of CP	20.33	220.84	4.49	0.73	18.25	13.76	3.06	89
C	16			20.46	210.98	4.32	0.72	18.00	13.68	3.17	92
B_1	18	NRC	NRC	20.24	223.99	4.53	0.76	19.00	14.47	3.19	92
C_1	16			20.71	219.59	4.55	0.73	18.25	13.70	3.01	87
B_2	18	NRC	Over NRC	20.04	228.12	4.57	0.81	20.25	15.68	3.49	101
C_2	16			20.41	228.06	4.65	0.77	19.25	14.60	3.14	91

*According to the local market price of feed ingredients at the year 2008.
**According to the local market price of an egg which was 25 PT.
***Net revenue = Egg price - Feed cost
****EE_f: Economical efficiency, net revenue per unit of feed cost.
*****Relative economical efficiency, assuming that the control treatment = 100 %.

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الملخص العربى

تأثيرإضافة الثريونين على السمان اليابانى المغذى على مستويات مختلفة من البروتين والأحماض الأمينية الكبريتية ٢- فترة وضع البيض

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أجريت هذه الدراسة باستخدام ٣٧٨ كتكوت سمان يابانى عمر ٦ أسابيع – بعد تقسيمها إلى ٧ مجاميع متساوية العدد والوزن وبكل منها ٣ مكررات – لتحديد إلى أى مدى يمكن تقليل مستوى بروتين العليقة فى فترة إنتاج البيض وذلك من خلال إضافة الأحماض الأمينية الكبريتية والحمض الأمينى "ثريونين" شريطة الحفاظ على آداء الطيور.

تم تكوين ٧ علائق بياض تجريبية كما يلى:-

١- عليقة كنترول إيجابية (A) لتغطى احتياجات السمان اليابانى البياض من البروتين (٢٠٪) والطاقة الممثلة والأحماض الأمينية الكبريتية والحمض الأمينى "ثريونين" خلال فترة إنتاج البيض وذلك طبقاً لتوصيات المجلس القومى الأمريكى للبحوث (NRC) سنة ١٩٩٤م.

كما تم تكوين

protein, methionine, threonine, performance, eggs, quails, layers

٢- عليقتين كنترول سلبية (C ، B) لتحتوى على ١٨ ، ١٦٪ بروتين خام على الترتيب ولكنهما يحتويان على الأحماض الأمينية الكبريتية والحمض الأميني "ثريونين" كنسبة مئوية من البروتين

٣- عليقتين (C_1 ، B_1) مماثلتين فى التركيب للعليقتين (C ، B) على الترتيب ولكنهما يحتويان على الأحماض الأمينية الكبريتية والحمض الأميني "ثريونين" بنسبة وجودهما فى العليقة (A).

٤- عليقتين (C_2 ، B_2) مماثلتين فى التركيب للعليقتين (C_1 ، B_1) على الترتيب ولكن أضيف لهما الحمض الأمينى "ثريونين" بمعدل ٠.٢ ، ٠.٤ ٪ فوق توصيات المجلس القومى الأمريكى للبحوث (NRC) سنة ١٩٩٤م على الترتيب.

تم تقدير وزن الجسم الحى والتغير فى وزن الجسم ومعدل النفوق وصفات إنتاج البيض والغذاء المأكول ومعامل تحويل الغذاء وصفات التفريخ وصفات جودة البيضة والكفاءة الأقتصادية

أوضحت النتائج - تحت ظروف التجربة الحالية - أن السمان اليابانى المغذى على العلائق المحتوية على ١٨٪ بروتين والمضاف لها المثيونين والليسين والثريونين طبقاً لتوصيات المجلس القومى الأمريكى للبحوث (NRC) سنة ١٩٩٤م والثريونين بمستوى أعلى بمقدار ٠.٢٪ من الموصى به من قبل المجلس القومى الأمريكى للبحوث (NRC) سنة ١٩٩٤م أعطى أحسن آداء وأعلى عائداً أقتصادياً بالمقارنة بتلك التى أعطته العليقة المرتفعة البروتين (٢٠٪).