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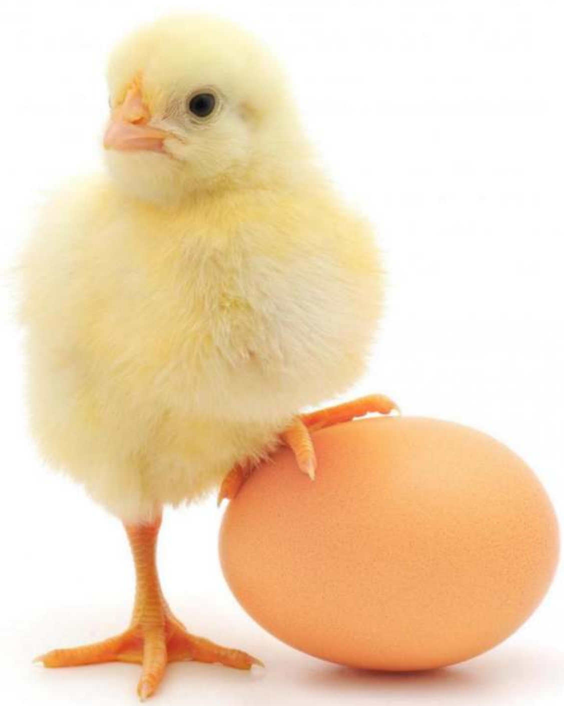

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Effect of Dietary Zinc and Niacin on Laying Hens Performance and Egg Quality

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Abstract: The experiment was designed to evaluate the effect of supplemented zinc (Zn) and niacin (Nia.) on laying hen performance, egg quality, nutrient digestabilities and relative economical efficiency (EEf) from 28-43 weeks of age. Bovans White Laying hens fed diets supplemented with four different levels of Zn (70,105,140 and 175 mg/kg diet) in combination with four different levels of Nia. (30,150,300,450 mg/kg diet) in a factorial arrangement design. The diets which contained on 70 mg Zn/kg and 30 mg Nia/kg considered as a control. The results indicated that supplemented Zn and Niacin (Nia.) increased the egg production significantly ($p \leq 0.05$) compared with the control group. The best feed conversion ratio (FCR) was observed when diet supplemented with Zn and Nia. at 175 and 30 or 175 and 450 mg/kg, respectively. Egg weight (EW) did not improve by supplementing Zn and Nia. Supplemented Zn at 105 mg/kg recorded the best serum total immunoglobulin titres (STIT), While, supplemented Nia. at 300 mg/kg gave the best STIT. Supplemented Zn and Nia. had significant effect on egg shell thickness (EST), blood hemoglobin (BH) and nutrient digestabilities especially improving crude protein digestibility linearly parallel with dietary Zn levels increased. Supplemented Zn at level of 105 mg/kg with 30 mg Nia/kg or 175 mg Zn/kg with 30 or 450 mg Nia/kg gave the highest economical efficiency. Feeding laying hen on diet containing 105 mg Zn and 30 mg Nia/kg resulted in the best performance, egg quality and economical efficiency.

Key words: Zinc, niacin, laying hens, egg quality

Introduction

Loss from cracked egg is a major problem on the egg industry worldwide. Economic losses because of poor shell quality around the world are estimated at proximately 500 million dollar per year (Etches, 1996). About 10% of all eggs produced are cracked or broken between oviposition and retail sale (Zeidler, 2001). The egg shell is an important structure for two reasons. First, it forms an embryonic chamber for the developing chick, providing mechanical protection and controlled gas exchange medium. Second, it is a container for the market egg, providing protection of the contents and a unique package for a valuable food (Hunton, 2005). It is widely acknowledge that egg shell quality is affected by many factors such as the laying strain, age, nutrition, disease and general stress (Roberts, 2004). Therefore, nutrition considered as the important elements that effect on egg shell quality especially minerals and vitamins (Nys, 2001). Zinc play an important role in metabolic activities such as protein synthesis and carbohydrates metabolism (Underwood and Suttle, 1999). Zinc is an essential component of many enzymes such as carbonic anhydrase which supplies the carbonic ions during egg shell formation (Innocenti *et al*., 2004). Inhibitor of this enzyme results in lowered bicarbonate ion secretion and an increase in shell less egg production (Nys *et al* .,1999). And alkaline phosphatase which helps build bone (Zhong *et al*., 2001). Zn required for growth, bone development, feathering, reproductive, normal immune function and appetite (Batal *et al*., 2001).

Niacin is essentially used in metabolism through coenzyme formation NAD and NADP (Flachowsky, 1993). These coenzymes are involved in transfers of hydrogen, which frequently occur in the synthesis and degradation of fatty acids, carbohydrates and amino acids. Feedstuffs as cereal grain and their by products contain niacin but much of the ingested niacin is in a form unavailable to the animal (Mcdowell, 1989). Niacin deficiency results in poor utilization of calcium and phosphorus which are required for normal bone formation and egg production (Leeson *et al*., 1979). Supplementation of niacin to diets of layer led to improvement in egg production, egg quality, feed intake and feed conversion (Gungor *et al*., 2003 and Kurtoglu *et al*., 2004). Zinc and niacin are involved in homocysteine metabolism (Fig. 1) (Ziad, 2003; Anna *et al*., 2007).
The objective of this study was to evaluate the effect of different levels of zinc and niacin supplementation on performance of laying hens and egg quality.

Materials and Methods

Experimental birds and management: A total of 1536, 28 weeks old, Bovans White laying hens was used. Hens were randomly divided into 16 groups of 96 hens each with four replicates of 24 hens each. Hens were kept in cleaned and famigented cages of wire floored batteries in closed system house. Feed and water were offered *ad-libitum* all over the experimental period (16 weeks) from 28-43 weeks of age, with a total of 16 h light per day regimen.

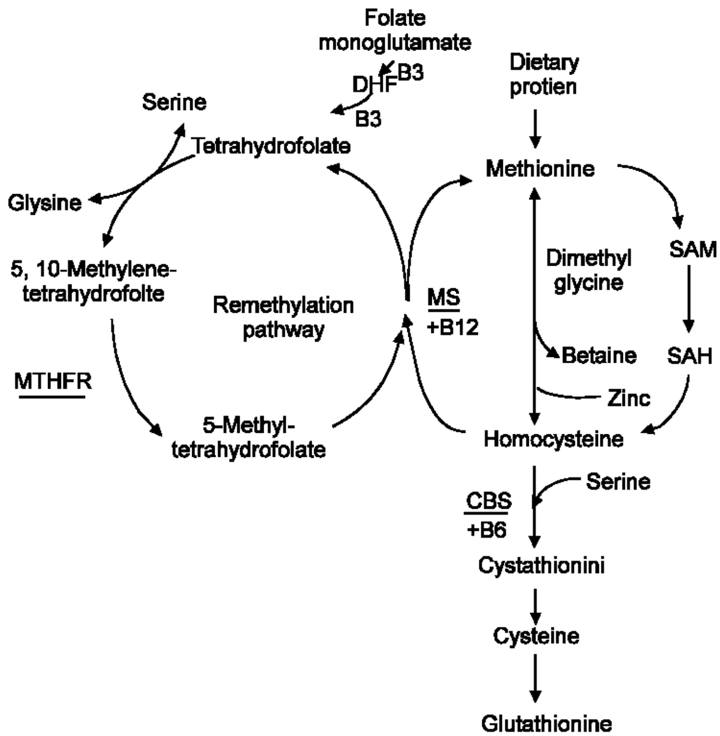

Fig. 1: Homocysteine metabolism (Ziad, 2003; Anna *et al*., 2007)

Table 1: Experimental design

Treatment	Zinc	Niacin	Treatment	Zinc	Niacin
T1	70 mg/kg diet	30 mg/kg diet	T9	140 mg/kg diet	30 mg/kg diet
T2	70 mg/kg diet	150 mg/kg diet	T10	140 mg/kg diet	150 mg/kg diet
T3	70 mg/kg diet	300 mg/kg diet	T11	140 mg/kg diet	300 mg/kg diet
T4	70 mg/kg diet	450 mg/kg diet	T12	140 mg/kg diet	450 mg/kg diet
T5	105 mg/kg diet	30 mg/kg diet	T13	175 mg/kg diet	30 mg/kg diet
T6	105 mg/kg diet	150 mg/kg diet	T14	175 mg/kg diet	150 mg/kg diet
T7	105 mg/kg diet	300 mg/kg diet	T15	175 mg/kg diet	300 mg/kg diet
T8	105 mg/kg diet	450 mg/kg diet	T16	175 mg/kg diet	450 mg/kg diet

Experimental design: The experiment design (Table 1) was conducted in a 4 x 4 factorial design. Four levels of Zinc oxide 72% (70, 105,140 and 175 mg/kg) and four levels of Nicotinic acid 99% (30, 150,300 and 450 mg/kg) were added to the basal diet that contained 9.1 mg Zn/kg and 5.0 mg niacin /kg.

Experimental diets: The basal diet and its chemical composition are presented in Table 2. Sixteen experimental diets were formulated using linear programing to be isocaloric (2788 al ME/kg) and isonitrogenous (18.59CP). The experimental diets were formulated to meet the nutrient requirements according to the recommended allowances of the Bovans White laying hens manual, where 70 mg Zn/kg and 30 mg nicin/kg which are considered as a control diet.

Measurements: All birds of each treatments were weighed at the beginning (initial live body weight, which was almost the same weight indicating the accurate randomization process of experimental birds) and at the end of experimental period (final live body weight) to calculate live body weight gain (LBWG). The daily feed intake per hen and hen-day egg production percentage (EP%) were calculated every four weeks intervals during the experimental period (16 weeks). Eggs were collected and weighed every four weeks. During the experimental periods records of EP and egg weight (EW) were used to calculate egg mass (EM) (g/hen/day), EM and feed intake (FI) were used to calculate the amount of feed (kg) which was required to produce one kg of eggs per hen or to calculate feed conversion ratio (FCR) during specific period.
Sell thickness (ST) was determined using a dial pipe gauge. Serum total immunoglobulin tetres (STIT) were determined according to Van der Zipp *et al*., (1983).Blood haemoglobin was measured according to Henry *et al*. (1974). Economic efficiency (Eef) of egg

Table 2: Composition of the experimental basal diet

Ingredients	(%)
Yellow corn	63.05
Soybean meal	18.50
Concentrate*	10.00
Limestone	7.50
Bone meal	0.50
Vit. and min. Premix **	0.10
Salt (NaCl)	0.25
DL-methionine,99%	0.10
Total	100.00
Calculated analysis* **	
ME (kcal/kg)	2788
CP (%)	18.59
Ether extract	3.07
Crude fiber	2.81
Methionine (%)	0.46
Lysine (%)	1.01
Calcium	3.64
Available phosphorus	0.47
Zinc mg/kg	9.10
Niacin mg/kg	5.00

*Concentrate composition: 50%Crude protein, 2554 Kcal Me/Kg, 1.26%Crude fiber, 5.29% Ether extract, 6.16% Calcium, 2.8% Phosphorus, 3.47% Lysine, 1.36% Methionine, Zinc 600 mg, Niacin 400 mg.

**Each one kg of vitamin and mineral mixture containing: Vit. A 4,000,000 I .U , vit.. D3 1,166,667 I.U, vit. E 6,667 mg, vit. K3 1,000 mg, vit B1 1,000 mg, vit B2 2,667 mg, vit. B6 1,000 mg, vit. B12 5 mg, calcium d. pantothenate 4,000 mg, niacin 13,333 mg, folic acid 500 mg, biotin 16.7 mg, manganese 26.7 gm, zinc 25 gm, iron 13.333 gm, copper 3.33 gm, iodine 0.66 gm, selenium 0.1 gm, cobalt 0.083 gm, choline chloride 200 gm and carrier ($CaCO_3$) to 1 kg.

***According to N.R.C. (1994)

production was calculated from the input-output analysis which was calculated according to the price of the experimental diets and egg produced during the entire experimental period. The values of economical efficiency were calculated as the net revenue per unit of feed cost. At the end of the experimental period, 43 weeks of age, a total number of 192 hens, 12 from each treatment were randomly taken for digestion trials to estimate the nutrient digestibility. Proximate analysis of the feed and dried excreta was done following the methods of A.O.A.C. (1990). Fecal nitrogen was determined according to Jakobsen *et al.* (1960).

Statistical analysis: The data pooled through the experiment were proceed by General Linear Model procedures (GLM) described in SAS User's Guide (SAS, Institute, 2004). The model for the design is:

$$Y_{ijl} = \mu + E_i + M_j + (EM)_{ij} + e_{ijl}$$

where,

Y_{ij} Is the observation of the parameter measured.
μ Is the overall mean, E_{iis} the zinc levels effect.
M_j Is the niacin levels effect.
$(EM)_{ij}$ Is the interaction between zinc and niacin.
e_{ijl} Is the random error term.

Differences among treatment means were separated by Duncan's new multiple-range test (Duncan, 1955).

Results and Discussion

Laying hen performance

Body weight gain: The live body weight gain of different experimental treatments are listed in Table 3. Significant differences of body weight gain (BWG) were observed for hens fed the different dietary Zn and Nia. levels. Interactions between Zn x Nia. on BWG were significant (P= 0.05). Hens fed diets containing 70 mg Zn and 450 mg Nia/kg (T_4) or 105 mg Zn and 30 mg Nia/kg (T_5) recorded the highest BWG ,while the lowest BWG was recorded for hens which fed the diets containing 140 mg Zn and 450 mg Nia/kg (T_{12}). Mohanna and Nys (1999) and Burrell *et al.* (2004) observed that supplemented Zn lead to increase BWG values. Gungor *et al.* (2003) reported that adding Nia to laying hen diets resulted in an increase in BWG. However, Sulekaya *et al.* (2001) noticed that supplemented Zn up to 200 mg/kg had no effect on BWG values.

Egg production: The effect of experimental treatments on egg production (EP) is presented in Table 3. EP increased with supplementing Zn but these increase not significant except at level of 175 mg/kg diet was significant ($p \leq 0.05$). The effect of niacin levels showed no significant differences in EP were observed. The differences in EP were significant ($p \leq 0.05$) due to Zn × Nia. interactions. Adding Zn and Nia. in the diet increased EP, being the highest EP for group fed diet containing 105 mg Zn/kg diet and 30 mg Nia/kg diet (T_5) Durmus *et al.* (2004), Gungor *et al.* (2003) and Kurtoglu *et al.* (2004). The least EP was obtained for T_1 which containing 70 mg Zn/kg diet and 30 mg Nia/kg diet .The significant increase in EP may be due to the important role of Zn in the synthesis and secretion of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) (Bedwal and Bahuguna., 1994) and the vital role of Nia. in utilization of calcium and phosphorus that laying hen require to produce optimum level of eggs (Leeson *et al.*, 1979).

Egg weight: The effect of dietary Zn and Nia.levels on egg weight was illustrated in Table 3. The different levels of Zn 70,105,140 and 175 mg/kg diet had no significant ($p \leq 0.05$) effect on egg weight (EW). No significant differences in EW due to Nia. supplementation up to 450 mg/kg. The interactions between Zn × Nia on EW was not significant compared with the control (T_1) except T_{15} recorded the least. These results agreed with Kim and patterson (2005) who found that supplemented Zn and Nia. to basal diet had no significant effect on EW.

Feed intake and conversion: The influence of Zn and Nia. levels in the diets on the amount of feed intake and conversion are tabulated in Table 3. Feeding laying hen diets supplemented with Zn upto 175 mg/kg

Table 3: Effect of experimental treatments on performance, eggshell quality, hemoglobin, immunoglobulin titre and economic efficiency

Experimental treatments	Body weight gain (g)	Egg production (H.D %)	Egg weight (g)	Feed intake (g/hen/d)	Feed conversion (g feed/g egg)	Egg shell thickness (mm)	Egg shell Percent (%)	Hemo-globin (g/dl)	Immuno-globulin titre	Relative economic efficiency
Main effect of Zn:										
70 mg/kg (Zn_1)	100.25^{a}	88.61^{b}	58.86	108.4^{a}	2.08^{a}	0.400^{a}	10.18^{ab}	20.96^{c}	6.75^{b}	97
105 mg/kg (Zn_2)	90.50^{b}	88.98^{ab}	58.98	108.2^{a}	2.06^{a}	0.404^{a}	10.39^{a}	22.34^{b}	7.00^{a}	98
140 mg/kg (Zn_3)	74.00^{d}	88.76^{b}	58.94	108.8^{a}	2.07^{a}	0.387^{b}	9.78^{c}	22.07^{b}	5.75^{c}	96
175 mg/kg (Zn_4)	87.00^{c}	89.72^{a}	58.87	106.6^{b}	2.02^{b}	0.388^{b}	10.03^{bc}	24.55^{a}	5.75^{c}	103
P value	<0.0001	0.03	0.67	<0.0001	<0.0001	<.0001	0.002	<0.0001	<0.0001	
Main effect of Nia:										
30 mg/kg. (Nia_1)	96.25^{a}	89.08^{ab}	59.08	106.9^{c}	2.03^{c}	0.385^{b}	9.75^{b}	20.59^{d}	5.75^{d}	102
150 mg/kg. (Nia_2)	89.50^{b}	88.88^{ab}	58.95	107.7^{b}	2.05^{b}	0.398^{a}	10.12^{a}	21.32^{c}	6.25^{b}	99
300 mg/kg (Nia_3)	85.00^{c}	88.49^{b}	58.81	108.5^{a}	2.09^{a}	0.399^{a}	10.25^{a}	23.26^{b}	7.25^{a}	97
450 mg/kg. (Nia_4)	81.00^{d}	89.61^{a}	58.81	108.9^{a}	2.07^{ab}	0.396^{a}	10.27^{a}	24.78^{a}	6.00^{c}	98
p-value	<0.0001	0.05	0.08	<0.0001	0.0002	0.004	0.005	<0.0001	<.0001	
Zn. × Nia effect:										
T1 (Zn_1) + (Nia_1)	98.00^{c}	86.96^{e}	58.89^{abc}	105.28^{g}	2.06^{ab}	0.377^{e}	9.59	20.19^{ef}	6.00^{c}	100
T2 (Zn_1) + (Nia_2)	98.00^{c}	88.47^{cde}	59.08^{ab}	107.58^{cde}	2.06^{ab}	0.408^{ab}	10.20	18.76^{g}	6.00^{c}	97
T3 (Zn_1) + (Nia_3)	100.00^{b}	88.68^{bcde}	59.04^{ab}	110.41^{a}	2.11^{a}	0.413^{a}	10.65	23.17^{c}	7.00^{b}	93
T4 (Zn_1) + (Nia_4)	105.00^{a}	90.32^{abc}	58.42^{cd}	110.34^{a}	2.09^{ab}	0.403^{abc}	10.31	21.88^{cd}	8.00^{a}	98
T5 (Zn_2) + (Nia_1)	105.00^{a}	90.57^{a}	59.02^{ab}	106.95^{def}	2.00^{cd}	0.400^{abcd}	10.16	14.01^{h}	7.00^{b}	105
T6 (Zn_2) + (Nia_2)	97.00^{c}	89.15^{abcd}	58.81^{abc}	107.45^{cdef}	2.05^{bc}	0.403^{abc}	10.17	24.97^{b}	8.00^{a}	101
T7 (Zn_2) + (Nia_3)	85.00^{e}	87.86^{de}	59.03^{ab}	108.43^{bc}	2.09^{ab}	0.403^{abc}	10.34	22.44^{cd}	8.00^{a}	95
T8 (Zn_2) + (Nia_4)	75.00^{g}	88.35^{cde}	59.07^{ab}	110.26^{a}	2.11^{a}	0.410^{a}	10.89	27.95a	5.00^{d}	92
T9 (Zn_3) + (Nia_1)	82.00^{f}	88.87^{abcd}	59.10^{ab}	109.09^{ab}	2.08^{ab}	0.388^{cde}	9.62	26.85^{a}	5.00^{d}	96
T10 (Zn_3) + (Nia_2)	75.00^{g}	88.90^{abcd}	59.19^{a}	109.11^{ab}	2.07^{ab}	0.395^{abcde}	9.87	20.23^{ef}	6.00^{c}	96
T11 (Zn_3) + (Nia_3)	70.00^{h}	88.02^{de}	58.94^{abc}	108.29^{bcd}	2.09^{ab}	0.383^{de}	9.68	19.49^{fg}	6.00^{c}	96
T12 (Zn_3) + (Nia_4)	69.00^{h}	89.25^{abcd}	58.56^{bcd}	108.57^{bc}	2.08^{ab}	0.383^{de}	9.94	21.70^{d}	6.00^{c}	97
T13 (Zn_4) + (Nia_1)	100.00^{b}	89.93^{abc}	59.30^{a}	106.12^{fg}	1.99^{d}	0.378^{e}	9.65	21.33^{de}	7.00^{b}	105
T14 (Zn_4) + (Nia_2)	88.00^{d}	89.02^{abcd}	58.74^{abcd}	106.80^{ef}	2.04^{bc}	0.385^{cde}	10.24	21.33^{de}	7.00^{b}	101
T15 (Zn_4) + (Nia_3)	85.00^{e}	89.39^{abcd}	58.24^{d}	106.99^{def}	2.06^{ab}	0.400^{abcd}	10.31	27.95^{a}	8.00^{a}	102
T16 (Zn_4) + (Nia_4)	75.00^{g}	90.52^{ab}	59.19^{a}	106.59^{efg}	1.99^{d}	0.390^{bcde}	9.94	27.59^{a}	5.00^{d}	105
p-value	<0.0001	0.003	0.0007	<0.0001	0.01	0.02	0.19	<0.0001	<0.0001	

a, b, c,…. etc. means in same column, within each factor with different superscripts are significantly ($P \leq 0.05$) different

significantly decreased in feed intake (FI) with a significant effect in FI due to increasing Nia. Levels in laying hen diets. Interactions between Zn x Nia showed significant ($p \leq 0.05$) effect on feed intake, may be due to a role of Zn and Nia. in synthesis serotonin hormone which involves control of appetite (Curzon, 1990). Birds of T_1(control diet) consumed the lowest feed intake, while T_3, T_4 and T_8 consumed the highest. Besides, there were significant ($p \leq 0.05$) differences in FI between control treatment and the other treatments. The authors had different vision view for the effect of Zn and Nia. levels in the diet on the amount of feed consumed, Mohanna and Nys (1999) observed that supplemented Zn resulted in significant increase in FI. Kim and patterson (2005) reported that added Zn had no significant effect on FI. Gungor *et al*. (2003) and Kurtoglu *et al*. (2004) noticed that supplemented Nia. to laying hen diets did not affect the amount of feed consumed significantly. No significant effect on feed conversion ratio (FCR) due to dietary Zn levels except at level of 175 mg/kg, which improved FCR. While, different levels of Nia. improved FCR. There were significant differences in Zn × Nia. interactions. The best FCR value was recorded for T_{13} and T_{16} while, T_3 and T_8 recorded the worst FCR. These resulted supported by Durmus *et al*. (2004) who found that supplemented Zn to basal diet up to 120 mg/kg lead to improve FCR. Gungor *et al*. (2003) and Kurtoglu *et al*. (2004) noticed that supplemented Nia. showed improve in FCR. However, Virden *et al*. (2003) and Kim and patterson (2005) reported that supplemented Zn had no significant effect on FCR.

Egg quality

Egg shell thickness and percentage: The effect of different dietary Zn and Nia. levels on egg shell thickness and percentage are summarized in Table 3. Significant effect ($p \leq 0.05$) was showed for egg shell thickness (EST) due to dietary Zn levels ($p \leq 0.05$). Supplemented laying hen diets with Nia led to significant differences in EST. The significant effects in EST due to Zn × Nia. interaction were observed. The highest EST (0.413 mm) was recorded by T_3 (70 mg Zn and 300 mg Nia / kg). While, the least (0.377 mm) was obtained by T_1 (70 mg Zn and 30 mg Nia /kg). These result may be due to T_3 was recorded the highest value for feed intake indicated that hens fed more nutrients especially calcium, phosphorus, Zn and Nia. to Fulfillment the requirement of calcium and phosphorus needed for formation of egg shell. Nia increase utilization of calcium and phosphorus, while Zn is a constituent of carbonic anhydrase, which involve in the production of carbonate ions that combine with calcium to form the shell Fig. 2. Klecker *et al*. (2002) observed significant increase in egg shell thickness when using

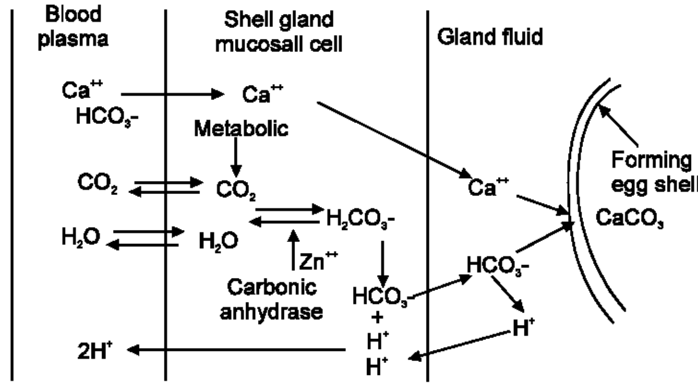

Fig. 2: Carbonic anhydrase and egg shell formation (Robinso and king, 1963)

40% of dietary zinc in organic form. Gungor *et al.* (2003) examined the effect of dietary niacin levels (0,250,500,1000 and 1500 mg/kg diet) on EST. They Found that supplementing niacin with 500,1000 and 1500 resulted in significant increase in egg shell thickness.

Significant differences in egg shell percentage (ESP) ($p \leq 0.05$) due to either Zn or Nia. diertary levels (Table 3). However, supplemented Zn at 140 mg/kg decreased ESP compared with the control group. While, supplemented Nia. increased ESP compared with the control group. Interaction between Zn × Nia. revealed no significant differences in ESP.

Blood parameters

Blood haemoglobin: Significant differences ($p \leq 0.05$) were observed due to adding different levels of Zn and Nia. on Blood haemoglobin (BH). BH increased with increasing either level of Zn or Nia. Supplemented Zn up to 175 mg/ kg did not effect on BH (anemia).There were significant differences ($p \leq 0.05$) in BH due to Zn x Nia. interactions (Table 3). The birds of T_8, T_9, T_{15} and T_{16} recorded the highest value of BH. While, the least was recorded for T_5. Commercial corn-soybean diets may not provide enough trace minerals to meet the requirement of chicks because of the phytate found in natural plant protein source such as corn and soybean meal (Underwood and Sutte, 1999). Therefore, trace minerals such as zinc should be added to broiler and layer diets, however the excess amount of Zn leads to anemia because of Zn is one of important trace elements that associated with iron metabolism (Miho, 2005). The experimental diets contained the same amount of iron suitable enough to prevent anemia symptoms to appear.

Serum total immunoglobulin titres: The Serum total immunoglobulin titres of different experimental birds are listed in Table 3. Significant differences due to supplemented Zn and Nia. levels on serum total immunoglobulin titres (STIT) were observed, the best STIT were recorded when diet supplemented Zn at 105 mg/kg or supplemented Nia. at 300 mg/ kg. Moreover, significant differences due to Zn × Nia. interactions on STIT. Where, the highest value of STIT being 8.0 was recorded for T_4, T_6, T_7 and T_{15} while, the lowest value being 5.0 for T_8, T_9 and T_{16}. These results may be due to Zn is crucial for normal development and function of cells mediating nonspecific immunity such as neutrophils and natural killer cells. (Anuraj and Ananda, 1998).

Relative economic efficiency: The relative economic efficiency of experimental treatments are tabulated in Table 3.The average relative economic efficiency (REE) increased with increasing levels of Zn and decreased with increasing levels of Nia. REE varied between 92-105%. The lowest values were listed for T_8. Meanwhile, the highest values were listed for T_5, T_{13} and T_{16}. Generally, it is recommended that the economical study was affected by different levels of Zn and Nia.

Digestibility coefficient: The nutrient digestibilities of different experimental treatments are shown in Table 4. Feeding laying hen diets with Zn or Nia. slightly decreased dry matter (DM) digestibility compared with the control group. Increasing dietary Zn level improved in crude protein (CP) digestibility, while supplemented Nia. at level of 150 mg/kg improved CP digestibility. The effect of Zn × Nia. interaction on CP digestibility was significant ($p \leq 0.05$). T_{13} which containing 175 mg Zn and 30 mg Nia/kg recorded the best value for CP digestibility. While, T_3 which containing 70 mg Zn and 300 mg Nia/kg recorded the least for CP digestibility. No significant differences were observed in ether extract (EE) digestibility due to supplemented Zn or Nia. except when diet supplemented with Zn at level of 175 mg/kg decreased EE digestibility and supplemented Nia. at level of 300 mg/kg improved EE digestibility. The effect of Zn × Nia. interactions on EE digestibility was significant ($p \leq 0.05$), being the least for T_{15} and T_7 was recorded the highest for EE digestibility. No significant differences in crude fiber (CF) digestibility due to

Table 4: Effect of experimental treatments on nutrient digestibility (%)

Experimental treatments	Digestion coefficient % Dry matter	Crude protein	Ether extract	Crude fiber	Nitrogen free extract	Organic matter
Main effect of Zn:						
70 mg/kg (Zn$_1$)	73.29^{a}	86.86^{d}	78.89^{a}	20.68^{ab}	81.23^{a}	78.35^{a}
105 mg/kg (Zn$_2$)	73.21^{b}	87.36^{c}	78.98^{a}	21.09^{a}	80.55^{b}	78.09^{b}
140 mg/kg (Zn$_3$)	73.16^{bc}	87.84^{b}	79.51^{a}	20.26^{b}	80.78^{b}	78.12^{b}
175 mg/kg (Zn$_4$)	73.09^{c}	88.25^{a}	77.50^{b}	19.98^{b}	79.46^{c}	77.27^{c}
p-value	<0.0001	<0.0001	0.0005	0.01	<0.0001	<0.0001
Main effect of Nia:						
30 mg/kg. (Nia$_1$)	73.29^{a}	87.53^{b}	78.12^{b}	20.27^{ab}	80.27^{c}	77.80^{c}
150 mg/kg. (Nia$_2$)	73.04^{c}	87.66^{a}	78.63^{ab}	20.88^{a}	81.15^{a}	78.43^{a}
300 mg/kg (Nia$_3$)	73.19^{b}	87.53^{ab}	79.42^{a}	20.00^{b}	80.01^{c}	77.59^{d}
450 mg/kg. (Nia$_4$)	73.23^{ab}	87.59^{b}	78.72^{ab}	20.87^{a}	80.58^{b}	77.99^{b}
p- value	<.0001	0.04	0.04	0.03	<0.0001	<0.0001
Zn. × Nia effect:						
T1 (Zn$_1$) + (Nia$_1$)	73.15^{b}	86.98^{g}	79.23^{cdef}	19.84	81.35^{bc}	78.40^{d}
T2 (Zn$_1$) + (Nia$_2$)	73.13^{b}	87.03^{g}	77.52^{fgh}	21.78	81.68^{b}	78.74^{bc}
T3 (Zn$_1$) + (Nia$_3$)	73.63^{a}	86.51^{h}	80.34^{abcd}	19.64	81.29^{bc}	78.49^{cd}
T4 (Zn$_1$) + (Nia$_4$)	73.26^{b}	86.91^{g}	78.48^{defg}	21.46	80.59^{de}	77.78^{f}
T5 (Zn$_2$) + (Nia$_1$)	73.65^{a}	87.12^{g}	76.15^{hi}	21.69	79.03^{g}	76.97^{h}
T6 (Zn$_2$) + (Nia$_2$)	73.09^{b}	87.42^{f}	79.37^{cdef}	21.36	80.98^{cd}	78.26^{de}
T7 (Zn$_2$) + (Nia$_3$)	72.86^{c}	87.51^{ef}	82.04^{a}	20.54	80.62^{de}	78.24^{de}
T8 (Zn$_2$) + (Nia$_4$)	73.23^{b}	87.39^{f}	78.38^{defg}	20.78	81.56^{bc}	78.91^{b}
T9 (Zn$_3$) + (Nia$_1$)	73.22^{b}	87.64^{de}	75.33^{i}	20.16	80.59^{de}	77.97^{ef}
T10 (Zn$_3$) + (Nia$_2$)	72.78^{c}	88.12^{bc}	80.98^{abc}	20.23	82.86^{a}	79.69^{a}
T11 (Zn$_3$) + (Nia$_3$)	73.16^{b}	87.76^{d}	81.73^{ab}	19.84	79.83^{f}	77.43^{g}
T12 (Zn$_3$) + (Nia$_4$)	73.21^{b}	87.82^{d}	79.99^{bcde}	20.81	79.82^{f}	77.33^{g}
T13 (Zn$_4$) + (Nia$_1$)	73.13^{b}	88.37^{a}	81.75^{ab}	19.38	80.14^{ef}	77.87^{f}
T14 (Zn$_4$) + (Nia$_2$)	73.14^{b}	88.06^{c}	76.66^{ghi}	20.16	79.08^{g}	77.05^{h}
T15 (Zn$_4$) + (Nia$_3$)	73.12^{b}	88.33^{ab}	73.56^{j}	19.98	78.28^{h}	76.22^{i}
T16 (Zn$_4$) + (Nia$_4$)	73.23^{b}	88.26^{abc}	78.04^{efgh}	20.41	80.34^{ef}	77.96^{ef}
p-value	<0.0001	<0.0001	<0.0001	0.17	<0.0001	<0.0001

a, b, c,…. etc. means in same column, within each factor with different superscripts are significantly ($p \leq 0.05$) different

Table 5: Efficiency of Energy utilization

Experimental treatments	Feed energy (Kcal/g)	Egg energy (Kcal/g)[2]	Nurient intake Zn. (mg/hen/d)	Nia. (mg/hen/	(A)[3] Zn. (mg)	Nia. (mg)	(B)[4] Zn. (mg)	Nia. (mg)
Main effect of Zn:								
70 mg/kg (Zn$_1$)	2.78	1.57	85.6^{d}	255.1	2.2^{d}	6.4	2.6^{d}	7.6^{a}
105 mg/kg (Zn$_2$)	2.78	1.57	113.7^{c}	253.7	2.9^{c}	6.4	3.4^{c}	7.6^{a}
140 mg/kg (Zn$_3$)	2.78	1.57	152.3^{b}	252.5	3.8^{b}	6.4	4.6^{b}	7.6^{a}
175 mg/kg (Zn$_4$)	2.78	1.57	186.6^{a}	248.2	4.8^{a}	6.5	5.5^{a}	7.4^{b}
p-value			<0.0001	1	<0.0001	0.3985	<0.0001	<0.0001
Main effect of Nia:								
30 mg/kg. (Nia$_1$)	2.78	1.57	131.1	32.1^{d}	3.4	0.83^{d}	3.88^{c}	0.95^{d}
150 mg/kg. (Nia$_2$)	2.78	1.57	132.1	161.6^{c}	3.4	4.2^{c}	3.94^{b}	4.8^{c}
300 mg/kg (Nia$_3$)	2.78	1.57	132.5	325.6^{b}	3.4	8.4^{b}	4.0^{b}	9.8^{b}
450 mg/kg. (Nia$_4$)	2.78	1.57	142.6	490.3^{a}	3.7	12.5^{a}	4.2^{a}	15.3^{a}
p-value			1	<0.0001	0.3985	<0.0001	0.0003	<0.0001
Zn.x Nia effect:								
T1 (Zn$_1$) + (Nia$_1$)	2.78	1.57	73.7	31.58	1.949^{d}	0.84^{d}	2.255^{f}	0.97^{e}
T2 (Zn$_1$) + (Nia$_2$)	2.78	1.58	75.31	161.4	1.949^{d}	4.1^{c}	2.255^{f}	4.87^{d}
T3 (Zn$_1$) + (Nia$_3$)	2.78	1.56	77.29	331.2	1.949^{d}	8.35^{b}	2.305^{f}	9.88^{c}
T4 (Zn$_1$) + (Nia$_4$)	2.78	1.56	115.9	496.6	2.923^{c}	12.53^{a}	3.432^{d}	14.71^{a}
T5 (Zn$_2$) + (Nia$_1$)	2.78	1.56	112.3	32.09	2.923^{c}	0.84^{d}	3.284^{e}	0.94^{e}
T6 (Zn$_2$) + (Nia$_2$)	2.78	1.58	112.8	161.2	2.923^{c}	4.18^{c}	3.393^{d}	4.85^{d}
T7 (Zn$_2$) + (Nia$_3$)	2.78	1.57	113.9	325.3	2.923^{c}	8.3^{b}	3.440^{d}	9.83^{c}
T8 (Zn$_2$) + (Nia$_4$)	2.78	1.56	115.8	496.2	2.923^{c}	12.53^{a}	3.454^{d}	14.80^{a}
T9 (Zn$_3$) + (Nia$_1$)	2.78	1.56	152.7	32.73	3.898^{b}	0.84^{d}	4.536^{c}	0.97^{e}

Table 5: Continued

Experimental treatments	Feed-energy (Kcal/g)	Egg energy (Kcal/g)[2]	Nurient intake Zn. (mg/hen/d)	Nurient intake Nia. (mg/hen)	(A)[3] Zn. (mg)	(A)[3] Nia. (mg)	(B)[4] Zn. (mg)	(B)[4] Nia. (mg)
T10 (Zn_3) + (Nia_2)	2.78	1.56	152.8	163.7	3.898^b	4.18^c	4.537^c	4.86^d
T11 (Zn_3) + (Nia_3)	2.78	1.58	151.6	324.9	3.898b	8.35^b	4.605^c	9.87^c
T12 (Zn_3) + (Nia_4)	2.78	1.58	152	488.6	3.898^b	12.53^a	4.586^c	14.74^a
T13 (Zn_4) + (Nia_1)	2.78	1.57	185.7	31.84	4.762^a	0.82^d	5.457^b	0.94^e
T14 (Zn_4) + (Nia_2)	2.78	1.56	186.9	160.2	4.872^a	4.18^c	5.564^b	4.77^d
T15 (Zn_4) + (Nia_3)	2.78	1.58	187.2	321	4.872^a	8.35^b	5.671^a	9.72^c
T16 (Zn_4) + (Nia_4)	2.78	1.57	186.5	479.7	4.872^a	12.53^a	5.466^b	14.05^b
p-value			1	1	<0.0001	<0.0001	0.04	0.0004

a, b, c,.... etc. means in same column, within each factor with different superscripts are significantly ($p \leq 0.05$) different. [1]Feed energy kcal/g calculated according to NRC (1994). [2]Egg energy Kcal/g calculated according to Merrill and Watt (1973). [3]Nutrient intake/ feed energy ratio (nutrient intake/ (feed energy per g * feed intake)). [4]Nutrient intake/ egg energy [nutrient intake/ (egg energy per g*egg mass)]

Table 6: Prediction of nutrient intake/ feed energy ratio by either nutrient intake or nutrient intake/ egg energy ratio

Y/X	NI*/ feed energy ratio Zinc (mg)	NI*/ feed energy ratio Niacin (mg)
NI*	Y= 0.0262x - 0.0595	Y = 0.0255x + 0.0384
R^2	0.9984	0.9995
NI*/egg energy ratio	Y= 0.0295x + 0.0482	Y = 0.0298x + 0.0268
R^2	0.998	0.9996

*NI = nutrient intake

different dietary levels of Zn or Nia. or their interactions between Zn × Nia on CF digestibility. Zn or Nia. levels had significant effect on nitrogen free extract (NFE) and OM digestibilities. Increased Zn levels in decrease in the diet decreased NFE and OM digestibilities. Supplemented Nia. at 150 and 450 mg/kg improved NFE and OM digestibilities. Interactions between Zn × Nia. on NFE and OM digestibilities were significant ($p \leq 0.05$) and T_{10} had the best value while T_{15} had the least value. These results may be due to Zn supplementation which is increased activity of some enzymes related to nutrients digestion as amylase, lipase, trypsinogen, chemotrypsinogen and some peptidases (Banerjee, 1988).

Energy utilization

Nutrient intake: Nutrients of Zn and Nia. intake were increased significantly ($p \leq 0.05$) with increasing dietary level of these nutrients (Table 5). The value of R^2 was high with equations predicted the nutrient intake/egg energy ratio from nutrient intake (Table 5).

Nutrient intake/ feed energy ratio: Nutrients intake/ feed energy ratio were increased significantly ($p \leq 0.05$) with increasing the level of these nutrients. The value of R^2 was high with equations predicted the nutrients intake/ egg energy ratio from nutrient intake/ feed energy ratio (Table 5).

Equations: Equations prediction of nutrients intake/egg energy ratio were calculated and described in Table 6.

Conclusion: Type of diet is a crucial factor in meeting the Zn requirements of poultry. Cereal based diets including plant sources such as soybean meal cannot deliver enough amount of Zn to the birds due to chelating effect of phytate. It is probable that the use of a corn-soybean diet for the feeding of the birds in the present study increased the demand for Zn. It may be concluded that feeding diet contain 105 mg Zn and 30 mg Nia/kg gave the best performance, egg shell thickness and economic

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