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INFLUENCE OF SUPPLEMENTARY COPPER ON THE PERFORMANCE OF LAYING NORFA HENS

G. A. Zanaty, A. A. Enab, A. A. Elfiky, Manal K. Abou-Elnaga and H. Z. Sewalem
Department of Poultry Production, Faculty of Agriculture, University of Minufiya, Shebin El - Kom, Egypt.

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ABSTRACT: *A total of 150 (105 females and 45 males) local Norfa hens, at 21 weeks of age were used to study the effects of dietary supplementation of copper (Cu) on some productive, reproductive traits, blood components and economical efficiency of laying Norfa hens. Birds were weighed and randomly distributed in to five experimental groups; each group contained 30 birds (21 females and 9 males). Diets were supplemented with 0, 100, 200, 300 and 400 mg Cu/ kg diet and were fed to their respective groups of Norfa hens. Egg production %, egg number, egg mass and feed conversion were improved significantly ($P \leq 0.05$) with addition of Cu. Pronounced effects on egg shell (weight, percentage, strength and thickness), albumen, yolk qualities and Haugh units were insignificantly ($P \geq 0.05$) noted. Hatchability of fertile eggs percentages and embryonic mortality (early and later) were significantly ($P \leq 0.05$) improved with supplementation of Cu (200 mg/ kg diet). Copper addition significantly ($P \leq 0.05$) increased total protein, high density lipoprotein cholesterol (HDL) and serum transaminase (GPT and GOT), while triglycerides, total cholesterol and low density lipoprotein cholesterol (LDL) were significantly ($P \geq 0.05$) decreased. Data indicated the beneficial economical effect of Cu supplementation, especially at the level of 200 mg Cu/ kg diet without any adverse effects under our experimental conditions.*

Key words: *Copper, performance, reproductive traits, blood components, laying hens.*

INTRODUCTION

Copper (Cu) is an essential trace mineral for poultry which functions in numerous physiological processes primarily as a constituent of several enzyme systems, such as cytochrome oxidase, lysine oxidase, ceruloplasmin and superoxide dismutase (Klasing 1998). The Cu is involved in mitochondrial oxidative phosphorylation, free radical detoxification, neurotransmitter synthesis and denaturation, pigment formation, connective tissue synthesis and iron (Fe) metabolism (Crisponi *et al.,* 2010).

Pesti and Bakalli (1998) reported that supplementation of 250 ppm Cu in the form sulfate pentahydrate improved egg production and reduced cholesterol levels of egg yolk and plasma. Copper is usually fed commercially at much higher pharmacological levels (100 – 300 mg/ kg diet) because of its growth promoting properties (Bakalli *et al.,* 1995).

Along with abnormal sized and shaped eggs (Baukgartner *et al.,* 1978), the eggshell of Cu- deficient diet fed hens is characterized by an abnormal distribution of the shell membrane fibers due to alterations in lysine-derived cross-links, which results in egg shape deformation and abnormal mechanical properties. Mabe *et al.* (2003) showed that addition of Zn, Mn, and Cu to a basal corn-soybean meal diet at 60, 60, and 10 mg/ kg improved eggshell quality. However, the optimum level of copper in diets of laying hens still needs to be determined.

The objective of this experiment was to study the effects of feeding different levels of copper on some productive, reproductive traits, blood components and economical efficiency of laying Norfa hens.

MATERIALS AND METHODS

The present study was conducted at the Poultry Research Unit, Faculty of Agriculture, Minufiya University, Shebin El-Kom, in order to investigate to study the effects of dietary supplementation of copper (Cu) on some productive, reproductive traits, blood components and economical efficiency of laying Norfa hens.

One hundred and fifty (105 females and 45 males) local Norfa hens, at 21 weeks of age with an average initial body weight of 924 g for females and 1175 g for males were used. Birds were allotted at random to five equal dietary treatments {30 birds (21 females and 9 males) each}. The experimental lasted from 20 up to 40 weeks of age. Artificial light was used beside the normal day light to provide 16 hour/ day photo period.

Basal diet was formulated to cover the total sulfur amino acids, lysine, calcium, available phosphorus, crude protein and metabolizable energy (ME) according to Zanaty (2006) recommendation for laying Norfa hens. The ingredients and chemical composition of the control basal diet are shown in Table 1. Copper sulfate pentahydrate ($CuSO_4$, $5H_2O$) was added in the diets to supply 100, 200, 300 or 400 mg/ kg diet for treatments 2, 3, 4 and 5, respectively.

Individual body weights were recorded on the first day of the experiment and monthly, thereafter. Feed intake (FI) was recorded and feed conversion (FC) was calculated. Egg production traits including hen day production percent (EP), egg weight (EW), egg number (EN) and egg mass (EM) were recorded and calculated on a daily basis. Representative egg samples (5 eggs) from each treatment were collected monthly throughout the experimental period in order to determine egg and shell quality. Egg shape and yolk index were determined according to Funk (1948) and Romanoff and Romanoff (1949) as follows:

Egg shape index (%)= (width / length) × 100.

Yolk index (%)= (height / diameter) × 100.

Egg shell thickness, including shell membranes, was measured using a micrometer at the equator. Haugh units was applied from a special chart using egg weight and albumen height which was measured using a tripod micrometer according to Haugh (1937), Kotaiah and Mohapatra (1974) and Eisen *et al.* (1962) as follows:

Haugh units = 100 log (H + 7.57 – 1.7 $W^{0.37}$),

Where:

H = Albumen height (mm) and W = Egg weight (g).

The egg yolk visual color was determined by matching the yolk with one of the 15 bands of the "1961, Roche Improved Yolk Color Fan".

Fertility and hatchability traits were measured by collecting eggs for 10 days during the laying period at 39 weeks of age, then stored and transferred to hatchery for incubation, data were recorded and parameters were calculated.

At 40 weeks of age blood samples were taken from the wing vein from 3 laying hens per treatment without anticoagulant and kept at room temperature for one hour to colt. Tubes were centrifuged at 300 rpm for 15 minutes to separate clear serum and determine serum total protein (Peters, 1968), total cholesterol (Ellefson and Caraway, 1976), triglycerides (Bucolo and David, 1973), HDL cholesterol (Siedel, 1983) and transaminase enzymes activities GPT and GOT (Reitman and Frankel, 1957).These biochemical determinations of blood serum were performed calorimetrically by using commercial kits (spectrum diagnostics which was manufactured at 2006 by MDSS Gmbh, schiffgraben 41, 30175 Hannover, Germany).

At 40 weeks of age, three eggs from each treatment group were randomly taken for chemical analysis, then samples were oven dried at 105 °C, ground and stored to chemical analysis. The determination of moisture, crude protein, ether extract and crude fiber in control basal diet were carried out according to the Official Methods (AOAC, 2003).

Table (1): Ingredients and chemical analysis of the control basal diet.

Ingredients	Basal diet
Yellow corn (8.8%)	65.02
Soybean meal (44%)	23.34
corn oil	1.17
Di-calcium phosphate	1.32
Limestone, ground	8.39
Vit. and Min. Mix. [1]	0.30
DL- methionine [2]	0.15
Sodium chloride	0.31
Total	100
Calculated values [3]:	
Crude protein, %	15.99
ME, Kcal/ kg diet	2801
C/P ratio	175
Lysine, %	0.80
Methionine, %	0.41
Met.+ Cysteine, %	0.66
Calcium, %	3.46
Av. Phosphorus, %	0.42
Copper, mg/ kg diet	7.11
Determined values:[4]	
Dry matter, %	89.54
Crude protein, %	15.96
Ether extract, %	3.75
Crude fiber, %	2.95

[1]Vitamins and minerals premix provided per kilogram of the diet: Vit. A, 1200 IU; Vit. D_3, 2500 IU; Vit E, 10 mg; Vit. K, 3 mg; Vit. B_1, 1 mg; Vit. $B_{2,\ 4}$ mg; Pantothenic acid, 10 mg; Nicotinic acid, 20 mg; Folic acid, 1 mg; Biotin, 0.05 mg; Niacin, 40 mg; Vit. B_6, 3 mg; Vit. B_{12}, 0.02 mg; Choline chloride, 500 mg; Mn., 62 mg; Fe., 30 mg; Zn., 56 mg; I., 1 mg; Cu., 10 mg; Se., 0.1 mg and Co., 0.1 mg.
[2]DL- methionine: 98 % feed grade (contained 98 % methionine).
[3]Calculated according to NRC (1994). [4]On as fed basis.

Economical efficiency for egg production was calculated from the input – output analysis (Heady and Jensen, 1954) according to the price of the experimental diets and egg produced. Values of economical efficiency were calculated as the net revenue per unit of total costs (Soliman and Abdo, 2005).

Data obtained were statistically analyzed by the completely randomized design using SPSS, 13.0 (2004) program and the differences among means were determined using Duncan's multiple range test (Duncan, 1955). Percentages were transformed to the corresponding arcsin values before performing statistical analysis. The following model was used:

Statistical model:

$Yij = \mu + ἁi + Eij$, Where:

Yij = An observation,

μ = Overall mean,

ἁi = Effect of treatment (1, 2, 3, … 5) and

Eij = Random error.

RESULTS AND DISCUSSION

Effect of copper supplementation on the performance of Norfa chickens is shown in Table 2. Experimental data indicated that dietary treatments T_2, T_3, T_4 and T_5 recorded that both Norfa males and females body weight at 40 wks were significantly differ. It is observed that body weight was significantly increased (P≤ 0.05) with the supplementation levels of 100 and 200 mg Cu/ kg diet in both males (1874 and 1882g) and females (1544 and 1550g) in a respective order compared to the control (1856 and 1533g). This increase in body weight (BW) suggests that copper is usually fed commercially at much higher pharmacological levels (100 to 300 mg/ kg) because of its growth promoting properties (Pesti and Bakalli 1996).

These results are in agreement with those obtained by Gheisari *et al.* (2011) and Lgbasan and Akinsanmi (2012) who found that diets supplemented with copper significantly improved body weight.

On the other hand, Awad *et al.* (2008); Abaza *et al.* (2009) and Jegede *et al.* (2011) reported that there were no significant effects on live body weight of laying hens fed diets supplementation with Cu sulfate during the experimental period.

Data in Table 2 indicated that egg number was significantly (P ≤ 0.05) increased with the supplementation of copper up to 300 mg Cu/ kg diet (T_4). The highest egg number was observed from feeding 200 mg Cu/ kg diet (T_3). Feeding higher levels of copper (400 mg Cu / kg diet) had no effect on egg number compared to the control (T_1).

Finding of Metwally (2002) showed that the highest average egg number (17.46 eggs/ 28 days) was observed by supplementing 300 mg Cu/ kg diet for laying hens. Abaza *et al.* (2009) showed that the addition of copper sulfate at levels of 100 and 200 mg Cu/ kg laying quail diets significantly (P ≤ 0.05) improved egg number rate.

Percentage of egg production was significantly (P ≤ 0.05) increased up to 300 mg Cu/ kg diet (T_4). Averages were 52.36, 55.27 and 51.96 % for T_2, T_3 and T_4, respectively compared to 50.04 % (T_1, control). The highest egg production 55.27 % was observed from feeding 200 mg Cu/ kg diet (T_3). Feeding higher levels of copper (400 mg Cu/ kg diet) did not effect on egg production compared to T_1 (control) Table 2.

The above results of egg production are in agreement with those finding of Metwally (2002) who showed that the highest average egg production (62.39 %) was observed by supplementation 300 mg Cu/ kg diet for laying hens.

On the other hand, Ankari *et al.* (1998) concluded that 250 mg Cu/ kg diet decreased egg production. While, Bank *et al.* (2004); Liu *et al.* (2005) and Lim *et al.* (2006) showed that there were no significant difference in egg production due to Cu supplementation to the diets.

Means of egg weight were 43.37, 43.21, 43.20 and 43.55 g for T_2, T_3, T_4 and T_5, respectively compared to 43.53 (T_1 control). This may be due to that the palatability of the diet was not changed by the addition of copper and it is possible that the detrimental

Table 2

effect of copper was directed towards increasing the requirement for the sulphur containing amino acids rather than depressing feed intake (Robbins and Baker 1980).

These results are agree with those finding of Bank *et al.* (2004), Lim *et al.* (2006), Awad *et al.* (2008) and Abaza *et al.* (2009) who showed that egg weight was not affected by copper supplementation to the diets. However, Lim and Paik (2006) reported that egg weight significantly increased in birds given a diet containing 200 mg Cu/ kg.

Generally diets supplemented with copper, resulted in a higher egg mass (Table 2). Egg mass was significantly improved (P ≤ 0.05) with addition of copper. Hens fed 200 mg Cu/ kg diets (T_3) had significantly higher value of egg mass (24.00 g/ hen/ d). These results may be due to the significant improvement in feed efficiency or copper growth promoting effects because copper is often added to poultry diets in order to stimulate growth (Harms and Buresh, 1987).

Similar findings were obtained by Abaza *et al. (*2009) who showed that egg mass was significantly (P≤ 0.05) differences among the experimental groups and the highest values of egg mass were recorded with 20 % protein plus 100 mg copper sulfate/ kg diet for quail layer as compared to other treatments. In contrast Liu *et al.* (2005) reported that egg mass was not affected (P ≥ 0.05) among the different supplemental copper sulfate.

Results in Table 2, showed the effect of dietary copper supplementation on feed intake (FI), (g/ h/ d). The average FI values were 99.37, 98.50, 95.73 and 94.73 g/ hen/ day for T_2, T_3, T_4 and T_5, respectively compared to control group being 97.09 g/ h/ d. Hens fed 100 mg Cu/ kg diet had significantly higher value of feed intake (99.37 g/ h/ d). Hens feeding higher levels of copper (400 mg/ kg) clearly decreased feed intake (94.73 g/ h/ d) compared to the control birds. This may be due to the palatability of the diet which was not changed by the addition of copper and it is possible that the detrimental effect of copper was increasing the requirement of the sulfur – containing amino acids rather than depressing food intake as reported by Robbins and Baker (1980).

Finding of Pesti and Bakalli (1998) reported that feed consumption decreased for laying hens fed diets supplemented with 125 and 250 mg Cu/ kg diet. While, Hussein *et al.* (2007) and Awad *et al.* (2008) showed no significant difference in feed consumption due to copper sulfate supplementation.

On the other hand, Jackson *et al.* (1979) reported that feed intake increased with diets containing 200 mg Cu/ kg diet compared to the control group. Also, Abbas *et al.* (2011) reported that feed intake was significantly affected by dietary treatments.

Data on the effect of dietary copper supplementation on feed conversion are presented in Table 2. Feed conversion ratio (FCR) was significantly (P ≤ 0.05) improved due to copper supplementation at 200 mg Cu/ kg diet; being 4.13 g feed/ g egg mass compared to 4.37, 4.27, 4.35 and 4.45 g /g for 100, 300, 400 mg Cu / kg diet and the control, respectively.

These results may be due to the better egg production rate of these birds, and may be due to the ability of copper to improve the performance by improvement the activities of total proteases, amylase and lipase in small intestinal contents (Xia *et al.,* 2004).

These results are in agreement with those obtained by Metwally (2002), Zanaty (2005), Hussien *et al.* (2007), Awad *et al.* (2008), Abaza *et al.* (2009) and Abbass (2011) who showed that feed conversion ratio was significantly (P≤ 0.05) improved due to copper sulfate supplementation.

On the contrary, Bank *et al*. (2004), Lim and Paik (2006), Lim *et al.* (2006), and Karimi *et al.* (2011) noted that copper sulfate had no significant effect on feed conversion ratio.

Data on the effect of dietary copper supplementation on eggshell percentage, shell strength and shell thickness are presented in Table 3. Dietary copper supplementation had not any significant differences on eggshell quality.

Table 3

Similar findings were reported by Metwally (2002), Bank *et al.* (2004), Lien *et al.* (2004), Lim *et al.* (2006), Abaza *et al.* (2009) and Abbas *et al*. (2011) who found that eggshell percent, shell strength and shell thickness were not significantly affected by copper sulfate supplementation. On the other hand, (Ankari *et al.,* 1998) noted that the highest shell thickness was observed from feeding 150 mg Cu/ kg feed

Effects of copper supplementation to layer on egg shape index are presented in Table 3. Data cleared that copper supplementation significantly ($P \leq 0.05$) improved egg shape index. Means for egg shape index were 75.81, 76.37, 76.13 and 75.88 % for 100, 200, 300 and 400 Cu/ kg supplemented diets compared to the 75.35 % in the control group. Hens fed 200 mg Cu/ kg diet had a significant higher value in egg shape index (76.37 %).

Similar finding on egg shape index were reported by Holoubek *et al.* (2002), Lim and Paik (2006) and Awad *et al.* (2008) who reported that egg weight significantly increased in birds due to copper sulfate supplementation. However Jackson *et al.* (1979) reported that egg weight significantly increased in birds given a diet containing 200 mg Cu/ kg diet.

These results disagreed with these finding of (Metwally, 2002, Bank *et al.,* 2004, Lim *et al.*, 2006, Abaza *et al.*, 2009 and Abbas *et al.,* 2011) who showed that egg shape index was not affected with copper supplementation to the diets.

Effect of copper supplementation to layer diet on albumen quality (albumen percent and Haugh units) is presented in Table 3. Insignificant differences were observed between copper supplementation with respect to albumen percent and Haugh units. Similar finding were reported by Pesti and Bakalli (1998), Metwally (2002), Bank *et al.* (2004), Awad *et al.* (2008) and Abaza *et al.* (2009).

Effects of tested diets on the internal egg quality traits are shown in Table 3. Insignificant differences were observed between copper supplementation with respect to yolk index and yolk percentages. A significant difference was noted in yolk colour values between dietary treatments; being 6.39, 7.17, 8.28, 9.61 and 10.17 for T_1, T_2, T_3, T_4 and T_5, respectively.

Similar findings were reported by Pesti and Bakalli (1998), Metwally (2002), Bank *et al.* (2004) and Awad *et al.* (2008) who reported that copper sulfate supplementation diets had no significantly effects on yolk index. However, Lim *et al.* (2006) noted that yolk colour was not affected by copper supplementation.

Experimental results indicated that egg yolk cholesterol was significantly ($P \leq 0.05$) decreased with copper supplementation. Means of egg yolk cholesterol (mg/ g yolk) were 12.48, 10.88, 8.27, 7.89 and 7.23 for the control (T_1), 100 (T_2), 200 (T_3), 300 (T_4) and 400 (T_5) mg Cu / kg diet, respectively (Table 3).

Similar findings on egg yolk cholesterol were reported by Pesti and Bakalli (1998), Metwally (2002), Wakwak (2006), Lim *et al.* (2006) and Abaza *et al.* (2009) who reported that egg yolk cholesterol was significantly reduced by copper sulfate supplementation.

Fertility, hatchability, embryonic mortality percentages and chick weights of incubated eggs of Norfa hens fed diets supplementation with different copper levels are presented in Table (4). The statistical analysis of incubated eggs showed that there were no significant differences among treatments in egg weights, fertility, hatchability of setting eggs percentages and chick weights. While, values of hatchability of fertile eggs percentage and early embryonic mortality percentages were significantly differed ($P \leq 0.05$). The fertility percentages was improved being 95.15, 95.14, 95.43 and 95.42 % for 100, 200, 300, 400 mg Cu/ kg diet, respectively compared to the control (94.30).

Both early and late embryonic mortality were significantly ($P \geq 0.05$) decreased being 1.32, 0.89, 0.77, 0.75 and 0.72 % for the early embryonic mortality and being 1.17, 0.91, 0.79, 0.81 and 0.85 % at late embryonic mortality for groups T_1, T_2, T_3, T_4 and T_5, respectively.

Table 4

These results may be due to the reduction in total cholesterol and triglycerides contents in egg, as well as Cu egg content by supplementing copper to the diet because Cu decreased hepatic glutathione formation. Also, it may be due to copper growth promoting effect because copper is often added to poultry diets in order to stimulate growth (Harms and Buresh, 1987). There are indications that copper may be also have some antibiotic properties (king, 1975), acting in some way to reduce bacterial toxin production.

Similar finding of fertility and hatchability traits were reported by Pesti and Bakalli (1998), Metwally (2002), Wakwak (2006), Awad *et al.* (2008) and Abaza *et al.* (2009) who showed that fertility and hatchability percent were improved by the dietary copper sulfate supplementation.

Data on some blood serum constituents of 40 wks – old laying hens fed diets supplemented with different levels of copper are presented in Table 5. Results showed that there were no significant differences among treatments in serum glucose. The opposite was true with total protein, high density lipoprotein cholesterol (HDL) and blood serum transaminase (GOT and GPT) which were showed significant ($P \leq 0.05$) increased by copper supplementation.

Triglycerides, total cholesterol and low density lipoprotein cholesterol (LDL) were significantly ($P \geq 0.05$) decreased by dietary copper supplementation. These results may be due to the change of lipid metabolism by Cu supplementation to the diet which was resulted in decreasing plasma lipid, 17 beta estradiol and hepatic lipogenic enzyme activity (Pearce *et al.,* 1983). Moreover, Konjufca *et al.* (1997) also indicated that the addition of copper decreased fatty acid synthesis activity.

Estradiol can stimulate lipid synthesis; thus, decrease estradiol concentrations, decrease triglycerides synthesis and the major triglycerides transport lipoprotein – LDL decreases as well, while HDL concentration increased. Also, the higher copper concentration resulted in decreasing the formation of hepatic glutathione and ultimately cholesterol formation (Kim *et al.,* 1992). The above results are agree with the results of Bakalli *et al.* (1995), Konjufca *et al.* (1997), Metwally (2002), Awad *et al.* (2008), Abaza *et al.* (2009) and Jegede *et al.* (2011) who found that dietary copper sulfate supplementation reduced serum triglycerides, total cholesterol and low density lipoprotein cholesterol (LDL) but increased serum high density lipoprotein cholesterol (HDL).

Results concerning economical efficiency evaluation of Cu incorporation in Norfa hen diets are shown in Table 6. The highest economical efficiency value was observed with the diet containing 200 mg Cu/ kg diet (T_3) followed by the diet containing 300 mg Cu/ kg diet (T_4) and lowest economical efficiency value obtained with the control diet (T_1). The relative economical efficiency values followed the same trend being highest for (T_3) and lowest (T_1).

Generally, the results indicate that supplementation of copper increases economical efficiency and relative economical efficiency. The best values were obtained with 200 mg Cu/ kg diet.

It could be concluded that 200 mg Cu/ kg diet (in addition to 7.11 mg copper/ Kg diet included in the control basal diet) can be used in laying Norfa hen diets. It will act as growth promoter, improving egg production, feed conversion, yolk colour and hatchability of fertile eggs, reducing egg yolk cholesterol, early and late embryonic mortality and low density lipoprotein cholesterol, increasing high density lipoprotein cholesterol and relative economical efficiency.

Table 5

Table (6): Economic efficiency for Norfa hens diets containing different levels of copper* addition.

Items	Dietary treatments[1]				
	T_1	T_2	T_3	T_4	T_5
Price of kg feed, (L.E.).	2.400	2.408	2.416	2.424	2.440
Total feed intake/ hen,(L.E.).	14.27	14.61	14.48	14.07	13.44
Total feed cost hen, (L.E.).	34.25	35.19	34.98	34.11	32.79
Total number of eggs/ hen.	73.55	76.97	81.25	76.38	73.25
Total price of eggs/ hen, (L.E.).[2]	36.78	38.49	40.63	38.19	36.63
Net revenue/ hen, (L.E.).[3]	2.53	3.30	5.65	4.08	3.84
Economic efficiency, (%).[4]	7.39	9.36	16.15	11.96	11.71
Relative economic efficiency.[5]	100	126.66	218.54	161.84	158.46

*Price of kg copper sulfate was 20 P.T. (according to Egyptian market, 2010).
[1]T_1,control, without additive; T_2 , 100 mg Cu/ kg diet; T_3, 200 mg Cu/ kg diet; T_4, 300 mg Cu/ kg diet and T_5, 400 mg Cu/ kg diet.
[2]Assuming that price of one egg was 50 P.T. (according to Egyptian market, 2010).
[3]Net revenue / hen, (L.E.)= Total price of eggs – Total feed cost.
[4]Economic efficiency = (Net revenue ÷ Total feed cost) x 100.
[5]Relative economic efficiency of control considered 100.

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تأثير إضافة النحاس على أداء دجاج النورفا

جمال عبد الستار زناتي ، أحمد عبد الوهاب عنب ، عبد المنعم عبد الحليم الفقى ،
منال كمال أبو النجا ، حسام زاهر سويلم
قسم إنتاج الدواجن – كلية الزراعة – جامعة المنوفية – شبين الكوم – مصر

الملخص العربى:

استخدم في هذه التجربة عدد ١٥٠ طائر نورفا (١٠٥ دجاجه و ٤٥ ديك) عمر ٢١ أسبوع متماثلة تقريبا في وزن الجسم (بمتوسط ٩٢٤ و ١١٧٥جم للدجاجات والديوك على التوالي)، لدراسة تأثير إضافة مستويات مختلفة من النحاس في العليقة على الأداء الإنتاجي والتناسلي وبعض مكونات الدم والكفاءة الاقتصادية لدجاج النورفا (Norfa) البياض. قسمت الطيور عشوائيا إلى خمس مجموعات تجريبية ، كل مجموعه احتوت على ٣٠ طائر نورفا (٢١ دجاجه و٩ ديوك). العليقة الأولى (لم يضف إليها النحاس) واستخدمت للمقارنة، بينما العلائق الثانية والثالثة والرابعة والخامسة أُضيف إليها النحاس بمعدل ١٠٠ ، ٢٠٠، ٣٠٠ ، ٤٠٠ مجم / كجم عليقة على التوالي.

وأظهرت النتائج تحسن معنوي (عند مستوى ٠.٠٥) في معدل إنتاج وعدد وكتلة البيض ومعدل تحويل الغذاء بإضافة النحاس وخصوصاً عند مستوى ٢٠٠ مجم نحاس/ كجم عليقة. كما أدت إضافة النحاس إلى تحسن لون صفار البيض ودليل شكل البيض وانخفاض كولستيرول صفار البيضة، بينما لم يؤثر على كل من: صفات قشرة البيض (الوزن، نسبة وزن القشرة وسُمكها وقوة الكسر) وجودة البياض والصفار ووحدات هاووف ونسبه الخصوبة ، ولوحظ تحسن نسبه الفقس المحسوبة على أساس عدد البيض المخصب، كما انخفضت نسبة الميت أول والميت ثاني بإضافة النحاس، بينما لم تؤثر الإضافة معنوياً (عند مستوى ٠.٠٥) على كل من: نسبة الفقس المحسوبة على أساس عدد البيض الموضوع بماكينة التفريخ ووزن الكتاكيت الفاقسة. كما أدت إضافة النحاس إلى زيادة معنوية (عند مستوى ٠.٠٥) في البروتين الكلى والكولستيرول عالي الكثافة (HDL) وإنزيمات الكبد (GPT و GOT)، بينما انخفض معنوياً (عند مستوى ٠.٠٥) كل من: الجليسريدات الثلاثية والكولستيرول الكلى في الدم والكولستيرول منخفض الكثافة (LDL). وأوضحت النتائج تحسن الكفاءة الاقتصادية والكفاءة الاقتصادية النسبية والأداء الإنتاجي والتناسلي بإضافة النحاس إلى العلائق وخصوصاً عند مستوى ٢٠٠ مجم نحاس/ كجم عليقة (بالإضافة إلى ٧.١١ مجم نحاس/ كجم عليقة التي تحتويها عليقة الكنترول) تحت ظروف التجربة دون حدوث تأثيرات ضارة.

Table (2): Performance of Norfa chickens as affected by dietary copper supplementation (Means ± S.E)

Items	Dietary treatments[1]					Sig.
	T_1	T_2	T_3	T_4	T_5	
Male body weight at 21 wks (g)	1169 ± 32.85	1180 ± 78.06	1181 ± 50.85	1174 ± 34.36	1171 ± 35.91	NS
Male body weight at 40 wks (g)	1856 ± 18.71^{b}	1874 ± 25.59^{a}	1882 ± 10.36^{a}	1824 ± 24.69b^{c}	1805 ± 12.98^{c2,3}	*
Female body weight at 21 wks (g)	922 ± 19.81	926 ±35 .61	925 ± 22 .36	923 ± 21.08	922 ± 20.95	NS
Female body weight at 40 wks (g)	1533 ± 15.64^{b}	1544 ± 20.32^{a}	1550 ± 17.38^{a}	1503 ± 15.34^{b}	1476 ± 17.30^{c}	*
Egg number (per hen/ 20 wks)	73.35 ±1.04^{c}	76.97± 1.16b	81.25 ± 1.18^{a}	76.38± 1.13^{b}	73.25± 1.06^{c}	*
Egg production,% (hen-day)	50.04 ± 0.52^{c}	52.36 ± 0.60^{b}	55.27 ± 0.60^{a}	51.96 ± 0.52^{b}	49.82 ± 0.61^{c}	*
Egg weight (g)	43.53 ± 0.39	43.37 ± 0.44	43.21 ± 0.42	43.20 ± 0.44	43.55 ± 0.40	NS
Egg mass (g/ hen/ d)	21.86 ± 0.37^{b}	22.81 ± 0.42^{b}	24.oo ± 0.45^{a}	22.53 ± 0.40^{b}	21.74 ± 0.38^{b}	*
Feed intake (g/ hen/ d)	97.09 ±1.40^{ab}	99.37 ± 1.66^{a}	98.50 ± 1.38^{ab}	95.73 ± 1.27^{ab}	94.73 ± 1.23^{b}	*
Feed conversion (g feed/ g egg mass)	4.45 ± 0.02^{a}	4.37 ± 0.02^{ab}	4.13 ± 0.03^{d}	4.27 ± 0.03^{c}	4.35 ± 0.04^{b}	*

[1]T_1,control, without additive; T_2 , 100 mg Cu/ kg diet; T_3, 200 mg Cu/ kg diet; T_4, 300 mg Cu/ kg diet and T_5, 400 mg Cu/ kg diet.
[2]Means ± S.E. of 3 replicates/ treatments.
[3]Means followed by different superscripts in the same row are significantly different (P< 0.05).
[*]Significant (P < 0.05). NS, Not significant.

Table (3): Effect of dietary copper supplementation on egg quality (Means ± S.E)

Items	Dietary treatments[1]					Sig.
	T_1	T_2	T_3	T_4	T_5	
Egg weight (g)	43.46 ± 0.39	43.44 ± 0.44	43.48 ± 0.42	43.46 ± 0.44	43.41 ± 0.40	NS
Shell (%)	10.72 ± 0.22	10.73 ± 0.24	11.06 ± 0.21	11.00 ± 0.18	10.94 ± 0.21	NS
Shell thickness (mm)	0.335 ± 0.009	0.339 ± 0.012	0.362 ± 0.010	0.358 ± 0.010	0.355 ± 0.009	NS
Eggshell strength (g)	29.61 ± 1.77	30.44 ± 2.46	31.22 ± 1.96	30.89 ± 1.62	30.78 ± 1.87	NS
Egg shape index (%)	75.35 ± 0.18^{b}	75.81 ± 0.30^{ab}	76.37 ± 0.23^{a}	76.13 ± 0.28^{ab}	75.88 ± 0.27^{ab2,3}	*
Albumen (%)	53.88 ± 0.50^{b}	53.94 ± 0.42^{ab}	54.02 ± 0.33^{a}	54.01 ± 0.33^{a}	53.66 ± 0.28^{c}	*
Haugh units	80.94 ± 0.43	81.02 ± 0.45	81.02 ± 0.39	81.02 ± 0.40	81.03 ± 0.44	NS
Yolk index (%)	44.83 ± 0.42	44.84 ± 0.63	44.85 ± 0.41	44.83 ±1.10	44.85 ± 0.47	NS
Yolk (%)	33.79 ± 0.54	34.91 ± 0.34	35.01 ± 0.34	34.81 ± 0.39	34.39 ± 0.34	NS
Yolk colour	6.39 ± 0.45^{c}	7.17 ± 0.29^{c}	8.28 ± 0.31^{b}	9.61 ± 0.34^{a}	10.17 ± 0.40^{a}	*
Egg yolk cholesterol (mg/ g yolk)	12.48 ± 0.29^{a}	10.88 ± 0.28^{b}	8.27 ± 0.17^{c}	7.89 ± 0.27^{cd}	7.23 ± 0.25^{d}	*

[1]T_1,control, without additive; T_2 , 100 mg Cu/ kg diet; T_3, 200 mg Cu/ kg diet; T_4, 300 mg Cu/ kg diet and T_5, 400 mg Cu/ kg diet.

[2]Means ± S.E. of 3 replicates/ treatments.

[3]Means followed by different superscripts in the same row are significantly different (P< 0.05).

[*]Significant (P < 0.05). NS, Not significant.

Table (4): Effect of dietary copper addition on fertility and hatchability of Norfa hens at 39 weeks of age (Mean ± S.E)

Items	Dietary treatments[1]					Sig.
	T_1	T_2	T_3	T_4	T_5	
Total egg set	36	36	36	36	36	NS
Egg weight (g)	47.16 ± 0.49	47.10 ± 0.18	47.21 ± 0.44	47.11 ± 0.51	46.95 ± 0.56	NS
Fertility (%)	94.30 ±0.20	95.15 ±0.14	95.14 ±0.14	95.43 ±0.29	95.42 ±0.17	NS
Hatchability of setting eggs (%)	78.85 ± 0.27	79.07 ± 0.09	78.95 ± 0.10	78.93 ± 0.14	79.41 ± 0.12	NS
Hatchability of fertile eggs (%)	82.49 ± 0.57^{c}	83.87 ± 0.30^{bc}	83.51 ± 0.12^{bc}	83.63 ± 0.13^{bc}	85.42 ± 0.26^{a2,3}	*
Early embryonic mortality (%)	1.32 ± 0.11^{a}	0.89 ± 0.91^{b}	0.77 ± 0.02^{c}	0.75 ± 0.01^{c}	0.72 ± 0.11^{c}	*
Late embryonic mortality (%)	1.17 ± 0.06^{a}	0.91 ± 0.04^{b}	0.79 ± 0.02^{c}	0.81 ± 0.02^{c}	0.85 ± 0.01^{bc}	*
Chick weight (g)	30.12 ± 0.41	30.09 ± 0.14	30.15 ± 0.21	30.13 ± 0.25	29.96 ± 0.20	NS

[1] T_1,control, without additive; T_2 , 100 mg Cu/ kg diet; T_3, 200 mg Cu/ kg diet; T_4, 300 mg Cu/ kg diet and T_5, 400 mg Cu/ kg diet.
[2] Means ± S.E. of 3 replicates/ treatments.
[3] Means followed by different superscripts in the same row are significantly different (P< 0.05).
[*] Significant (P < 0.05). NS, Not significant.

Table (5): Some blood serum constituents as affected by dietary copper addition of Norfa hens at 40 weeks of age (Means ± S.E)

Items	Dietary treatments[1]					Sig.
	T_1	T_2	T_3	T_4	T_5	
Glucose mg/ dl.	229.31 ± 0.61	230.11 ± 0.23	231.23 ± 0.79	230.62 ± 0.01	230.75 ± 0.46	NS
Total protein, g/ dl.	3.25 ± 0.07[b]	3.76 ± 0.38[ab]	3.91 ± 0.42[ab]	4.22 ± 0.14[a]	4.35 ±0.04[a2,3]	*
HDL cholesterol, %[4]	14.33 ± 0.28[e]	17.65 ± 0.16[d]	25.12 ± 0.10[c]	30.20 ± 0.19[b]	32.16 ± 0.47[a]	*
GOT U/ L.	81.12 ± 0.18[c]	82.26 ± 0.28[b]	85.34 ± 0.20[a]	86.11 ± 0.12[a]	85.73 ± 0.33[a]	*
GPT U/ L.	13.76 ± 0.08[d]	15.23 ± 0.13 [c]	16.12 ± 0.13[ab]	16.31 ± 0.08[a]	15.88 ± 0.09[b]	*
Triglycerides, mg/ dl.	192.83 ± 0.44[a]	185.50 ± 0.60[b]	172.30 ± 0.44[c]	169.25 ± 0.56[d]	161.13 ± 0.45[e]	*
Total cholesterol, mg/	153.16 ± 0.36[a]	144.33 ± 0.49[b]	137.25 ± 0.17[c]	130.15 ± 0.20[d]	128.26 ± 0.46[e]	*
LDL cholesterol, %[5]	85.67 ± 0.27[a]	82.35 ± 0.29[b]	74.88 ± 0.38[c]	69.80 ± 0.05[d]	67.39 ± 0.44[e]	*

[1]T_1,control, without additive; T_2 , 100 mg Cu/ kg diet; T_3, 200 mg Cu/ kg diet; T_4, 300 mg Cu/ kg diet and T_5, 400 mg Cu/ kg diet.
[2]Means ± S.E. of 3 replicates/ treatments.
[3]Means followed by different superscripts in the same row are significantly different (P< 0.05).
[4]High density lipoprotein cholesterol.
[5]Low density lipoprotein cholesterol.
[*]Significant (P < 0.05). NS, Not significant.