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Alleviating Effect of Some Environmental Stress Factors on Productive Performance in Japanese Quail 2. Laying Performance

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Abstract: The main objective of the study was to elucidate the effect of short- term exposure of quail eggs to acute high incubation temperature on the ability of laying quail to cope with the heat stress condition during laying period. Four dietary treatments were also examined in an attempt to alleviate the possible negative effect (s) of heat stress on the subsequent reproductive performance of quails. A total number of 998 fertile quail eggs were divided into two groups, the first one (470 eggs) was maintained at the recommended incubation temperature (37.5°C), while the second (528 eggs) was exposed to 39.5°C for two hours at days 3, 7 and 13 of embryogenesis. At laying period, quails hatched from each incubation temperature were randomly assigned to four dietary treatments, *i.e.* control (recommended requirements), high-energy diet (+150 Kcal ME/Kg diet more than the control), high-lysine (10 % more) and vitamin C (200 ppm) supplemented diet. All quails were fed *ad libitum* and received similar hygienic and managerial conditions. The obtained results showed that: Dietary treatments significantly affected egg mass ($P \leq 0.05$) and feed intake ($P \leq 0.05$) while feed conversion ratio (Kg feed: Kg egg) was not affected. Egg shell percent, breaking strength (Kg/ cm^2) and egg shape index showed no significant changes neither with heat exposure nor with dietary treatments, however, shell thickness was significantly ($P \leq 0.05$) improved by feeding treatments. Digestibility coefficients showed that apparent digestibility of crude fiber (CF), ether extracts (EE), nitrogen free extract (NFE) and organic matter (OM) were not significantly influenced by treatments. However, the digestibility of crude protein (CP) was significantly higher ($P \leq 0.05$) in the control, followed by the high- energy and then the high- lysine diets. It could be concluded that pre-hatching exposure of quail eggs to high temperature and feeding a high-energy or vitamin C supplemented diets did alleviate the deleterious effects of heat stress during laying period and enhance the productive performance of quails.

Key words: Laying quail · Heat stress · Egg quality · Energy · Lysine · Vitamin C

INTRODUCTION

Japanese quail (*Coturnix coturnix japonica*) is becoming more popular as a source of meat and eggs in various parts of the world including Egypt. It has also assumed worldwide importance as a laboratory animal [1] with distinct characteristics such as rapid growth- enabling quail to be marketed for human consumption at 5- 6 weeks of age, early sexual maturity- resulting in a short generation interval, high rate of lay and much lower feed and space requirements than the domestic fowl. Commercial quail production has grown steadily in Egypt utilizing strains of Japanese quail selected for rapid growth and higher body weight. The nutrient requirements of these strains and the optimum housing temperature along with their physiological response(s) to acute heat stress environments are still obscure. It is suggested that acclimatization to heat stress may be induced through pre- hatch and /or post- hatch short- time exposure to high temperature [2, 3]. The rapid heat stress response can be modulated by early- age thermal conditioning [4] which may affect the integration of thermal information in the hypothalamus which in turn reduce heat production by reducing the circulating concentration of thyroid hormones [5].

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It is well accepted that the main consequence of heat stress is the reduction in feed intake to reduce metabolic heat production [6]. This will cause poor growth, low rate of egg production, reduced feed efficiency, immune- suppression and enhanced fat deposition due to hypothyroid activity [7-10].

To reduce the deleterious effect (s) of heat stress, many practical approaches have been developed to facilitate thermotolerance of birds, leading to minimize the adverse effects on productivity. These approaches include pre and /or post acclimation of birds [11, 12], use of some electrolytes and vitamins [13] and dietary energy or lysine levels manipulation [14, 15]. There is, however, a paucity of information on the beneficial effects of such approaches to improve quail production.

Therefore, the present experiment was conducted on quail produced from pre-hatching exposure eggs to high temperature to study the possible effect (s) of increasing dietary energy on alleviating the adverse effects of heat stress, during laying period and asses the role of higher dietary lysine level in combating distress conditions, during laying period. The influence of vitamin C on productive performance of quail sush as egg quality was studied.

MATERIALS AND METHODS

The present experiment was carried out during summer season in Egypt.

Experimental Procedures

Incubation Period: A total number of 998 fertile Japanese quail (*Coturnix coturnix japonica*) eggs were incubated in a forced draught laboratory incubator. At the first day of incubation, eggs were divided into two groups. The first group (470 eggs) was maintained at the recommended temperature, while the second one (528 eggs) was exposed to 39.5°C for two hours at days 3rd, 7th and 13th of embryogenesis. The recommended incubation temperature (37.5°C) and relative humidity between 55 and 66% [16]. Turning of eggs was automatically done every four hours until the day 14th of incubation.

Laying Period: Quails from both two groups were brooded in electrically heat-controlled batteries at 32°C±2°C during the whole experimental period. Quails were exposed to 16L: 8D lighting programme during the laying period (after six weeks of age). A total of 240 sexually mature quail birds (6 weeks old) obtained from two incubation temperature groups were used in this experiment. Birds of each group were sub- divided randomly into four dietary experimental groups, 30 birds each (20 females: 10 males). Birds were fed on a layer diet which was formulated to meet the requirements of quail layers according to NRC [17]. The formulation and calculated composition of the diets are presented in Table 1. Feed and water were provided *ad libitum*. All groups received the same hygienic and managerial conditions. These treatments were extended till the week 14th of age.

Table 1: Formulation and calculated composition of the experimental diets during the laying period

Ingredients	Control	High energy	High lysine	Vitamin C
Yellow corn	61.55	59.47	61.70	61.56
Soybean meal 48%	23.10	21.10	23.00	22.84
Corn gluten meal 62%	7.30	9.00	7.10	7.44
DL-methionine 99%	0.06	0.05	0.07	0.05
L-lysine HCl	0.04	0.11	0.18	0.05
Soy oil	-	2.30	-	-
Mono-Ca phosphate	1.18	1.20	1.18	1.20
Premix*	0.30	0.30	0.30	0.30
Limestone	6.13	6.13	6.13	6.12
Salt	0.34	0.34	0.34	0.34
Vitamin C (20%)	-	-	-	0.10
Calculated composition				
CP %	21	21	21	21
ME (Kcal/ Kg)	2900	3050	2900	2900
Calcium %	2.60	2.60	2.60	2.60
Av.Phosphorus %	0.36	0.36	0.36	0.36
Methionine %	0.44	0.45	0.45	0.45
Methionine+ Cystine %	0.81	0.82	0.82	0.82
Lysine %	1.00	1.00	1.10	1.00
EE %	2.75	4.97	2.75	2.75
CF %	2.35	2.25	2.35	2.34

*Each 3 Kg contains: Vit A 12000000 IU, Vit D_3 2500000 IU, Vit E 10g, Vit K_3 2g, Vit B_1 1g, Vit B_2 5g, Vit B_6 1.5g, Vit B_{12} 0.01g, Niacin 30g, Folic 1g, Biotin 0.05g, Pantothenic acid 10g, Copper 10g, Iodine 1g, Selenium 0.1g, Iron 30g, Manganese 60g, Zinc 50g, Cobalt 0.1g.

The Four Experimental Diets Were:

- Control basal diet formulated to satisfy the requirements of Japanese quail according to NRC [17].
- High-energy diet comprised 150 Kcal ME/Kg over the recommended level (2900 *vs.* 3050 Kcal ME/ Kg of diet).
- High-lysine diet comprised 10% lysine over the recommended level (1.32% *vs.* 1.45%).
- Vitamin C supplemented diet (200ppm) (0.1% of vitamin C 20%concentration).

Egg production was recorded daily for eight weeks after sexual maturity. Egg laying commenced at 36-40 days of age and all laying quails reached more than 40% of egg production rate at seven weeks of age.

Eggs were collected daily and weighed to the nearest milligram. Egg number and egg mass (g/ bird/ day) were recorded.

Egg Quality Traits: Three freshly laid consecutive eggs were collected from each group during two periods of egg production (8 and 14 weeks of age) to study their exterior and interior quality traits. The exterior traits were egg weight (g), egg width and length (mm). Egg quality traits included: Yolk index, Yolk percentage, Albumen percentage, Haugh Units measured according to the equation mentioned by Card and Nesheim [18], Shell percentage, Shell strength determined according to Fathi and El- Sahar [19] and Shell thickness. A digestion trail was conducted at the end of the experimental period (14 wks old) to estimate the digestion coefficients and nitrogen retention of the experimental diets. A total number of 48 males were used in 8 treatments (6 males/ treatment with 2 male/ replicate). Feed and fresh water were offered *ad libitum* during 6 days of collection period. The feed consumption was recorded and the excreta, were collected quantitatively every 24 hrs. Feathers and scattered feed were taken out of the excreta. The excreta of each treatment were pooled together and then dried at 60°C till a constant weight. The dried excreta for the successive three days were left for few hrs to get equilibrium with the atmosphere then weighed, ground, well mixed and stored for analysis. The analysis of feed and dried excreta were analyzed for moisture, ash, nitrogen (N), ether extract (EE), crude fiber (CF) and nitrogen free extract (NFE) according to A. O. A. C. [20]. Fecal nitrogen was determined according to Jakobson *et al.* [21].

Data were subjected to the analysis of variance by using the General Linear Models Procedure (GLM) of the Statistical Analysis System [22]. Differences among treatment means were detected by using Duncan's multiple range tests [23].

RESULTS AND DISCUSSION

Egg weight, egg mass, feed intake and feed conversion ratio of laying quails as influenced by different treatments are presented in Table 2. The average egg weight was not significantly changed with either pre-hatch temperature or feeding treatments. However, egg mass reflected considerable changes. Dietary treatments caused significant ($P \leq 0.05$) effects on egg mass, where the value obtained for the control- fed quails was 415.69 g (the lowest) and Vitamin C supplemented diet recorded the highest (540.75 g). Neither heat stress during incubation nor dietary manipulation procedures showed significant influence on egg weights of laying quails when exposed to high environmental temperature of 32±2°C during the laying period. However, albumen weight and egg mass values were significantly affected only by dietary treatments. The increased egg mass may reflect an improvement in egg weight and/or egg number. In this respect results reveal that no significant effect of treatments on egg weight, since the enhanced egg mass values are due to higher egg number, being more in females fed high energy and Vitamin C - supplemented diets.

The positive effects of Vitamin C and the highest energy diets on egg production are consistent with enhanced metabolic activity of treated quails. It is generally accepted that performance of laying hens is adversely affected under heat stress conditions and Vitamin C is perhaps the most widely studied vitamin when attempting to alleviate heat stress. The results are in agreement with the findings of Tillman [24], Bains [25], Sahin and Kucuk [26] and Seyrek *et al.* [27] who reported several beneficial effects of Vitamin C on egg production of laying fowls. The effect of dietary energy in enhancing egg production was not observed by Moraes *et al.* [28] and Njoya [29] who found insignificant effects of energy intake on egg production and shell thickness. The highest dietary lysine has no significant effect on different egg production. This was not supported by the findings of Novak and Scheideler [30] who observed higher egg mass and egg production traits when dietary lysine levels increased from 0.85 to 0.90 % in White Leghorn hens. The present experiment utilize quail layer which may indicate species differences.

Table 2: Effect of different dietary treatments on productive performance of laying quails

Treatments	Egg weight (g)	Egg mass (g/bird)	Feed intake (g/bird)	Feed conversion ratio
A-Non heat treatment				
Control	12.51	354.20	1771.00	5.00
Energy	12.97	457.43	1601.00	3.50
Lysine	12.58	503.94	1663.00	3.30
Vitamin C	12.81	515.43	1804.00	3.50
B-Heat treatment				
Control	12.86	477.18	1694.00	3.55
Energy	14.18	424.00	1484.50	3.50
Lysine	12.64	519.10	1713.00	3.30
Vitamin C	12.71	566.07	1726.50	3.05
Effect of feed				
Control	12.68	415.69^{b}	1732.50^{a}	4.28
Energy	13.58	440.72^{ab}	1542.75^{b}	3.50
Lysine	12.61	511.52^{ab}	1688.00^{a}	3.30
Vitamin C	12.76	540.75^{a}	1765.25^{a}	3.28
Effect of heat				
Non heat	12.71	457.75	1709.75	3.83
Heat	13.09	496.59	1654.50	3.35
SEM (±)	2.10	2.51	59.38	0.41
Source of variation				
Feed	NS	0.04	0.02	NS
Heat	NS	NS	NS	NS
Feed* Heat	NS	NS	NS	NS

a, b Means within a columns with no common superscripts differ significantly (P<0.05), SEM=Standard error of means

Table 3: Effect of different treatments on exterior egg quality traits at laying period

	Egg			Shell				
Treatments	Weight (g)	Length (mm)	Width (mm)	Weight (g)	%	Breaking strength (Kg/ cm^2)	Thickness (mm)	Shape index %
A-Non heat treatment								
Control	12.60^{ab}	33.53^{ab}	26.39	1.06^{abc}	8.39	2.43	22.60^{bc}	78.74
Energy	12.55^{ab}	33.59^{ab}	26.32	1.08^{abc}	8.62	2.64	24.50^{abc}	78.67
Lysine	12.58^{ab}	32.91^{ab}	26.16	1.09^{abc}	8.67	2.17	24.30^{abc}	79.54
Vitamin C	12.98^{a}	33.42^{ab}	26.54	1.16^{ab}	9.01	2.11	25.25^{a}	79.48
B-Heat treatment								
Control	12.92^{ab}	33.53^{ab}	26.55	1.10^{abc}	8.54	2.16	23.90^{abc}	79.21
Energy	13.30^{a}	34.36^{a}	26.60	1.18^{a}	8.89	2.77	25.17^{ab}	77.45
Lysine	11.96^{b}	32.28^{b}	26.02	1.00^{c}	8.36	2.10	22.44^{c}	80.65
Vitamin C	11.98^{b}	32.91^{ab}	25.88	1.04^{bc}	8.68	2.53	24.78^{abc}	79.33
Effect of feed								
Control	12.76	33.53^{ab}	26.47	1.08	8.47	2.30	23.25^{b}	78.98
Energy	12.93	33.98^{a}	26.46	1.13	8.76	2.71	24.84^{a}	78.06
Lysine	12.27	32.60^{b}	26.09	1.05	8.52	2.14	23.37^{b}	80.10
Vitamin C	12.48	33.17^{ab}	26.21	1.10	8.85	2.32	25.02^{a}	79.41
Effect of heat								
Non heat	12.68	33.36	26.35	1.10	8.67	2.34	24.16	79.11
Heat	12.54	33.27	26.26	1.08	8.62	2.39	24.07	79.16
SEM (±)	0.71	1.55	0.37	0.01	0.66	0.40	4.76	7.57
Source of variation								
Feed	NS	0.02	NS	NS	NS	NS	0.05	NS
Heat	NS	NS	NS	NS	NS	NS	NS	NS
Feed* Heat	0.02	NS	NS	0.04	NS	NS	NS	NS

a, b and c Means within a columns with no common superscripts differ significantly (P<0.05), SEM=Standard error of means

The average feed intake of laying quails was not significantly changed with pre-hatch temperature. However, dietary treatments caused a significant ($P \leq 0.02$) effect on feed intake, where the value obtained for the high- energy fed quails was the lowest (1542.75 g) and the Vitamin C-supplementation was the highest (1765.25 g). Also, feed conversion ratio was not significantly changed with either pre- hatch temperature or feeding treatments. It appears that the pre-hatching temperature and post-hatching feeding treatment were able to compete the negative effects of temperature on feed consumption and feed conversion. Birds fed Vitamin C supplemented diet consumed more feed than the other treatments. This could be explained by the fact that Vitamin C caused a reduction in corticosteroid secretions, which main the normal physiological response of quails and facilitates the turnover of nutrients to growth and /or productive performance.

These results are in close agreement with those observed by Seyrek *et al*. [27], Sahin *et al*. [31, 32] and Abdel- Fattah [33]. Egg, shell quality and shape index % as influenced by different treatments are presented in Table 3. Egg weight significantly ($P \leq 0.05$) changed with both heat exposure of eggs and dietary treatments. The highest egg weight values were recorded for quails fed the high- energy (13.30 g) and control 12.92 g) of heat treatments supplemented diets followed by the Vitamin C diet (12.98 g) in non heat exposed treatment. Significant ($P \leq 0.05$) effects of dietary treatments on egg length were observed. The lowest egg length value was recorded for quails fed the lysine (32.60 mm) supplemented diets and the highest value for quails fed the high- energy (33.98 mm) diet. However, egg width was not significantly changed with either pre- hatch temperature or feeding treatments.

Shell weight significantly ($P \leq 0.05$) changed with both heat exposure of eggs and dietary treatments. The lowest shell weight value was recorded for quails fed lysine (1.00 g) supplemented diets and the highest value for quails fed the high- energy (1.18 g) diet. Shell percentage (%) and breaking strength were not significantly changed with either pre- hatch temperature or feeding treatments. However, shell thickness was significantly ($P \leq 0.05$) changed with feeding treatments. The highest shell thickness values were recorded for quails fed the Vitamin C (25.02 mm) supplemented diets followed by the high-energy (24.84 mm) diet. Also, Shape index % was significantly ($P \leq 0.05$) changed with neither pre- hatch temperature nor feeding treatments. Egg yolk, albumen and Haugh Units as influenced by different treatments are presented in Table 4. Yolk weight, yolk % and yolk index % were significantly changed with

Table 4: Effect of different treatments on interior egg quality traits at laying period

	Yolk					Albumen			
Treatments	Weight (g)	%	Height (mm)	Diameter (mm)	Index %	Weight (g)	%	Height (mm)	Haugh Units
A-Non heat treatment									
Control	3.90	31.02	10.50	18.45^{ab}	56.86	7.64^{ab}	60.59	4.06^{ab}	86.22^{ab}
Energy	4.07	31.34	10.19	21.00^{a}	48.94	7.70^{ab}	59.64	4.06^{ab}	85.79^{ab}
Lysine	3.92	31.03	11.16	18.57^{ab}	60.45	7.63^{ab}	60.06	4.31^{ab}	87.16^{ab}
Vitamin C	3.87	30.01	11.19	19.03^{ab}	59.53	7.86^{ab}	60.95	3.85^{b}	84.64^{b}
B-Heat treatment									
Control	3.98	30.87	10.11	18.61^{ab}	56.43	7.80^{ab}	60.57	4.54^{ab}	88.64^{ab}
Energy	3.86	28.93	9.91	17.77^{b}	56.07	8.30^{a}	62.09	4.62^{ab}	88.84^{ab}
Lysine	3.90	32.37	10.29	16.94^{b}	62.04	7.13^{b}	59.21	3.44^{b}	82.22^{b}
Vitamin C	3.79	31.66	10.02	18.18^{ab}	56.75	7.41^{ab}	60.36	5.34^{a}	93.56^{a}
Effect of feed									
Control	3.94	30.95	10.31	18.53	56.65	7.72^{ab}	60.58	4.30	87.43
Energy	3.97	30.14	10.05	19.39	52.51	8.00^{a}	60.87	4.34	87.32
Lysine	3.91	31.70	10.73	17.76	61.25	7.38^{b}	59.64	3.88	84.69
Vitamin C	3.83	30.84	10.61	18.61	58.14	7.64^{ab}	60.66	4.60	89.10
Effect of heat									
Non heat	3.94	30.85	10.76	19.26^{a}	56.45	7.71	60.31	4.07	85.95
Heat	3.88	30.96	10.08	17.88^{b}	57.82	7.66	30.56	4.49	88.32
SEM (±)	0.19	7.78	1.86	2.27	9.77	0.46	8.85	0.89	8.89
Source of variation									
Feed	NS	NS	NS	NS	NS	NS	NS	NS	NS
Heat	NS	NS	NS	0.05	NS	NS	NS	NS	NS
Feed* Heat	NS	NS	NS	NS	NS	NS	NS	0.02	0.03

a, b and c Means within a columns with no common superscripts differ significantly ($P<0.05$), SEM=Standard error of means.

Table 5: Effect of different treatments on nutrients digestibility of the experimental diets during laying period

Treatments	CP	CF	EE	NFE	OM
A-Non heat treatment					
Control	86.16^{a}	40.03	73.59^{a}	72.21	73.77
Energy	82.31^{ab}	40.01	71.63^{ab}	72.17	72.79
Lysine	82.70^{ab}	32.86	73.87^{a}	72.76	73.39
Vitamin C	75.45^{b}	44.21	55.59^{b}	76.79	68.76
B-Heat treatment					
Control	85.79^{a}	32.85	61.07^{ab}	72.78	73.41
Energy	83.28^{ab}	35.74	69.96^{ab}	73.30	73.57
Lysine	81.54^{ab}	26.50	66.37^{ab}	74.43	73.93
Vitamin C	82.87^{ab}	30.04	65.78^{ab}	72.23	72.25
Effect of feed					
Control	85.98^{a}	36.44	67.33	72.50	73.59
Energy	82.80^{ab}	37.88	70.80	72.73	73.18
Lysine	82.12^{ab}	29.68	70.12	73.59	73.66
Vitamin C	79.16^{b}	35.71	60.69	74.05	70.51
Effect of heat					
Non heat	81.66	38.83	68.67	73.18	72.18
Heat	83.37	31.28	65.80	73.18	73.29
SEM (±)	5.13	11.30	9.01	4.14	5.82
Source of variation					
Feed	0.05	NS	NS	NS	NS
Heat	NS	NS	NS	NS	NS
Feed* Heat	NS	NS	NS	NS	NS

a, b and c Means within a columns with no common superscripts differ significantly (P<0.05). SEM=Standard error of means

neither pre- hatch temperature nor feeding treatments. However, pre- hatch exposure of eggs to high temperature significantly (P ≤ 0.05) decreased yolk diameter. The values recorded were 19.26 and 17.88 (mm) for the control non heated and heated treatments, respectively.

Albumen weight and percentage (%) were not significantly changed with either pre- hatch temperature or feeding treatments. However, the albumen height was significantly (P ≤ 0.05) changed with both heat exposure of eggs and dietary treatments. The lowest albumen height value was recorded for quails fed the heat treatment- control (3.44 mm) and the highest value fed heat treatment- Vitamin C (5.34 mm) supplemented diets. Haugh Units score was significantly (P ≤ 0.05) changed with both heat exposure of eggs and dietary treatments. The lowest value was recorded for quails from heat treatment- lysine (82.22) and the highest value was recorded for quails from heat treatment- Vitamin C (93.56) supplemented diets. There is a tendency for enhancing shell quality traits (i.e. shell thickness and weight) by increasing the energy level of the diet and by Vitamin C - supplementation, which in turn increase shell breaking strength. It appears from the results that the dietary lysine supplements has no significant influence on the previous egg quality traits which are in close agreement with the findings of Scheideler *et al.* [34] and Novak *et al.* [35]. However, our data reflected the positive effects of Vitamin C supplemented and high energy level on egg quality parameters, especially shell quality traits. It is suggested that Vitamin C may enhance calcium metabolism, causing increased plasma calcium concentration and improve egg shell quality by promoting mineral mobilization from bone. Moreover, it is likely that oil supplementation could facilitate the action of vitamin D3, which is known as a member fat soluble vitamin, for increasing calcium metabolism. Similar findings are reported by many investigators who observed that Vitamin C increase blood calcium and reduce bone ash indicating a positive response in shell quality [2, 27, 36, 37].

Nutrients digestibility coefficients of the experimental diets as affected by pre- hatching temperature and post-hatching feeding treatments are shown in Table 5. The apparent digestibility coefficients of CF, EE, NFE and OM were insignificantly changed due to feeding treatments. However, CP digestibility was significantly higher (P ≤ 0.05) in the control, followed by the high- energy and then the lysine supplemented diets. The lowest value for CP digestibility was recorded for the Vitamin C supplemented diet. Heat exposure was found to improve CP and OM digestibility and decrease both CF and EE but these changes were not significant. It is well documented that environmental stressors have been shown to decrease nutrients digestibility as the temperature increased from thermoneutral zone (21°C) to 32°C. This was the case in the present study, where the mean ambient temperature during the whole experimental period was approximately

(32°C). Indeed, the improvements in productive performance of observed in the current study could be explained as a result of increasing nutrients digestibility. Such positive effects may be due mainly to the dietary supplementations and (or) pre- hatching exposure of eggs. It is suggested, however, that both Vitamin C, energy and lysine supplements could stimulate and help pancreas in elaborating digestive enzymes and insulin (suggested as an anabolic hormone for amino acids), thus improving utilization, absorption and retention of dietary nitrogen and minerals. Also dietary treatments could stimulate the liver to secrete bile acids and salts, needed for emulsifying dietary fats and increased their utilization. This may explain the enhanced productivity of quails under the present experimental conditions. Similar results dealing with the important role of Vitamin C, high- energy and high- lysine in the diets for better performance of different avian species under stress conditions [38- 42]. These studies are in accordance with the results of the present study. It could be concluded that pre-hatching exposure of quail eggs to high temperature and post-hatching feeding of a high-energy or vitamin C supplemented diets could be recommended for alleviating the deleterious effects of heat stress during laying periods. Therefore, it is suggested that supplementation of 200 ppm of Vitamin C or increasing dietary energy by 150 Kcal more than the recommended levels may be practically effective in enhancing the general performance of quails.

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