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EFFECT OF DIETARY CALCIUM AND VITAMIN D_3 LEVELS ON EGG PRODUCTION AND EGG SHELL QUALITY OF HY-LINE BROWN - EGG TYPE LAYING HENS

By

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Abstract: *This experiment was conducted to study the effect of different levels of calcium and vitamin D_3 on egg production, egg shell quality and some blood parameters of laying hens. A total number of 240 hens (Hy-Line Brown-egg type) from 24 to 40 weeks of age were randomly divided into sixteen experimental treatments; 15 hens each. Each treatment was sub-divided into five replicates, (three hens each). The experimental design consisted of a 4 X 4 factorial arrangement with four levels of Ca (3.25, 3.50, 3.75 and 4.00 %) and four levels of vitamin D3 (2500, 3000, 3500 and 4000IU /kg diet) . Results obtained indicate the following:*

1 - Increased dietary Ca levels up to 4% showed the highest insignificant value of egg production, egg weight and egg mass during the whole experimental period. However, hens fed 4% Ca showed significantly ($P<0.01$) the highest values of egg production and egg mass (86.73%and56.69g) respectively from 36 to 40 wk of age. Moreover, hens fed diets containing vitamin D_3 at 3000 or 2500 IU /kg diet showed significantly($P<0.01$) the highest values of egg production(76.55 % and 84.61%)during 32 to 36 wk and 36 to 40 wk of age period, respectively. In addition, hens fed diets containing 4% Ca with 4000 vitamin D_3 IU /kg diet showed significantly ($P<0.01$) the highest value of egg mass (58.65g) during 36 to 40 wk of age period .

2 - Hens fed diets containing 3.75,4.00,3.50 and 4.00% Ca recorded significantly ($P<0.01$) higher values of feed consumption during the period 24 to 28 wk, 28 to 32 wk , 32 to 36 wk and 36 to 40 wk of age, respectively compared with hens fed 3.25% dietary Ca level. The interactions between dietary levels of Ca and vitamin D_3 had significant ($P<0.01$) effect on feed consumption during the different interval periods and the whole experimental period.

3 - Feed conversion was not significantly affected by dietary Ca levels during the different intervals and the whole experimental period, except the hens that fed 4% Ca which showed significantly ($P<0.01$) the best value of feed conversion (1.85 g feed/g egg mass) compared with the other levels during the period 36 to 40 wk of age. Moreover, feed conversion was not significantly influenced by increasing dietary vitamin D_3 levels during the different interval periods. However, hens fed diet containing 3000 IU/kg D_3 level during the whole experimental showed significantly ($P<0.01$) the best value (2.15g feed/g egg mass) compared to the other levels. Regarding the interaction between dietary Ca and vitamin D_3 had significant ($P<0.01$) effect on feed conversion during the period 36 to 40 wk of age. Moreover, hens fed 4% Ca with vitamin D_3 at 4000IU/kg diet showed the best value of feed conversion (1.79 g feed/g egg mass).

4 - Hens fed diet containing 4% Ca level showed significantly ($P<0.01$) the highest value of shell weight (8.51g) compared with the other groups. Moreover, the increase of dietary Ca level up to 4% with vitamin D_3 4000IU/kg diet showed the highest ($P \geq 0.05$) values of egg surface area (ESA), egg shell volume (ESV) and shell thickness compared with the other experimental groups.

5 - Hens fed diet containing vitamin D_3 at 3000, 3500 and4000 IU/kg showed significantly ($P<0.01$) the highest value of Ca concentration in plasma compared with the control diet.

6 - Hens fed diets containing Ca level at 4.00, 3.75 and 3.50% showed significantly ($P<0.01$) higher values of Ca concentration in eggshell compared to the control group. Moreover, increasing vitamin D_3 up to 4000 IU/kg diet showed significantly ($P<0.01$) the highest value (459.11 mg/g) of Ca concentration in eggshell compared to the other experimental groups. There was significant ($P<0.01$) interaction between Ca and vitamin D_3 level on Ca concentration in egg shell , where hens fed diets containing Ca at 3.25 , 3.50, 3.75 or 4.00 % with vitamin D_3 at 4000 IU/kg showed higher values of Ca concentration in eggshell .

The results indicated that increasing dietary levels of Ca up to 4% with a level of 4000 IU/kg diet of vitamin D_3 improved eggshell quality without adverse effects on laying performance.

INTRODUCTION

Calcium is one of the most important compositions of egg shell. It has a significant effect on performance and egg shell quality of laying hens **(William *et al.*, 2006)**. Egg shell quality is an important factor in poultry production because a large number of eggs with defective shells cause a great economical loss to the producer **(Lavelin *et al.*, 2000)**. Inadequate Ca significantly decreased egg production, egg weight, egg specific gravity, feed consumption, and bone density and strength **(Roland *et al.*, 1996)**. On the other hand, excess Ca significantly reduced egg production, egg weight and feed consumption **(Harms and Waldroup, 1971)**. The available information about the amount of Ca needed in laying hen diet for maximum performance and egg shell quality is somewhat contradictory. Because there are many factors affect Ca requirement such as, strain, age of birds and temperature. Other nutrients such as, phosphorus, dietary protein and energy may be also involved. **NRC (1994)** suggested a Ca requirement of 3.6% for Brown laying hens at a feed consumption of 110 g/bird per day, which seems insufficient, because Ca requirement recommended by the commercial management guides of Brown Hy-Line is from 3.75 to 4.25 % for laying hens at a feed consumption of 113 to 100g/bird per day **(Hy-Line international, 2008)**. Moreover, **Castillo *et al.* (2004)** indicated that the biological optimum Ca level for maximum egg production was 4.38 % and 4.64% in diet for the best feed conversion and maximum specific gravity. Dietary Ca requirements for maximum egg production and egg mass, and the best feed conversion were 3.52, 3.54 and 3.62% respectively **(William *et al.*, 2006)**. However, **Lim *et al.* (2003)** indicated that increased Ca level from 3 to 4% in laying diet did not affect egg production and egg weight but the 4% Ca diet increased egg shell strength. Moreover, egg production, egg weight, egg mass, feed conversion, and shell quality were not influenced by the Ca levels from 2.5 up to 4.5% in laying diet **(Clunies *et al.*, 1992; Leeson *et al.*, 1993 and Keshavarz and Scott, 1993)**

Vitamin D_3 is necessary for the bird to absorb, transport and utilize calcium and phosphorus through the intestinal wall. Calcium absorption and deposition are controlled by the active metabolite of cholecalciferol which undergoes to sequential hydroxylation in liver to form 25-cholicalciferol and then converted to 1, 25 - dihydroxycholecalciferol in kidney **(Norman, 1987)**. This active form of vitamin D_3 is involved in the biosyntheses of Ca-binding protein, which is involved in active transport of Ca across the intestinal wall. Additionally, this active form is promoting absorption of Ca for bone and egg shell formation **(Stevens and Blair, 1984 and Keshavarz, 2003)**. A number of studies stated the improvement in eggshell quality and bone mineralization by increasing the level of dietary cholicalciferol above the requirement level **(Keshavarz, 1996; Hansen *et al.*, 2004; Saban *et al.*, 2005 and Cesar *et al.*, 2010).**

The current study was conducted to determine the effect of different calcium and vitamin D_3 levels and their interaction on egg production and egg shell quality in Hy – Line Brown – egg type laying hens.

MATERIALS AND METHODS

This experiment was carried out at Maryot Research Station, Alexandria to study the effect of different levels of calcium and vitamin D_3 on performance of laying hens. A total number of 240 hens (Hy-Line Brown-egg type) from 24 up to 40 weeks of age were randomly divided into sixteen experimental groups; 15 hens each. Each group was sub-divided into five replicates, (three hens each). A (4 X 4) factorial experimental design with four levels of Ca (3.25, 3.50, 3.75 and 4.00 %) and four levels of vitamin D_3 (2500, 3000, 3500 and 4000IU /kg diet) was tested for 16 weeks. All the experimental diets were iso-nitrogenous and iso-caloric (2750ME/kg and 18% CP) according to **NRC (1994).** Vitamin D_3 in concentrate 50.5 % was taken into consideration at the time of diet mixing .Composition and calculated analysis of the experimental diets are presented in Table 1. Diets and water were offered *ad lib.*. All hens were kept under the same managerial and environmental conditions and artificial light source was used giving a total of 16 hours of light per day through the experimental periods.

Body weights were recorded at the beginning and at the end of the experiment (40 week of age). Egg weight and egg number were recorded daily to calculate the egg production percentage and egg mass (g/hen/day) which was calculated by multiplying egg number by average egg weight. Feed consumption was recorded biweekly and feed conversion values (g feed /g eggs) were calculated as the amount of feed consumed divided by egg mass.

Egg quality parameters were measured using 96 eggs (6 eggs / each treatment group). These measurements involved yolk, albumen and shell weight percentage. However, egg shell thickness was measured in µm using a micrometer. Egg shape index was calculated according to **Romanoff and Romanoff (1949)** as an egg diameter divided by egg length. Yolk index was calculated according to **Funk *et al.*, (1958)**, as yolk height divided by yolk diameter. Haugh unit was calculated according to **Eisen *et al.* (1962)** using the calculation chart for rapid conversion of egg weight and albumen height. Egg surface area (ESA) was calculated according to **Paganelli *et al.*(1974)** as ESA=4.835 x $W^{0.662}$ Cm^2 where W=Egg mass in grams. Shell weight per unit surface area (SWUSA) was calculated as shell weight, mg/ESA, Cm^2. Egg shell volume (ESV) was estimated according to **Rahn (1981)** as ESA, Cm^2 x Shell thickness. At the end of the experiment, three egg shell samples from each treatment were taken and ground prior to ashing. Calcium was determined by flame photometric procedure **(Jackson, 1958)**. Phosphorus was colorimetrically determined by a Spectrophotometer **(Murphy and Riley, 1962)**.

At the end of the experiment, three blood samples from each treatment were taken from the brachial vein. Plasma total protein and albumin, were measured according to **Henry (1964)** and **Doumas *et al.*** (1971), respectively. Plasma total lipids were measured by the procedure of **Zollner** and **Kirsch (1962)** . Alanine aminotransferase (ALT) and Aspartate aminotransferase (AST) were measured according to **Reitman and Frankel (1957)**. Plasma triglycerides were estimated according to **Fassati and Prencipe (1982)**. The concentration of plasma globulin was calculated by subtracting plasma albumin from plasma total protein. In this respect. Ca. inorganic P were measured by specific diagnostic kits **(Bio Merieux, France)** according to guidelines and recommendation of **Bogin and Keller (1987)**.

Data obtained were statistically analyzed using the General Linear Model Procedure **(SAS, 1994)**. Duncan's multiple range test was used to test the significance ($P<0.05$) of mean differences **(Duncan, 1955)**.

RESULTS AND DISCUSION

Effect of calcium and vitamin D_3 levels and their interaction on:

1-Body weight and egg production parameters:

There were no significant differences in final body weight due to increasing Ca level up to 4% in diet (Table 2). This result influenced agreed with **(Keshavarz and Scott, 1993; Abou Egla, 1995 and Chowdhury and Smith, 2002)** who reported that Ca level up to 4 % in layer diet had no significant effect on final body weight.

Generally, increased dietary Ca levels up to 4% showed the highest ($P \geq 0.05$) values of egg production, egg weight and egg mass during the whole experimental period. However, hens fed diet containing 4% Ca recorded significantly ($P<0.01$) greater egg production (86.73%) and egg mass (56.69g) compared with the other treatments during 36 to 40 wk of age (Table 2). The present results were previously confirmed by several studies **(Sohail and Roland, 2000; Lim *et al.*, 2003and Castillo *et al.* 2004)** who indicated that increasing Ca level in laying diet did not affect egg production, egg weight and egg mass. In contrast. **Chowdhury and Smith (2002) ; Khidr *et al.* (2003) and William *et al.*(2006)** stated that, increasing dietary Ca level in laying diet showed a significant increase in egg production and egg mass.

The contradiction among the previous studies and the present study may be due to the difference in Ca levels of the basal diet, strain, and experimental conditions which showed insignificant effect on egg production, egg weight and egg mass. Furthermore. the amount of Ca level (3.25%) in control diet might be sufficient to marginal layer performance and could not have been caused a significant response with increased Ca level in the experimental diets. This fact was confirmed by **William *et al.* (2006)** who indicated that many factors can affect Ca requirement of laying hens including other nutrients. strains. age of birds and temperature.

Dietary vitamin D_3 level did not significantly affect final body weight. Moreover. egg production during 24 to 28 wk. 28 to 32 wk of age or during the total experimental period was not influenced by different levels of vitamin D_3. However, hens fed diets containing vitamin D_3 at 3000 or 2500 IU /kg diet showed significantly ($P<0.01$) the highest values of egg production(76.55 % and 84.61%)during 32 to 36 wk and 36 to 40 wk of age. respectively. Egg weight and egg mass were not significantly affected by different levels of vitamin D_3 during the different interval periods and through the whole experimental period (Table 2).

The interaction between dietary levels of Ca and D_3 had no significant effect on final body weight, egg production. egg weight and egg mass during the different interval periods and the whole experimental period. except hens fed diet containing 4% Ca with 4000 vitamin D_3 IU /kg diet which showed significantly ($P<0.01$) the highest value of egg mass (58.65g) during 36 to 40 wk of age (Table 3). This significant interaction might be a consequence of the significant effect of Ca level on egg mass during 36 to 40 wk of age (Table 2). as the increasing vitamin D_3 levels in diets did not significantly affect egg mass during the same period. Moreover, in the current experiment, the level of D_3 used in control diet was 2500IU/kg. This level in several times is higher than the recommended level of **NRC (1994)** being 300IU/kg diet for laying hens and equivalent to that used by the industry. Consequently, it is surprising that no beneficial effect obtained from increasing level of vitamin D_3 particularly when the Ca level in the diet was plentiful. Similar results were obtained by **Soares *et al.* (1988) and Keshavarz(1996)** who reported that egg production, egg weight and egg mass were insignificantly affected by increasing dietary vitamin D_3.

2- Feed consumption and feed conversion values:

Results in Table (4) showed that feed consumption recorded significantly (P<0.01) a higher value for hens fed diets containing 3.75,4.00,3.50 and 4.00% Ca during the period 24 to 28 wk, 28 to 32 wk . 32 to 36 wk and 36 to 40 wk of age, respectively compared with hens fed 3.25% dietary Ca level. However, feed consumption for the total experimental period was not significantly influenced by increasing dietary Ca levels. Feed conversion was not significantly affected by dietary Ca levels during the different intervals and the whole experimental period. except the hens that fed 4% Ca which showed significantly (P<0.01) the best value of feed conversion (1.85 g feed/g egg mass) compared with the other levels during the period 36 to 40 wk of age. The highest significant value of egg mass was recorded in group fed diet containing 4% Ca during the period from 36 to 40 wk of age (Table 2). These results were in agreement with **Clunies *et al.* (1992)** who stated that increasing Ca level from 2.5 to 3.5 and up till 4.5% in laying diet showed significant effect on feed intake, with no differences between 3.5 and 4.5% dietary Ca . Moreover, **Castillo *et al.* (2004)** reported that dietary Ca levels (2.98, 3.22, 3.83, 4.31 and 4.82%) had a significant effect on feed consumption. On the other hand, results obtained herein showed insignificant effect of dietary Ca level on feed consumption and feed conversion during the whole experimental period. These results were similarly obtained by **Chowdhury and Smith (2002) and Kermanshahi and Habavi (2006)**, who stated that dietary Ca levels had no significant effect on feed consumption and feed conversion.

Feed consumption was significantly (P<0.01) affected by dietary vitamin D_3 levels during the different interval periods. Moreover, this significant effect was inconsistent on feed consumption by dietary vitamin D_3 levels. However, dietary vitamin D_3 levels had no significant effect on feed consumption during the whole experimental period (Table 4). These results were in agreement to those obtained by **Keshavarz and Scott (1993) and Keshavarz(1996)** who stated that, increasing dietary vitamin D_3 in laying diet had no effect on feed consumption. Similar results were obtained in laying quail hens by **Abdel-Azeem and El-Shafei, 2006 and Abdel-Fattah *et al.*, 2007).**

Feed conversion was not significantly influenced by increasing dietary vitamin D_3 levels during the different interval periods. However, hens fed diet containing vitamin D_3 at 3000 IU/kg diet showed significantly (P<0.01) the best value (2.15 g feed/g egg mass) compared to the other groups during the whole experimental period (Table 4). These results were confirmed by **Abdel-Fattah *et al.* (2007)** who showed that feed conversion improved with increasing vitamin D_3 in laying quail diet.

The interaction between dietary levels of Ca and vitamin D_3 had a significant (P<0.01) effect on feed consumption during the different interval periods and the whole experimental period. Moreover, hens fed diet containing 4% Ca with vitamin D_3 at 2500 IU/kg showed significantly (P<0.01) the highest value of feed consumption during the whole experimental period(Table 5). Feed conversion was insignificantly influenced by the interaction between dietary levels of Ca and vitamin D_3 during the different intervals and the whole experimental period. The only exception during the period 36 to 40 wk feed conversion was significantly (P<0.01) influenced by the interaction between dietary levels of Ca and vitamin D_3 Moreover, hens fed diet containing 4% Ca with vitamin D_3 at 4000IU/kg diet showed the best value of feed conversion (1.79 g feed/g egg mass) (Table 5).

3- Egg quality measurements:

Egg quality was not significantly affected by different levels of Ca or vitamin D_3 and their interactions in laying diets (Table 6). These results were in agreement with the results obtained by **Chowdhury and Smith (2002)** who reported that dietary Ca level had no significant effect on yolk weight, albumen height, and haugh units. Moreover. **Khidr *et al.* (2003)** showed that dietary Ca levels did not significantly affect yolk weight, albumen weight, shape index and yolk index.

Hens fed diet containing 4% Ca showed significantly (P<0.01) the highest value of shell weight (8.51g) compared to the other experimental groups. Also dietary Ca at 4% level recorded the insignificantly higher values of ESA (62.97 cm^2), SWUSA (135.52 mg/cm^2), ESV (25.41 cm^2) and shell thickness (0.4034μm) compared to the other experimental groups (Table 7). These results were similar to previous study of **Clunies *et al.* (1992) and William *et al.* (2006)** stated that eggshell weight increased linearly (P< 0.05) with increasing level of dietary Ca up to 4%. In this connection, eggshell quality and shell thickness were improved when the amount of Ca into the diet increased (**Roland *et al.*, 1996; Scott *et al.*, 1999 and Kermanshahi and Habavi, 2006**).

Egg shell parameters were not significantly influenced by increasing dietary vitamin D_3 levels. Furthermore, interaction between dietary levels of Ca and vitamin D_3 had no significant effect on egg shell parameters. In addition, hens fed diet containing 4.00% Ca with vitamin D_3 at 4000 IU/kg diet showed insignificantly higher values of ESA, ESV, shell weight and shell thickness compared with the other experimental groups (Table 7) .These improvements of eggshell quality may be due to that vitamin D_3 tend to increase the deposition of calcium and phosphorus in egg shell, (**Keshavarz, 2003**). The present results are agree with the finding of **Abdel-Azeem and El-Shafei (2006)** who reported that shell quality was maximized when laying quail diet contained vitamin D_3 at 3000 IU/kg diet Furthermore, **Frost and Roland (1990)** indicated that adding 1,25 (OH) 2 D3 in layer diet increased eggshell percentage, egg breaking strength and shell weight.

4-Some plasma blood parameters and mineral content in egg shell:

Plasma blood parameters and some mineral (Ca and P) content in egg shell are shown in (Table 8). There was no significant effect on plasma blood parameters by increasing Ca or vitamin D_3 levels and their interaction in laying diets. On the other hand, hens fed diets containing vitamin D_3 at 3000, 3500 or 4000 IU/kg showed significantly ($P<0.01$) the highest values of Ca concentrations in blood plasma compared to the control level. This result was similar to those of **Abdel-Azeem and El-Shafei (2006)** who showed that plasma calcium increased ($P<0.05$) when the vitamin D_3 increased from 2000 to 3000 IU/kg in laying quail diet.

Hens fed diets containing Ca level at 4.00, 3.75 or 3.50% showed significantly ($P<0.01$) higher values of Ca concentration in eggshell compared to the control group. Moreover, increasing vitamin D_3 up to 4000 IU/kg diet showed significantly ($P<0.01$) the highest value (459.11 mg/g) of Ca concentration in eggshell compared to the other experimental groups. These results may be attributed to the increase in eggshell weight when dietary Ca level increased up to 4%. The amount of Ca deposited in eggshell increased, because calcium makes up to 40% of the eggshell. This also confirmed the positive improvement in other eggshell measurements such as shell weight and shell thickness (Table 7).Moreover, **Khidr *et al.* (2003)** reported that increasing Ca level up to 4.50% in laying diet increased significantly ($P<0.05$) Ca concentration in eggshell. In addition, **Abdel-Azeem and El-Shafei (2006)** showed significant ($P<0.05$) increase in calcium level of eggshell when laying quail fed diet containing 3000 IU/kg of vitamin D_3

There was a significant ($P<0.01$) interaction between Ca and vitamin D_3 level on Ca concentration in egg shell. Moreover, hens fed diets containing Ca at 3.25, 3.50, 3.75 or 4.00 % with vitamin D_3 at 4000 IU/kg showed higher values of Ca concentration in eggshell. This result may be explained by **Rama-Rao *et al.*(2006)** who stated that higher concentration of vitamin D_3 in the diet are known to improve Ca absorption through the gut, because, vitamin D_3 is essential for Ca metabolism. These results cleared the beneficial effect on shell quality which can be obtained by supplementing vitamin D_3 in laying diet. Thus, the recommended level of vitamin D_3 (300 IU/kg) of **NRC (1994)** may be insufficient for optimal egg shell quality.

However, P concentration in eggshell was not significantly influenced by different levels of Ca or vitamin D_3 and their interactions in laying diets. Similar results were obtained by **Khidr *et al.* (2003)** who reported that increasing Ca level up to 4.50% in laying diet had insignificantly ($P<0.05$) affect P concentration in eggshell.

In conclusion, the results indicated that increasing dietary Ca level up to 4% with vitamin D_3 up to 4000 IU/kg diet improved eggshell quality without adverse effect on laying performance. Moreover, new strains like Hy-Line Brown-egg type might need dietary Ca and vitamin D_3 at higher than those recommended by **NRC (1994)** for laying hen to meet high egg yield.

Table 1: Composition and calculated analysis of the experimental basal diets.

Ingredients:	Ca%			
	3.25	3.50	3.75	4.00
Yellow corn	62.75	63.00	63.25	63.25
Soybean meal 44%	16.00	16.50	17.00	17.00
Concentrate 50.5%[1]	10.00	10.00	10.00	10.00
Wheat brain	4.00	2.50	1.03	0.00
Limestone	6.25	7.00	7.72	8.52
Dicalcium P	0.75	0.75	0.75	0.73
Salt(NaCl)	0.25	0.25	0.25	0.25
Gluten meal 60%	0.00	0.00	0.00	0.25
Total	100	100	100	100
Calculated analysis :				
ME kcal /kg	2755	2755	2755	2751
CP %	18.05	18.06	18.06	18.06
CF %	3.14	3.02	2.89	2.78
EE %	3.92	3.89	3.86	3.84
Ca %	3.25	3.50	3.75	4.00
Total P%	0.75	0.74	0.73	0.71
Available P %	0.58	0.58	0.58	0.57
Lysine%	0.95	0.96	0.96	0.96
Methionine&Cystine%	0.69	0.69	0.69	0.69
D_3 IU	2500	2500	2500	2500

[1]Concentrate composition: 50.5% CP, 2442 Kcal ME/Kg, 2% CF, 7.9% EE, 8.50% Calcium, 3.35%,Phosphorus,1.70% Methionine, 2.4% , Methionine & Cystine and 2.85% Lysine. Vit A 1,200001U, Vit D_3 250001U, Vit E 125mg, Vit K 30 mg , Vit $B_1$10 mg, Vit $B_2$50mg , Vit $B_6$20 mg, Vit B_{12}120 mic, Biotin 500 mic, Manganese 800 mg, Iron 300 mg, Zinc 500 mg, Copper 100mg, Folic acid 10 mg, Niacin 300 mg, Pantothenic acid 100 mg, Choline Chloride 3120 mg, Selenium 1.5 mg, Cobalt 1mg and Iodine 4 mg. Product of Pyramid Poultry(Concord).

Table 2. Body weight, egg production, egg weight, and egg mass of laying hens as affected by Ca and vitamin D_3 levels.

Main effects:		Initial body wt.(g)	Final body wt.(g)	Egg Production (%)					Egg Weight(g)					Egg Mass(g)				
				Period in weeks														
Ca%	D_3IU /kg diet			24-28	28 - 32	32-36	36 -40	Overall mean	24-28	28-32	32- 36	36-40	Overall mean	24-28	28-32	32- 36	36-40	Overall mean
3.25		1720.55	1835.06	72.42	76.31	74.80	80.17^{b}	75.92	57.59	59.97	62.05	63.93	60.88	42.34	45.85	46.33	51.25^{b}	46.44
3.50		1715.83	1817.86	73.35	73.20	73.06	82.20^{b}	75.46	58.10	59.38	61.93	64.43	60.96	42.63	43.42	45.22	52.97^{b}	46.06
3.75		1715.50	1826.03	75.95	75.65	71.78	76.81^{c}	74.80	58.35	60.88	62.99	63.70	61.48	44.28	46.02	45.21	48.35^{c}	45.96
4.00		1719.33	1837.12	72.61	77.61	73.75	86.73^{a}	77.68	58.61	61.53	63.07	65.41	62.16	42.46	47.74	46.47	56.69^{a}	48.34
SEM		20.5102	15.5731	2.7862	2.1170	1.6623	1.4160	1.3661	0.8041	0.5864	0.4806	0.5267	0.4168	1.6505	1.3173	1.0361	0.9689	0.8294
P-value		0.9974	0.8082	0.7957	0.5186	0.6292	0.0001	0.4895	0.8292	0.0572	0.2052	0.1113	0.1252	0.8208	0.1522	0.7248	0.0001	0.1574
	2500	1720.48	1818.30	71.11	73.26	71.19^{b}	84.61^{a}	75.13	56.69	60.10	62.63	63.87	60.82	40.41	44.02	44.51	54.00	45.73
	3000	1716.18	1833.72	73.49	76.66	76.55^{a}	82.37^{ab}	77.27	58.30	59.93	62.04	64.49	61.19	43.42	45.91	47.46	53.16	47.49
	3500	1718.38	1834.09	74.28	76.19	74.75^{ab}	78.95^{b}	76.04	58.59	60.15	62.57	64.12	61.36	43.56	45.89	46.75	50.68	46.72
	4000	1716.16	1829.96	75.11	76.66	70.92^{b}	79.00^{b}	75.42	59.06	61.59	62.80	64.98	62.11	44.32	47.21	44.52	51.42	46.87
SEM		20.5102	15.5731	2.7862	2.1170	1.6623	1.4160	1.3661	0.8041	0.5864	0.4806	0.5267	0.4168	1.6505	1.3173	1.0361	0.9689	0.8294
P-value		0.9986	0.8788	0.8128	0.6192	0.0497	0.0141	0.6950	0.1897	0.1694	0.7089	0.4802	0.1806	0.3578	0.4010	0.1020	0.0679	0.5158

^{a,b,c} Means with different superscripts in same columns for each criterion are significantly different ($P \leq 0.05$).

SEM : Standard error mean

Table 3. Body weight, egg production, egg weight and egg mass of laying hens as affected by the interaction between Ca and vitamin D_3 levels.

Treatments:		Initial body wt.(g)	Final body wt.(g)	Egg Production (%)					Egg Weight(g)					Egg Mass(g)				
				Period in weeks														
Ca%	D_3 IU/kg diet			24-28	28-32	32-36	36-40	Overall mean	24-28	28-32	32-36	36-40	Overall mean	24-28	28-32	32-36	36-40	Overall mean
	2500	1731.33	1806.64	68.10	70.95	70.70	79.76	72.32	54.46	59.14	62.95	62.67	59.80	37.02	41.96	44.31	49.98^{cdef}	43.23
	3000	1718.33	1854.64	73.25	82.62	80.95	87.14	80.99	57.79	59.24	60.67	63.77	60.37	44.78	48.91	49.06	55.57^{abc}	49.58
3.25	3500	1715.86	1832.98	74.05	76.19	76.38	79.28	76.47	59.13	60.01	62.11	64.41	61.41	44.18	46.17	47.38	51.08^{cde}	47.20
	4000	1716.66	1845.98	74.29	75.47	71.42	74.52	73.92	58.98	61.49	62.48	64.89	61.96	43.73	46.37	44.58	48.35^{def}	45.76
	2500	1713.33	1823.64	72.48	72.35	70.00	83.44	74.56	58.50	59.25	61.78	64.99	61.13	42.37	42.77	43.25	54.07^{abcd}	45.61
	3000	1702.66	1813.98	71.90	71.90	77.85	82.19	75.71	57.86	59.87	61.70	63.46	60.72	41.58	43.00	48.08	51.59^{bcde}	46.06
3.50	3500	1722.67	1827.86	71.67	74.05	73.57	81.05	75.08	58.29	58.91	62.30	64.33	60.96	41.85	43.58	45.86	52.21^{bcde}	45.88
	4000	1724.67	1805.98	77.37	74.52	70.83	83.13	-76.46	57.74	59.51	61.95			44.72	44.32	43.70	54.01^{abcd}	46.69
.	2500	1713.27	1810.31	73.33	67.14	66.90	86.91	73.57	55.69	60.38	64.55	64.81	61.36	41.13	40.46	43.13	56.35^{abc}	45.26
	3000	1722.41	1809.64	78.33	78.80	72.14	74.19	75.87	58.27	60.00	61.86	64.01	61.03	45.61	47.27	44.62	47.51^{ef}	46.25
3.75	3500	1713.67	1822.90	77.61	79.76	77.38	71.43	76.54	58.93	60.48	62.79	62.84	61.26	45.40	48.15	48.55	44.88^{f}	46.74
	4000	1712.66	1861.28	74.53	76.90	70.71	70.71	73.21	60.49	62.68	62.77	63.14	62.27	45.01	48.21	44.54	44.65^{f}	45.60
	2500	1723.99	1832.62	71.90	82.61	77.37	88.33	80.06	58.12	61.62	61.24	63.02	61.01	41.46	50.88	47.35	55.58^{abc}	48.82
4.00	3000	1721.33	1856.62	70.47	73.33	75.28	86.95	76.51	59.30	60.62	63.95	66.74	62.65	41.71	44.47	48.07	57.98^{ab}	48.06
	3500	1721.33	1852.64	73.81	74.76	71.66	83.04	76.07	58.00	61.19	63.07	64.92	61.79	42.81	45.65	45.20	54.55^{abcd}	47.05
	4000	1710.67	1806.62	74.29	79.76	70.70	87.62	78.09	59.04	62.68	64.02	66.97	63.18	43.86	49.95	45.27	58.65^{a}	49.43
SEM		41.0204	31.1463	5.5724	4.2341	3.3246	2.8320	2.7322	1.6083	1.1729	0.9613	1.0535	0.8336	3.3011	2.6346	2.0723	1.9378	1.6589
P-value		1.00	0.8752	0.9972	0.2915	0.4285	0.186	0.6385	0.7515	0.9748	0.2637	0.2045	0.8734	0.9677	0.2898	0.7438	0.0032	0.6128

^{a,b,c} Means with different superscripts in same columns for each criterion are significantly different ($P \leq 0.05$).

SEM : Standard error mean

Table 4. Feed utilization of laying hens as affected by Ca and vitamin D_3 levels.

Main effects:		Feed consumption(g/ hen/day)					Feed conversion (g feed/ g egg mass)				
		Period in weeks									
Ca%	D_3IU/kg diet	24- 28	28 - 32	32-36	36 -40	Overall mean	24-28	28-32	32- 36	36-40	Overall mean
3.25		103.94^{b}	105.55^{c}	113.86^{b}	103.46^{b}	107.20	2.60	2.37	2.47	2.03^{b}	2.37
3.50		103.03^{c}	106.56^{b}	115.02^{a}	104.13^{ab}	107.19	2.46	2.49	2.57	1.98^{b}	2.22
3.75		107.21^{a}	103.92^{d}	113.41^{b}	104.37^{a}	107.22	2.47	2.29	2.53	2.19^{a}	2.37
4.00		103.57^{c}	108.47^{a}	113.40^{b}	104.61^{a}	107.51	2.55	2.29	2.45	1.85^{c}	2.29
SEM		0.2384	0.2889	0.2518	0.2663	0.1359	0.1258	0.0805	0.0586	0.0396	0.0502
P-value		<0.0001	<0.0001	<0.0001	0.0212	0.2889	0.8243	0.2829	0.4899	<0.0001	0.1105
	2500	105.69^{a}	104.67^{c}	113.24^{b}	105.35^{a}	107.24	2.73	2.41	2.56	1.95	2.42^{a}
	3000	104.97^{b}	106.18^{b}	114.31^{a}	104.01^{b}	107.36	2.44	2.36	2.42	1.98	2.15^{b}
	3500	104.56^{b}	106.54^{ab}	114.07^{a}	104.06^{b}	107.30	2.52	2.38	2.46	2.07	2.36^{a}
	4000	104.52^{b}	107.11^{a}	114.07^{a}	103.16^{c}	107.21	2.39	2.29	2.59	2.04	2.33^{a}
SEM		0.2384	0.2889	0.2518	0.2663	0.1359	0.1258	0.0805	0.0586	0.0396	0.0502
P-value		0.0029	<0.0001	0.0212	<0.0001	0.8534	0.2418	0.7353	0.1414	0.1496	0.0028

^{a,b,c} Means with different superscripts in same columns for each criterion are significantly different ($P \leq 0.05$).
SEM : Standard error mean

Table 5. Feed utilization of laying hens as affected by the interaction between Ca and vitamin D_3 levels.

Main effects:		Feed consumption(g/ hen/day)					Feed conversion (g feed/ g egg mass)				
		Period in weeks									
Ca%	D_3IU/kg diet	24- 28	28 - 32	32-36	36 -40	Overall mean	24-28	28-32	32- 36	36-40	Overall mean
Ca%	D_3IU/kg diet										
	2500	105.51^{d}	104.69^{d}	113.89^{bcd}	103.66^{cdefgh}	106.94^{bc}	2.88	2.50	2.58	2.07^{abc}	2.51
	3000	108.33^{c}	103.53^{de}	114.05^{bcd}	105.26^{bc}	107.79^{ab}	2.45	2.12	2.33	1.89^{cd}	2.20
3.25	3500	104.92^{d}	106.51^{c}	114.29^{bc}	102.86^{fgh}	107.14^{bc}	2.59	2.51	2.44	2.02^{bcd}	2.39
	4000	105.00^{d}	107.50^{bc}	113.21^{cd}	102.06^{h}	106.94^{bc}	2.49	2.33	2.56	2.13^{abc}	2.38
	2500	102.14^{fg}	103.29^{de}	116.78^{a}	104.76^{bcde}	106.74^{c}	2.45	2.43	2.72	1.94^{bcd}	2.38
	3000	99.54^{i}	112.62^{a}	114.64^{bc}	103.26^{defgh}	107.52^{abc}	2.44	2.72	2.41	2.02^{bcd}	1.79
3.50	3500	108.33^{c}	102.02^{ef}	113.44^{cd}	105.86^{b}	107.41^{abc}	2.65	2.34	2.48	2.04^{bcd}	2.38
	4000	102.14^{fg}	108.33^{b}	115.24^{b}	102.66^{gh}	107.09^{bc}	2.30	2.47	2.68	1.91^{cd}	2.34
	2500	104.05^{de}	106.43^{c}	109.79^{e}	108.13^{a}	107.09^{bc}	2.68	2.68	2.55	1.92^{cd}	2.46
	3000	112.62^{a}	100.29^{g}	113.79^{bcd}	103.06^{efgh}	107.43^{abc}	2.47	2.13	2.57	2.19^{ab}	2.34
3.75	3500	101.67^{gh}	108.49^{b}	115.36^{ab}	103.26^{defgh}	107.19^{bc}	2.26	2.26	2.40	2.32^{a}	2.31
	4000	110.48^{b}	100.48^{fg}	114.76^{bc}	103.06^{efgh}	107.19^{bc}	2.47	2.11	2.62	2.32^{a}	2.38
	2500	111.07^{b}	104.30^{d}	112.54^{d}	104.86^{bcd}	108.19^{a}	2.92	2.06	2.42	1.89^{cd}	2.32
4.00	3000	99.40^{i}	108.29^{b}	114.76^{bc}	104.46^{bcdef}	106.73^{c}	2.42	2.47	2.39	1.80^{d}	2.27
	3500	103.33^{ef}	109.17^{b}	113.21^{cd}	104.26^{bcdefg}	107.49^{abc}	2.58	2.40	2.51	1.92^{cd}	2.35
	4000	100.48^{hi}	112.14^{a}	113.10^{cd}	104.86^{bcd}	107.64^{abc}	2.31	2.25	2.50	1.79^{d}	2.21
SEM		0.4769	0.5779	0.5037	0.5326	0.2719	0.2516	0.1610	0.1173	0.0793	0.1005
P-value		<0.0001	<0.0001	<0.0001	<0.0001	0.0057	0.9477	0.620	0.8211	0.0381	0.0821

a,b,c Means with different superscripts in same columns for each criterion are significantly different ($P < 0.05$).

SEM : Standard error mean

Table6. Egg quality measurements of laying hens as affected by Ca, vitamin D_3 levels and their interaction.

Main effects: Ca%	D_3 IU/kg diet	Egg wt.(g)	Albumen wt.(%)	Yolk wt.(%)	Shell wt.(%)	Shape index	Yolk index	Haugh unit
3.25		65.80	64.10	23.91	11.98	76.83	49.36	90.29
3.50		66.52	63.62	24.16	12.26	77.22	49.22	90.46
3.75		65.09	63.36	24.17	12.45	78.24	49.08	90.12
4.00		68.17	63.04	24.21	12.46	77.49	49.70	90.91
SEM		0.9548	0.5049	0.4475	0.2167	0.7353	0.8250	0.2311
P-value		0.1405	0.5113	0.9627	0.3660	0.5849	0.9571	0.1052
	2500	64.99	63.83	24.02	12.13	77.03	48.80	90.09
	3000	67.51	63.46	24.18	12.26	77.36	49.70	90.73
	3500	66.57	63.34	24.13	12.3	77.51	49.13	90.51
	4000	66.48	63.48	24.12	12.42	77.88	49.73	90.43
SEM		0.9548	0.5049	0.4475	0.2167	0.7353	0.8250	0.2311
P-value		0.3219	0.9122	0.9959	0.8133	0.8766	0.8248	0.2888
Treatments :								
Ca%	D_3 IU/kg diet							
	2500	62.27	64.57	23.66	11.76	77.23	49.08	89.40
	3000	69.02	63.99	24.04	11.95	76.97	49.91	91.08
3.25	3500	67.10	63.96	23.99	12.04	75.38	48.95	90.62
	4000	64.80	63.87	23.94	12.18	77.73	49.49	90.04
	2500	67.10	63.82	24.03	12.14	75.88	48.03	90.60
	3000	66.25	63.71	24.04	12.24	77.78	49.55	90.41
3.50	3500	65.95	63.34	24.38	12.26	78.01	49.65	90.34
	4000	66.77	63.58	24.19	12.37	77.21	49.68	90.49
	2500	65.25	63.65	24.01	12.33	77.63	48.73	90.18
	3000	64.97	63.10	24.44	12.45	78.49	49.41	90.09
3.75	3500	65.45	63.34	24.16	12.48	79.04	48.25	90.21
	4000	64.67	63.35	24.08	12.56	77.79	49.94	89.99
	2500	65.35	63.29	24.39	12.31	77.37	49.38	90.20
4.00	3000	69.82	63.03	24.18	12.42	76.22	49.95	91.32
	3500	67.80	62.72	23.98	12.53	77.61	49.67	90.89
	4000	69.70	63.12	24.29	12.59	78.77	49.82	91.22
SEM		1.9096	1.0098	0.8950	0.4335	1.4706	1.6500	0.4622
P-value		0.6049	1.000	1.000	1.000	0.8969	0.9998	0.5887

No significant differences were observed among treatments in all criteria.
SEM = Standard error mean

Table 7. Egg shell quality measurements of laying hens as affected by Ca, vitamin D_3 levels and their interaction

Main effects: Ca%	D_3IU/kg diet	Shell wt.	ESA(cm²)	SWUSA (mg/ cm²)	ESV(cm³)	Shell thickness (μm)
3.25		7.87[b]	61.29	128.75	24.57	0.4006
3.50		8.13[b]	61.00	133.63	24.17	0.3968
3.75		8.08[b]	60.91	133.10	24.32	0.4023
4.00		8.51[a]	62.97	135.52	25.41	0.4034
SEM		0.1206	0.7283	2.2451	0.4492	0.0072
P-value		0.0046	0.1625	0.1921	0.2192	0.9239
	2500	7.87	60.70	129.97	23.68	0.3900
	3000	8.28	62.24	133.32	24.66	0.3995
	3500	8.21	61.54	133.90	24.91	0.4046
	4000	8.23	61.69	133.81	25.22	0.4089
SEM		0.1206	0.7283	2.2451	0.4492	0.0072
P-value		0.0838	0.5191	0.5601	0.0990	0.2953
Treatments:						
Ca%	D_3IU/kg diet					
	2500	7.29	58.52	124.73	22.70	0.3880
	3000	8.25	64.07	128.88	25.41	0.3967
3.25	3500	8.05	61.86	131.35	25.22	0.4072
	4000	7.88	60.71	130.03	24.96	0.4105
	2500	8.13	60.61	134.32	23.40	0.3860
	3000	8.10	60.96	133.71	23.93	0.3937
3.50	3500	8.07	60.85	132.55	24.50	0.4030
	4000	8.24	61.56	133.96	24.85	0.4047
	2500	8.05	60.30	133.91	23.89	0.3960
	3000	8.05	61.19	131.75	23.89	0.4025
3.75	3500	8.15	61.59	132.82	24.83	0.4032
	4000	8.07	60.56	133.94	24.67	0.4075
	2500	8.03	63.37	126.94	24.75	0.3902
4.00	3000	8.70	62.75	138.93	25.42	0.4052
	3500	8.57	61.85	138.87	25.07	0.4052
	4000	8.75	63.92	137.32	26.39	0.4130
SEM		0.2412	1.45676	4.4903	0.8985	0.0144
P-value		0.5576	0.6273	0.8816	0.9225	1.000

[a,b] Means with different superscripts in same columns for each criterion are significantly different ($P \leq 0.05$). SEM = Standard error mean

Table 8. Plasma blood constituents and mineral content of egg shell of laying hens as affected by Ca, vitamin D_3 levels and their interaction.

Main effects :		AST,U/dl	ALT,U/dl	Total protein,g/dl	Albumine ,g/dl	Globuline ,g/dl	Triglycerides mg/dl	Lipids g/dl	Ca mg/dl	P mg/dl	Mineral content of egg shell	
Ca%	D_3 IU/kg diet										Ca, mg/g	P,mg/g
3.25		24.58	10.65	5.64	1.84	3.80	425.86	3.72	18.73	6.58	405.24[b]	1.38
3.50		24.16	10.91	5.45	1.85	3.60	452.71	3.88	19.75	6.17	409.40[ab]	1.37
3.75		24.16	11.72	5.44	1.87	3.56	420.34	3.63	19.92	6.15	416.01[a]	1.35
4.00		24.66	11.33	5.60	1.95	3.65	415.98	3.73	19.18	6.25	418.41[a]	1.33
SEM		0.5921	0.5288	0.1693	0.1316	0.2081	13.3650	0.1260	0.3782	0.1873	3.4313	0.0145
P-value		0.8936	0.5115	0.7689	0.9373	0.8650	0.2273	0.5582	0.8621	0.3441	0.0407	0.2367
	2500	23.66	10.47	5.56	1.85	3.71	418.05	3.68	17.17[b]	6.43	351.47[d]	1.37
	3000	24.41	11.75	5.65	1.86	3.79	433.63	3.71	19.17[a]	6.06	406.80[c]	1.36
	3500	24.66	11.24	5.55	1.91	3.64	435.36	3.82	19.44[a]	6.39	431.67[b]	1.36
	4000	24.83	11.166	5.39	1.92	3.47	427.85	3.75	19.74[a]	6.27	459.11[a]	1.35
SEM		0.5921	0.5288	0.1693	0.1316	0.2081	13.3650	0.1260	0.3782	0.1873	3.4313	0.0145
P-value		0.5263	0.4117	0.7482	0.9758	0.7352	0.7957	0.8799	0.0001	0.5108	<.0001	0.8731

Table 8. (Cont.)

		Treatments :										
Ca%	D_3IU/kg diet											
	2500	23.00	8.00	5.69	1.85	3.83	386.19	3.64	1680	6.81	338.02^{f}	1.39
	3000	25.00	12.00	5.59	1.80	3.78	440.74	3.68	19.06	6.06	410.94^{d}	1.36
3.25	3500	25.66	11.96	5.64	1.84	3.80	448.83	3.92	19.40	6.71	420.66^{cd}	1.38
	4000	24.66	10.66	5.66	1.88	3.77	427.70	3.63	19.66	6.75	451.35^{ab}	1.37
	2500	24.33	10.66	5.58	1.80	3.78	454.66	3.74	16.84	6.63	375.65^{e}	1.37
	3000	23.66	11.66	5.76	1.88	3.87	464.29	3.95	19.14	5.90	385.99^{e}	1.38
3.50	3500	24.00	10.66	5.31	1.9	3.40	449.29	3.94	19.30	6.15	415.86^{d}	1.36
	4000	24.66	10.66	5.16	1.82	3.34	442.61	3.91	19.71	6.01	460.10^{ab}	1.35
	2500	24.00	11.89	5.17	1.75	3.41	427.96	3.57	17.35	6.23	338.53^{f}	1.35
	3000	24.33	11.66	5.39	1.77	3.62	414.63	3.68	19.22	6.26	411.11^{d}	1.36
3.75	3500	24.00	12.00	5.97	2.06	3.90	421.70	3.69	19.39	5.95	450.89^{ab}	1.35
	4000	24.33	11.33	5.24	1.91	3.32	417.06	3.58	19.72	6.15	463.61^{a}	1.34
	2500	23.3	11.33	5.79	1.97	3.81	403.39	3.77	17.71	6.06	353.67^{f}	1.34
4.00	3000	24.66	11.66	5.86	1.96	3.90	414.85	3.53	19.28	6.03	419.18^{cd}	1.33
	3500	25.00	10.33	5.27	1.81	3.46	421.64	3.72	19.68	6.76	439.29^{bc}	1.34
	4000	25.66	12.00	5.50	2.05	3.45	424.05	3.89	19.86	6.17	461.49^{a}	1.33
SEM		1.1843	1.0577	0.3386	0.2633	0.4163	26.7300	0.2521	0.7565	0.3746	6.8627	0.0290
P-value		0.9565	0.4779	0.7218	0.9980	0.9879	0.9531	0.9896	0.9999	0.7921	0.0005	0.9996

^{a,b,c} Means with different superscripts in same columns for each criterion are significantly different ($P \leq 0.05$).

SEM = Standard error mean

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الملخص العربي

تأثير مستوى الكالسيوم وفيتامين د٣ فى العليقة على إنتاج البيض وجودة القشرة للدجاج البياض هاى لاين البنى

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أجريت هذه الدراسة لبحث تأثير المستويات المختلفة من الكالسيوم و فيتامين د٣ فى العليقة على أنتاج البيض وجودة القشرة للدجاج البياض. أستخدم في هذه التجربة عدد ٢٤٠ دجاجة هاى لاين البنى عمر ٢٤ أسبوع وزعت على ١٦ مجموعة تجريبية بمعدل ١٥ دجاجة لكل معاملة مقسمة على خمس مكررات بكل مكررة ثلاث دجاجات. أجريت التجربة فى تصميم إحصائى متداخل ٤ X ٤ بإستخدام أربع مستويات كالسيوم (٣,٢٥، ٣,٥، ٣,٧٥، ٤ %) وأربع مستويات فيتامين د٣ (٢٥٠٠،٣٠٠،٣٥٠٠،٤٠٠٠ وحدة دولية فيتامين د٣/كجم عليقه).أشارت النتائج إلى :

١ - زيادة مستوى الكالسيوم حتى ٤% أعطى أعلى قيم غير معنوية لإنتاج البيض، وزن البيض و كتلة وزن البيض خلال الفترة الكلية للبحث. بينما أعطى أعلى قيمة معنوية لإنتاج البيض وكتلة وزن البيض(٨٦,٧٣ %و٥٦,٦٩جم) على التوالى خلال الفترة من ٣٦ الى ٤٠ أسبوع. من ناحية أخرى سجل الدجاج المغذى على عليقة محتوية على فيتامين د٣ بمعدل ٣٠٠٠ أو ٢٥٠٠

وحدة دولية /كجم علف أعلى قيمة معنوية لإنتاج البيض (٧٦,٥٥ ، ٨٤,٦١ %) خلال الفترة من ٣٢ ألى ٣٦ أسبوع ، ٣٦ الى ٤٠ أسبوع على التوالى. أضافة الى ذلك الدجاج المغذى على ٤% كالسيوم مع ٤٠٠٠ وحدة دولية فيتامين د٣ أظهرت أعلى قيمة معنوية لكتلة وزن البيض(٥٨,٦٠ جم) خلال الفترة من ٣٦ الى ٤٠ أسبوع.

٢ – سجل الدجاج المغذى على عليقة محتوية على (٣,٧٥ ، ٤ ، ٣,٥ ، ٤ %) كالسيوم أعلى قيمة معنوية للغذاء المستهلك خلال الفترة من ٢٤ الى ٢٨ ، ٢٨ الى ٣٢ ، ٣٢ الى ٣٦ و٣٦ الى ٤٠ أسبوع مقارنة مع ٣,٢٥ % كالسيوم لعليقة الكنترول ، وكان للتداخل بين الكالسيوم وفيتامين د٣ تأثيرا معنويا على الغذاء المستهلك خلال الفترات المختلفة للبحث والفترة الكلية.

٣ – لم يتأثر معامل التحويل الغذائى معنويا بمستوى الكالسيوم خلال الفترات المختلفة للبحث والفترة الكلية، ماعدا الدجاج المغذى على ٤% كالسيوم حيث أظهر أحسن قيمه معنوية لمعامل التحويل الغذائى (١,٨٥ جم/جم بيض) مقارنة مع باقى المستويات خلال الفترة من ٣٦ الى ٤٠ أسبوع. لم يتأثر أيضا معامل التحويل الغذائى معنويا بمستوى فيتامين د٣ خلال الفترات المختلفة للبحث ، بينما أظهر الدجاج المغذى على ٣٠٠٠ وحدة دولية فيتامين د٣ خلال الفترة الكلية للبحث أحسن قيمة معنوية لمعامل التحويل الغذائى (٢,١٥ جم/جم بيض) مقارنة مع المستويات الأخرى وكان للتداخل بين الكالسيوم وفيتامين د٣ تأثيرا معنويا على معامل التحويل الغذائى خلال الفترة من ٣٦ الى ٤٠ أسبوع. حيث سجل الدجاج المغذى على ٤% كالسيوم مع ٤٠٠٠ وحدة دولية فيتامين د٣ أحسن قيمة لمعامل التحويل الغذائى (١,٧٩ جم/جم بيض).

٤ – سجل الدجاج المغذى على عليقة محتوية على ٤% كالسيوم أحسن قيمة لوزن القشره (٨,٥١ جم) مقارنة مع المجاميع الأخرى ، وبزيادة كالسيوم العليقة الى مستوى ٤% مع ٤٠٠٠ وحدة دولية فيتامين د٣ سجل الدجاج أعلى قيمة غير معنوية لمساحة القشرة ، حجم القشرة وسمك القشرة مقارنة مع المجاميع الأخرى.

٥ – سجل الدجاج المغذى على عليقة محتوية على ٣٠٠٠ ، ٣٥٠٠ ، ٤٠٠٠ وحدة دولية فيتامين د٣ أعلى قيمة لتركيز الكالسيوم فى بلازما الدم مقارنة مع مجموعة الكنترول.

٦ - سجل الدجاج المغذى على عليقة محتوية على ٤% ، ٣,٧٥ % و٣,٥ % كالسيوم أعلى قيمة معنوية لتركيز الكالسيوم فى قشرة البيض مقارنة بمجموعة الكنترول ، وبزيادة فيتامين د٣ الى مستوى ٤٠٠٠ وحدة دولية سجل الدجاج أحسن قيمة معنوية لتركيز الكالسيوم فى قشرة البيضة (٤٥٩,١١ ملجم/جم قشرة) مقارنة مع المجاميع الأخرى ، وكان للتداخل بين الكالسيوم وفيتامين د٣ تأثيرا معنويا على تركيز كالسيوم قشرة البيضةحيث سجل الدجاج المغذى على أى من مستويات الكالسيوم المستخدمة فى الدراسة مع ٤٠٠٠ وحدة دولية/ كجم علف أحسن قيمة معنوية لتركيز كالسيوم قشرة البيضة.

تشير النتائج الى أن زيادة مستوى الكالسيوم الى ٤% مع إستخدام فيتامين د٣ بمستوى ٤٠٠٠ وحدة دولية/ كجم علف حسن من جودة قشرة البيضة دون تأثير سلبى على الأداء الإنتاجى للدجاج البياض هاى لاين البنى .