EFFECT OF DIETARY SUPPLEMENTATION OF COPPER SULFATE ON PRODUCTIVE PERFORMANCE OF PEKIN DUCKS: 2- LAYING PERFORMANCE AND HATCHABILITY TRAITS

By

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Received: **19/11/2007** Accepted: **10/1/2008**

Abstract: *A total number of 168 Pekin ducks 14 weeks-old were selected, weighed, and divided into four treatments of 3 replicates to investigate the effect of supplementing copper sulfate as a growth promoter at levels of 0 , 100 , 300 and 500 mg / kg diet from 14 weeks until 45 weeks of age on laying performance parameters , hatchability , chemical analysis as will as quality of egg , some blood constituents and economic efficiency during the studied laying period (22-45 wks).*

The results indicated that copper sulfate supplementations resulted in insignificant effect on body weight change of ducks from 22 to 45 weeks of age , but the first eggs were early laid by about 6 and 13 days by feeding diets supplemented with 300 and 500 mg $CuSO_4$/kg, respectively . Egg number, egg mass per duck and laying rate were significantly improved by approximately 13, 21 and 28% for each trait during the overall experimental period (22-45 wks) for groups fed diets supplemented with 100 , 300 and 500 mg Cu SO_4 / kg compared to the control group, respectively . Egg weights slightly increased during the overall period (22-45 wks) due to treatments. Feed consumption per duck during overall period was significantly decreased by about 12.11 and 7.98 % for the groups fed diets supplemented with 100 and 500 mg Cu SO_4 /kg compared to the control . Feed conversion (g. feed / g. egg mass) were significantly affected due to treatments during the whole period (22-45 wks), improvement values reached 28.9 , 22.8 and 17.0 % for the groups fed diets supplemented with 500 , 100 and 300 mg Cu SO_4 /kg compared to the control, respectively. Hatchability of fertile eggs was significantly improved by 7.27, 3.56 and 2.07 %. Late embryonic mortality percentages decreased by about 35.4 , 23.7 and 18.0 % for the groups fed diets supplemented with 500 , 300 and 100 mg Cu SO_4 / kg compared to the control, respectively. Early embryonic mortality was significantly decreased by about 32 % for

the group fed diet supplemented with 500 mg Cu SO_4 / kg compared to the control and other treatments .Blood serum constituents such as serum triglycerides , cholesterol , HDL cholesterol and serum transaminases (GOT and GPT) were insignificantly decreased by the treatments . Egg components and quality measurements were not significantly affected at 28 and 40 wks of age ,while , dry matter and ether extract composition of egg were significantly decreased by about 6.91 and 20.95 % by feeding diet supplemented with 500 mg Cu SO_4 /kg compared to the control , respectively. The treatments resulted in clear improvement of net return per duck and economic efficiency. These results indicated that copper sulfate could be supplemented to grower and layer duck diets up to 500 mg / kg without any adverse effects and may be alternative methods to maximize the productivity and profitability of Pekin ducks on laying performance , hatchability traits and economic efficiency .

INTRODUCTION

Copper (Cu) is a very essential mineral in poultry nutrition, copper deficiency in laying hens results in hypercholesterolemia ***Kelvay et al., 1984)***. Copper is usually fed commercially at much higher pharmacological levels (100 to 300 mg/kg diet) because of its growth promoting properties ***(Wang et al., 1987; Bakalli et al., 1995; Pesti and Bakalli, 1996)***. Along with abnormal sized and shaped eggs ***(Baukgartner et al., 1978)*** , the egg shell 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 egg shell quality. So, a great deal of effort has been applied to improve eggshell quality in the fields of genetics, environmental condition, and nutrition, especially mineral nutrition ***(Nys, 2001)***.

Addition of different amounts of Cu to laying hens ration have resulted in reductions in yolk cholesterol concentrations and blood plasma lipid concentrations ***(Pearce et al., 1983; Ankari et al., 1998 and Pesti and Bakalli, 1998)***. Dietary pharmacological doses of Cu amounting to several hundred milligrams per kilogram of feed decreased cholesterol concentrations in eggs and poultry meat ***(Bakalli et al., 1995 and Pesti and Bakalli, 1998).Pearce et al.(1983)*** demonstrated that pharmacological levels of Cu (≥250 mg/kg diet) caused changes in 17 beta-estradiol and enzymes involved in carbohydrate, lipid, and amino acid metabolism in mature laying hens and suggested that Cu supplements can affect reproductive physiology and lipid metabolism beyond changes simply due

to reduced feed intake. ***Pesti and Bakalli (1998)*** reported that egg production of laying hens was significantly increased in the second 4-wk period by supplementing diet with Cu. Egg production and feed conversion of laying hens were improved by addition of 300 mg Cu/kg to the diet ***(Metwally,2002)*** .Objectives of the present study were to assess if the supplementation of copper sulfate as a growth promoter (0, 100, 300 and 500 mg/kg) to the diet of Pekin ducks during growing and laying periods would affect body weight, feed conversion, egg production and quality; serum constituents and hatchability traits of eggs produced .

MATERIALS AND METHODS

This study was carried out at El – Serw Water Fowl Research Station, Animal Production Research Institute, Agricultural Research Center, Ministry of Agriculture, Egypt. Started in December 2006 and was terminated in August 2007 .One hundred and sixty eight (144 females and 24 males) Pekin duck 14 weeks-old were weighed and randomly distributed into four experimental groups , each group contained 42 ducks . Ducks in each treatment were reared under similar hygienic and managerial conditions. The duck of each treatment (36 females and 6 males) were taken at random, weighed then divided into equal three replicates (12 females and 2 males). Throughout the experimental period, feed and fresh water were available all the time. Ducks were fed grower diet from 14 to 18 weeks and layer diets from 19 weeks up to the end of the experimental period (45 wks).The composition and calculated analysis of the basal feed rations are shown in (Table 1). Four graded levels of copper sulfate as dietary source of Cu (0, 100, 300 and 500 mg / kg diet) were supplemented to the basal diet and fed to the four experimental groups of Pekin ducks from 14 to 37 weeks followed by another 8 weeks without copper sulfate supplementation during the experimental period. Feed consumption of each replicate for all treatments were weekly recorded , it was then averaged and expressed in grams per duck / 28 days throughout the experimental period (from 14-22 and then from 22-45 wks of age). Feed conversion for egg production during egg production period (22-45 wks) was also calculated. Egg number was daily recorded for 24 weeks from 22 to 45 wks of age. Egg weight was recorded to the nearest gram for each replicate and egg mass was calculated per duck for the same periods as follows:

Egg mass per duck =Total egg mass produced / Number of duck at housing

At 28 and 40 weeks of age a total number of 40 eggs (10 from each treatment) were taken to determine egg components and quality. At 42 weeks of age, three eggs from each treatment group were randomly taken for chemical analysis , then samples were dried at 105ºC until constant weight, ashed at 600ºC for 6 hour's a forced draught oven, ground and stored to chemical analysis . Proximate analysis was carried out according to the official methods ***(AOAC, 1995)***. Fertility and hatchability traits were measured by collecting eggs for 10 days during the laying period at three hatches along with different ages, then stored and transferred to hatchery for incubation, data were recorded and parameters were calculated.

At 45 weeks of age blood samples were taken from the wing vein from 3 laying ducks per treatment without anticoagulant and kept at room temperature for one hour to clot. Tubes were centrifuged at 3000 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, J.,1983)*** and transaminase enzymes activities GPT and GOT **(Reitman and Frankel,1957)** . These biochemical determinations of blood serum were performed colorimetrically by using commercial kits (Spectrum diagnostics which was manufactured at 2006 by MDSS GmbH, Schiffgraben 41, 30175 Hannover, Germany).

Statistical analysis : Data were analyzed by the analysis of variance according to ***Snedecor and Cochran (1982)*** and significant differences among means were detected by the Duncan's Multiple Range Test ***(Duncan,1955)*** .The following model was used: $Y_{ij} = \mu + T_i + e_{ij}$ where,

Y_{ij} = An observation,

μ = overall mean,

T_i = Effect of treatment (1, 2, ..., b) and

e_{ij} = Random error

RESULTS AND DISCUSSION

Pekin laying ducks performance:

Results in Table (2) revealed that no significant differences were recorded in live body weights at 14 , 22 and 45 wks-old of Pekin laying ducks and feed consumption during the pre laying period (14 to 22 weeks of age) as a result of feeding experimental diets. Feed consumption non significantly decreased by 6.7, 3.0 and 3.6% for the group fed diet

supplemented with 500, 300 and 100 mg Cu sulfate / kg, respectively as compared to the control group at the pre laying period. These results of live body weight may be due to the age of duck and duck feeding on diet which contained lower crude protein and energy during this period, and this agree with those findings of Bank **et al. (2004) and Balevi and Coskun (2004)** who reported no significant effects on live body weight of laying hens fed diets supplemented with Cu sulfate during the experimental period.

Results in Table (3) revealed no significant differences was recorded in the age of layers at 25 and 50 % egg production levels of Pekin laying ducks as a result of feeding experimental diets. While, the age at first egg and peak of egg production levels was significantly affected ($p \leq 0.05$). First egg was laid earlier by 6 and 13 days for the groups fed diets supplemented with 300 and 500 mg Cu sulfate / kg , respectively as compared to the control group. Similar result was recorded with age of peak of egg production by about 11.3 and 13 days. However, the laying age decreased by approximately 8.7 and 6.0 days for the group fed diet supplemented with 500 mg Cu sulfate / kg as compared to the control at 25 and 50 % egg production, respectively. These results may be due to the feeding on diet supplemented with copper sulfate resulted in rapid sexual maturity of birds because it's growth promoting effects ***(Harms and Buresh, 1987)***.

Results in Table (4) showed that significant differences among the experimental groups in egg number and mass per duck and laying rate (%) during all the interval periods with the exception of the period 38-41 wks of age which was insignificantly affected of egg number per duck. Egg number per duck and laying rate were improved at all studied periods for groups fed diets supplemented with 100, 300 and 500 mg Cu sulfate / kg diet by 12.75, 21.11 and 27.69 % more eggs during the overall period (22-45 wks) as compared to the control group, respectively. Similarly, egg mass during the overall period (22-45 wks) for groups fed diets supplemented with 100, 300 and 500 mg Cu sulfate / kg as compared to the control group. 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)*** although there are indications that copper may also have some antibiotic properties ***(King,1975)***, acting in some way to reduce bacterial toxin production .The above results of egg production are in agreement with those findings of ***Atalla (2002)*** who showed that copper sulfate pentahydrate (1000 mg / kg diet) had no adverse effect on egg production rate which was increased by about 8 % through 4-week post supplementation. Also, ***Metwally (2002)*** showed

that the highest average egg number (17.46 eggs/28 days) and egg production (62.39%) were observed by supplementing 300 mg Cu/kg diet for laying hens . ***Pesti and Bakalli (1998)*** found that egg production was significantly increased ($P<0.05$) after 8 wks of supplementation of 250 mg Cu/kg in laying hen diets. ***Jackson (1977)*** reported that the highest level of egg production was observed by feeding 256 mg Cu/kg diet. On the other hand , ***Pearce et al., (1983) ; Stevenson et al., (1983) and Ankari et al., (1998)*** concluded that Cu supplementation with 250 mg Cu/kg diet decreased egg production .While, ***Balevi and Coskun (2004); Lien et al., (2004) and Bank et al.(2004)*** showed that no significant differences in egg production due to Cu supplementation to the diets.

No significant differences were observed among the experimental groups regarding egg weights at different periods due to the experimental treatments with the exception of the period 38-41 wks of ages which was significantly affected ($p \leq 0.05$). These results are in agreement with those findings of ***(Pesti and Bakalli, 1998; Metwally, 2002; Balevi and Coskun, 2004; Lien et al., 2004, and Bank et al., 2004)*** they showed that egg weight was not affected with copper supplementation to the diets .However, ***Jackson et al. (1979)*** reported that egg weight significantly increased in birds given a diet containing 200 mg Cu /kg.

Significant differences were observed among the experimental groups in feed consumption and feed conversion during all production periods (Table 5). Feed consumption values (g / duck / 28 days) were significantly decreased during all studied periods for groups fed diets supplemented with 100, 300 and 500 mg Cu sulfate / kg diet compared to the control except for the group fed diet supplemented with 300 mg / kg at periods 26 –29, 38-41 and 42-45 wks which increased significantly as compared to the control group. However, feed consumption per duck during the overall period decreased by about 12.11 and 7.98 % for the groups fed diets supplemented with 100 and 500 mg Cu sulfate /kg compared to the control, respectively ,while , the group fed diet supplemented with 300 mg/ kg insignificantly increased by about 1.53 % than the control group. 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)***. Significant decreases in feed consumption were reported in the literature of Cu supplemented diets ***(Pearce et al., 1983; and Stevenson et al., 1983).*** Also, ***Pesti and Bakalli (1998)*** reported that feed consumption decreased for layer hens fed diets supplemented with 125 and 250 mg Cu /kg. On the other hand, ***Jackson et***

al. (1979) reported that feed intake increased with diets containing 200 mg Cu /kg compared to the control group. While, ***Ankari et al. (1998); Metwally (2002) ; Bank et al.(2004), and Balevi and Coskun (2004)*** showed no significant differences in feed consumption due to copper sulfate supplementation.

Feed conversion (g. feed / g. egg mass) was significantly improved due to treatments during all interval periods. This improvement values reached 28.6, 16.2 and 22.0 % for the groups fed diets supplemented with 500, 300 and 100 mg Cu sulfate /kg diet, respectively during the overall period 22-45 wks compared to the control. These results may be indicated that the better egg production rate of these birds, and may be due to 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 ***Pesti and Bakalli (1998)*** reported that feed conversion ratio was significantly improved by supplementation of 150 mg Cu /kg diet. In contrast, it was negatively affected in laying hens by a diet containing 250 mg/kg Cu compared with the control diet in a study reported by ***Ankari et al. (1998)***.While , feed conversion was not affected due to Cu supplementations to the diets ***(Bank et al. , 2004, and Balevi and Coskun, 2004).***

Fertility and hatchability traits:

Fertility, hatchability, embryonic mortality percentages and chick weights of incubated eggs of Pekin laying ducks fed the diets supplemented with different copper sulfate levels are presented in Table (6). The statistical analysis of three hatches data of incubated eggs showed no significant differences among treatments in egg fertility, hatchability, late embryonic mortality percentages and chick weights, while values of hatchability of fertile eggs and early embryonic mortality percentages were significantly differed ($p \leq 0.05$). The hatchability percentages improved by about 2.20 , 2.95 and 6.57 % of eggs set and 2.07 , 3.56 and 7.27 % of fertile eggs for the groups fed diets supplemented with 100 ,300 and 500 mg Cu sulfate / kg, respectively as compared to the control. Early embryonic mortality significantly decreased by about 32 % for the group fed diet supplemented with 500 mg Cu sulfate / kg compared to the control similar result was noticed between treatment of 500 mg Cu sulfate / kg and the other studied treatments. Late embryonic mortality percentages significantly decreased by 35.4 , 23.7 and 18.0 % for the groups fed diets supplemented with 500 ,300 and 100 mg Cu sulfate / kg, respectively as compared to the control group. These results may be due to the reduction in total cholesterol and triglycerides contents in egg, as will as Cu-egg content by supplementing

copper sulfate to the diet because Cu decreased hepatic glutathione formation. Also, it may be due to copper growth promoting effects because copper is often added to poultry diets in order to stimulate growth ***(Harms and Buresh, 1987)*** although there are indications that copper may also have some antibiotic properties ***(King,1975)***, acting in some way to reduce bacterial. Toxin production.

Blood serum parameters:

Blood serum parameters of Pekin laying ducks, measured in the present study, were estimated to show the metabolic status of ducks and their health. Data on some blood serum constituents of 45 wks -old Pekin laying ducks fed the diets supplemented with different levels of copper sulfate (Table 7) showed no significant differences among treatments in total protein and blood serum transaminases (GOT and GPT). The opposite was true with triglycerides, total cholesterol and HDL cholesterol which were showed significant differences between experimental groups due to the treatment of copper sulfate. A decrease of triglycerides by about 22.20, 3.1 and 10.19 % was noticed for groups fed diets supplemented with 500, 300 and 100 mg Cu sulfate / kg, respectively as compared to the control. Also, serum cholesterol was significantly decreased by 23.23 and 20.94 % for groups fed diets supplemented with 500 and 300 mg Cu sulfate / kg, respectively as compared to the control. While, the lowest values of HDL cholesterol occurred by feeding diets supplemented by 100 and 300 mg copper sulfate / kg (65.3 and 60.0 U/L). Means of serum transaminases (GOT and GPT) were lowered than the control due to treatments, which reflected the good metabolic status of ducks. 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 Cu decreased fatty acid synthesis activity. Estradiol can stimulated lipid synthesis; thus, decreased estradiol concentrations decreased triglycerides synthesis and the major triglycerides transport lipoprotein-VLDL decreased as well; meanwhile HDL concentration increased. Also, the higher copper concentration resulted in decreasing the formation of hepatic glutathione and ultimately cholesterol formation ***(Kim et al., 1992).*** Glutathione is known to regulate cholesterol biosynthesis through the stimulation of the enzyme 3-hydroxy-3 methylglutaryl- coenzyme A (HMG-CoA) reductase ***(Kim et al.1992; Pesti and Bakalli, 1996)***. The above results in this study , as in the reports ***of Bakalli et al, (1995)*** demonstrated that feeding 250mg copper/kg diet (in addition to the copper needed to meet the classical nutritional requirement), reduced

plasma total cholesterol (26%), plasma triglycerides (43%), blood glutathione (40%) and breast muscle cholesterol (27%). However high density lipoprotein cholesterol increased (1.9%). ***Konjufca et a[1]., (1997)***, stated that plasma cholesterol level was reduced in male broilers fed 250 mg copper sulfate/kg diet. ***Pearce et al. (1983) ; Ankari et al. (1998) and Pesti and Bakalli (1998)*** they reported that plasma cholesterol and triglycerides were significant reduction by feeding hens on diet supplemented with 250 mg Cu/kg (20 and 24%); .Also, ***Metwally (2002)*** reported that supplementing dietary copper with 150 mg/kg diet decreased the amount of cholesterol in plasma at 4 and 8 wks after feeding by 17.71% and 21.1%, and ***Atalla (2002)*** concluded that feeding laying hens on diet supplemented with 250 mg copper sulfate / kg resulted in significant decreasing serum cholesterol and triglycerides

Egg quality characteristics:

Data on components and quality measurements of eggs produced by Pekin laying ducks fed the different diets supplemented with copper sulfate at 28 and 40 wks-old are presented in Tables (8 and 9). No significant differences were observed among the experimental groups in egg components and quality measurements .At 28 wks-old of Pekin laying ducks , albumen , egg shell weight % , yolk index and Haugh Units improved by copper sulfate supplementation to the diets compared to the control whereas, yolk weight % was decreased due to studied treatments. The same trend was occurred for albumen and yolk weight % and yolk index at 40 wk-old of layers.

Data on chemical composition of eggs produced by Pekin duck layers fed the different diets supplemented with copper sulfate at 42 wks-old are presented in Table (10). Significant differences were observed among the experimental groups in moisture content, dry matter and ether extract. While, no significant differences of crude protein and ash due to studied treatments. Dry matter and ether extract were significantly decreased by about 6.91 and 20.95 % by feeding diet supplemented with 500 mg Cu SO_4 /kg, respectively as compared to the control group. While crude protein and ash were slightly increasing by feeding all diets supplemented with $CuSO_4$ compared to the control, but without significant. The present results of egg quality characteristics and chemical composition may be due to the effects of copper on internal body functions during egg formation especially lipid metabolism, these results are in agreement with those findings of ***Metwally (2002)*** who reported that copper sulfate supplementation diets had no significant effects on albumen %, shell %, shape index, yolk index, Haugh Units and specific gravity. Similar results were reported by ***Pesti and Bakalli (1998); Mabe***

et al.(2003);Bank et al. (2004), and Lien et al. (2004). On the other hand, the highest yolk % and shell thickness were observed from feeding 150 mg Cu/kg. *(Ankari et al., 1998).*

Economic efficiency

Calculations were carried out according to the prices of feed ingredients, additives and eggs prevailing during year 2006 / 2007 as listed in Table (11). The economic efficiency values of Pekin laying ducks fed diets supplemented with copper sulfate during the entire period from 22-45 weeks of age were 2.23 , 31.28 , 20.83 and 38.24 % by feeding diets supplemented with 0.0 , 100 , 300 and 500 mg $CuSO_4$ / kg , respectively . The treatments resulted in clear improvement of net return per duck and economic efficiency compared to the control group .These results may be due to the improvement of egg production rate and feed conversion as will as decreasing amount of feed consumption.

CONCLUSION

Results generally showed that the best results in most studied traits were recorded for the supplementation of duck diets with copper sulfate up to 500 mg / kg during pre laying and laying periods. So, it could be advised that the supplementation of copper sulfate to growing and laying duck diets may be an alternative method to maximize the productivity and profitability of Pekin ducks with no adverse effects on laying performance, hatchability traits and economic efficiency .

Table (1): Composition and calculated analysis of the basal diet fed to Pekin ducks throughout the experimental period.

Ingredients %	Grower	Layer
Yellow corn	63.00	66.00
Soya bean meal (44 %)	15.50	21.50
Wheat bran	17.75	2.70
Di-calcium phosphate	1.25	1.50
Limestone	1.80	7.60
Vit & Min. premix *	0.30	0.30
Salt (NaCl)	0.30	0.30
DL. Methionine (97%)	0.10	0.10
Total	100.0	100.0
Calculated Analysis **		
Crude protein %	15.04	15.50
ME (Kcal / kg)	2687	2724
Calcium (%)	1.041	3.410
Available phosphorus (%)	0.41	0.45

* Each 3kg of Vit .and Min. premix contains 100000000 IUVit A;2000000 IU Vit.D3;10 g Vit.E; 1 g Vit.K ; 1 g Vit B1; 5 g Vit B2 ;10 mg Vit.B12 ; 1.5 g Vit B6; 30 g Niacin ;10 g Pantothenic acid ;1g Folic acid;50 mg Biotin ; 300 g Choline chloride; 50 g Zinc; 4 g Copper; 0.3 g Iodine ; 30 g Iron; 0.1 g Selenium ;60g Manganese ;0.1 g Cobalt; and carrier $CaCo_3$ to 3000 g .

** According to NRC (1994)

Table (2): Live body weight, feed consumption and age at different egg production levels (Means ±SE)) of Pekin laying ducks as affected by copper sulfate supplementation levels to the diets during experimental periods.

Criteria	Copper sulfate level (mg / kg)			
	0.0	100	300	500
Live body weight (g)				
14 wks	2370±190	2400±160	2480±175	2450±185
22 wks	2100±220	2190±280	2150±200	2140±190
45 wks	2010±260	2050±270	2090±240	1990±150
Change of LBW* (g) between 22 - 45 wks				
	- 90	- 140	- 60	-150
Feed consumption (g /duck/day) during 14 to 22 wks				
	165±14	159±17	160±16	154±20

* LBW =live body weight

Table (3): Age (days) at different egg production levels (Means ±SE)) of Pekin laying ducks as affected by copper sulfate supplementation levels to the diets during experimental periods.

Criteria	Copper sulfate level (mg / kg)				P.*
	0.0	100	300	500	
First egg	149.3±6.0[a]	149.3±3.8[a]	143.7±0.6[a]	136.3±5.3[b]	0.05
25% production	154.7±6.1	157.3±1.5	154.7±7.4	146.0±1.7	Ns
50% production	164.7±15.5	163.3±17.0	159.3±5.1	158.7±6.5	Ns
Peak of egg production	201.0±5.3[a]	197.0±3.0[a]	189.7±5.0[b]	188.0±5.3[b]	0.05

a,b, .means in the same row bearing different superscript are significantly different ($p \leq 0.05$).
* P = probabilities

Table (4): Egg number, laying rate, egg mass and egg weight (Means ±SE) of Pekin laying ducks as affected by copper sulfate supplementations to the diets during experimental periods.

Criteria	Copper sulfate level (mg / kg)				P.*
	0.0	100	300	500	
Egg number / duck / 28 day					
22 - 25	11.7 ±2.4^{b}	12.6 ±1.0^{b}	16.0 ±0.9^{a}	16.5 ±1.1^{a}	0.01
26 - 29	18.9 ±1.6^{b}	21.6 ±1.8^{ab}	21.8 ±2.3^{ab}	24.4 ±2.2^{a}	0.05
30 - 33	18.5 ±1.9^{c}	20.5 ±1.9^{bc}	23.3 ±1.6^{ab}	25.1 ±1.4^{a}	0.01
34 - 37	21.2 ±1.4^{b}	24.2 ±1.4^{ab}	24.8 ±2.3^{a}	25.4 ±1.8^{a}	0.05
38 - 41	21.3 ±1.9	22.5 ±1.0	23.9 ±1.7	24.0 ±1.4	NS
42 - 45	13.4 ±0.4^{b}	17.1 ±1.6^{a}	17.5 ±2.2^{a}	18.8 ±1.4^{a}	0.01
Overall period	105.1±9.6^{c}	118.5±8.7^{bc}	127.3±11^{ab}	134.2±9.3^{a}	0.05
Laying rate %					
22 - 25	41.8±8.4^{b}	44.9±3.5^{b}	57.3±3.3^{a}	58.8±4.1^{a}	0.01
26 - 29	67.4±5.8^{b}	74.7±6.4^{ab}	77.9±8.1^{ab}	87.2±7.9^{a}	0.05
30 - 33	71.0±7.4^{b}	73.2±6.6^{b}	79.7±5.6^{ab}	89.3±5.1^{a}	0.05
34 - 37	75.7±4.9^{b}	86.5±5.1^{ab}	88.6±8.3^{a}	90.5±6.5^{a}	0.05
38 - 41	76.1±5.4^{b}	80.2±3.6^{ab}	85.3±6.0^{a}	85.9±5.3^{a}	0.01
42 - 45	47.7±1.5^{b}	61.2±5.8^{a}	62.7±8.0^{a}	67.3±4.9^{a}	0.05
Overall period	62.5±7.4^{c}	70.5±3.6^{bc}	75.8±4.3^{ab}	79.9±0.6^{a}	0.01
Egg mass (g / duck /28 day)					
22 - 25	717±125^{b}	806±50^{b}	1013±35^{a}	1047±45^{a}	0.01
26 - 29	1230±105^{b}	1436±103^{ab}	1461±109^{a}	1640±135^{a}	0.01
30 - 33	1373±131^{b}	1392±149^{b}	1509±53^{ab}	1684±96^{a}	0.05
34 - 37	1518±98^{b}	1684±96^{ab}	1779±121^{a}	1751±101^{a}	0.05
38 - 41	1360±102^{b}	1524±61^{ab}	1630±123^{a}	1695±113^{a}	0.01
42 - 45	904±54^{b}	1155±104^{a}	1212±144^{a}	1324±89^{a}	0.01
Overall period	7102±649^{c}	7997±578^{bc}	8604±743^{ab}	9141±630^{a}	0.01
Egg weight (g)					
22 - 25	61.6±2.5	64.0±1.4	63.2±1.6	63.6±2.7	NS
26 - 29	65.1±0.3	66.8±2.3	67.4±2.1	67.2±0.9	NS
30 - 33	69.0±2.9	67.9±1.1	67.7±3.2	67.2±0.5	NS
34 - 37	71.3±3.6	69.50±0.7	71.8±2.9	69.1±1.8	NS
38 - 41	63.9±1.6^{c}	67.9±0.5^{b}	68.2±0.9^{b}	70.5±0.5^{a}	0.05
42 - 45	67.7±2.1	67.5±0.9	69.1±0.7	70.3±0.6	NS
Overall period	67.6±1.3	67.5±0.4	67.6±1.6	68.0±0.8	NS

a,b,c :means in the same row bearing different superscript are significantly different ($p \leq 0.05$).

* P. = probabilities

Table (5): Feed consumption and feed conversion (Means ±SE) of Pekin laying ducks as affected by copper sulfate supplementations to the diets during experimental periods

Criteria	Copper sulfate level (mg / kg)				P.*
	0.0	100	300	500	
Feed consumption (g / duck / 28 day)					
22 - 25	5812±357^{a}	4284±208^{c}	5543±577^{ab}	4975±322^{bc}	0.01
26 - 29	5412±264^{a}	4427±638^{b}	5613±100^{a}	5358±392^{a}	0.05
30 - 33	6987±157^{a}	6410±183^{c}	6805±164^{ab}	6592±167^{bc}	0.01
34 - 37	7488±632^{a}	6585±534^{bc}	7320±282^{ab}	6298±403^{c}	0.05
38 - 41	5216±581^{b}	4992±168^{b}	5888±252^{a}	4962±158^{b}	0.05
42 - 45	5842±169^{ab}	5608±196^{b}	6151±856^{a}	5638±156^{b}	0.05
Overall period	36757±964^{ab}	32306±1064^{c}	37320±1029^{a}	33823±999^{bc}	0.05
Feed conversion (g. feed / g. egg mass)					
22 - 25	8.23±1.14^{b}	5.32±0.07^{a}	5.46±0.38^{a}	4.42±0.30^{a}	0.01
26 - 29	4.43±0.54^{b}	2.98±0.85^{a}	3.86±0.22^{ab}	3.27±0.10^{a}	0.05
30 - 33	5.13±0.60^{b}	4.64±0.44^{ab}	4.52±0.25^{ab}	3.93±0.28^{a}	0.05
34 - 37	4.93±0.09^{c}	3.92±0.11^{ab}	4.13±0.31^{b}	3.59±0.19a	0.01
38 - 41	3.83±0.22^{c}	3.28±0.04^{ab}	3.62±0.28b^{c}	2.96±0.21^{a}	0.01
42 - 45	6.49±0.54^{b}	4.88±0.48^{a}	5.14±0.84^{b}	4.27±0.37^{a}	0.01
Overall period	5.18±0.64^{b}	4.04±0.31^{a}	4.34±0.13^{a}	3.70±0.11^{a}	0.05

a,b,c :mans in the same row bearing different superscript are significantly different ($p \leq 0.05$).
* P. = probabilities

Table (6): Fertility and hatchability % (Means ±SE) of eggs produced by Pekin laying ducks as affected by copper supplementations to the diets

Criteria	Copper sulfate level (mg / kg)				P.*
	0.0	100	300	500	
Total egg set	360	360	360	360	
Egg weight g	75.34±0.49	74.74±0.52	74.07±1.47	75.68±0.70	Ns
Fertility %	90.97±2.42	91.53±1.38	91.53±2.80	90.91±3.28	Ns
Hatchability of setting eggs %	76.30±5.92	77.98±2.12	78.55±3.90	81.31±3.80	Ns
Hatchability of fertile eggs %	82.55±3.58^{b}	84.26±0.80^{b}	85.49±1.59^{ab}	88.55±1.83^{a}	0.05
Early E.M** %	5.25±0.83^{a}	5.75±1.15^{a}	5.21±0.34^{a}	3.57±0.64^{b}	0.05
Late E.M. %	12.19±2.87	9.99±0.68	9.30±1.36	7.87±2.28	Ns
Chick weight g	47.30±0.79	46.83±0.74	47.53±0.26	48.24±1.45	Ns

a,b :means in the same row bearing different superscript are significantly different ($p \leq 0.05$).
* P. = probabilities ** EM = embryonic mortality

Table (7): Blood serum constituents for 45 wks-old (Means ±SE) of Pekin laying ducks as affected by copper sulfate supplementations to the diets during experimental periods.

Criteria	Copper sulfate level (mg / kg)				P.*
	0.0	100	300	500	
Total protein g/dl	6.73±1.27	6.40±0.17	7.63±1.10	5.67±0.98	Ns
Triglycerides mg /dl	653.3±23.1^{a}	586.7±31.7^{b}	633.3±28.8^{ab}	508.3±27.3^{c}	0.01
Total cholesterol mg/dl	143.3±17.5^{a}	145.0±16.3^{a}	113.3±13.1^{b}	110.0±17.3^{b}	0.05
HDL cholesterol mg/dl	77.7±6.3^{a}	65.3±5.8^{ab}	60.0±7.2^{b}	78.7±9.8^{a}	0.05
GOT U/L	138.3±14.4	121.7±16.4	111.7±14.9	110.0±13.3	Ns
GPT U/L	65.0±8.7	70.0±5.9	61.7±2.9	56.7±2.9	Ns

a,b,c :means in the same row bearing different superscript are significantly different ($p \leq 0.05$).
* P = probabilities

Table (8): Egg components and some egg quality measurements (Means ±SE).of eggs produced by Pekin laying ducks as affected by copper supplementations at 28 weeks of age.

Criteria	Copper sulfate level (mg / kg)			
	0.0	100	300	500
Egg weight gm	67.8±4.4	64.6 ±9.1	66.3 ±3.4	66.5±6.0
Yolk weight %	31.8 ±1.7	29.7 ±3.9	31.2 ±2.0	30.2 ±3.5
Albumen weight %	56.3 ±1.4	58.2 ±3.8	57.3 ±2.5	57.7 ±4.5
Egg shell weight %	11.9 ±0.7	12.2 ±1.4	11.6 ±1.0	12.1 ±1.4
Haugh units	94.7 ±4.7	96.7 ±5.0	98.0 ±3.4	98.0 ±1.2
Eggshell thickness (mm)	0.39±0.03	0.39 ±0.01	0.39 ±0.03	0.39 ±0.02
Yolk index	0.60±0.04	0.63 ±0.08	0.60 ±0.04	0.65 ±0.04
Shape index	0.76±0.02	0.77 ±0.06	0.76 ±0.03	0.77 ±0.03

No significant differences were observed among treatments in all criteria

Table (9): Egg components (%) and some egg quality measurements (Means ±SE).of eggs laid by Pekin laying ducks as affected by copper supplementations at 40 weeks of ages.

Criteria	Copper sulfate level (mg / kg)			
	0.0	100	300	500
Egg weight gm	69.9 ±8.0	67.0 ±4.4	71.5 ±5.2	70.5 ±5.6
Yolk weight %	32.0 ±1.3	32.1 ±2.2	30.6 ±1.5	31.6 ±1.0
Albumen weight %	56.0 ±1.1	56.2 ±2.8	57.7 ±1.4	57.2 ±1.3
Egg shell weight %	11.9 ±0.8	11.5 ±1.0	11.6 ±0.9	11.2 ±1.0
Haugh units	90.2 ±11.3	84.8 ±7.0	89.8 ±8.3	95.5 ±8.7
Eggshell thickness (mm)	0.41 ±0.01	0.39 ±0.02	0.41 ±0.02	0.38 ±0.02
Yolk index	0.37 ±0.02	0.38 ±0.02	0.39 ±0.02	0.40 ±0.03
Shape index	0.79 ±0.05	0.80 ±0.02	0.77 ±0.04	0.80 ±0.03

No significant differences were observed among treatments in all criteria

Table (10): Chemical composition of eggs produced by Pekin laying ducks at 42 wks-old (Means ±SE) as affected by copper sulfate supplementations to the diets.

Criteria	Copper sulfate level (mg / kg)				P.*
	0.0	100	300	500	
Moisture	68.02±0.96^{b}	68.53±0.55^{b}	69.73±0.55^{ab}	70.23±0.93^{a}	0.05
Dry matter	31.98±0.96^{a}	31.46±0.55^{a}	30.27±0.6^{ab}	29.77±0.93^{b}	0.05
Crude protein	13.33±2.12	13.80±2.46	13.93±1.94	13.83±2.86	NS
Ether extract	16.61±2.99^{a}	16.01±1.28^{a}	13.64±1.51^{b}	13.13±1.35^{b}	0.05
Ash	1.11±0.17	1.12±0.11	1.19±0.05	1.22±0.06	NS

a,b :mans in the same row bearing different superscript are significantly different ($p \leq 0.05$).
* P. = probabilities

Table (11): Economic efficiency of Pekin laying ducks fed diets supplemented with copper sulfate (mg / kg) from 22-45 weeks of age.

Criteria	Copper sulfate level (mg / kg)			
	0.0	100	300	500
Average feed consumption kg per duck during overall period	36.757	32.306	37.320	33.823
Feed cost , L.E [1]	52.38	46.03	53.18	48.20
$Cu.SO_4$ cost , L.E. [2]	---	0.13	0.44	0.72
Total feed cost , L.E	52.38	46.16	53.62	48.92
Number of small egg /duck [3]	30.6	34.2	37.7	40.9
Number of medium egg /duck [3]	39.7	44.7	48.1	50.5
Number of large egg /duck [3]	34.8	39.6	41.4	42.8
Total price of eggs /duck , L.E [4]	53.55	60.60	64.53	67.58
Net return / duck . LE	1.17	14.44	10.91	18.66
EEF % [5]	2.23	31.28	20.35	38.14

L.E = Egyptian pound
1- Cost of one kg feed 1.425 LE at time of experiment .
2-Cost of 500 gm copper sulfate pentahydrate =19.0 LE .
3-Small egg (first 8 wks), medium (second 8 wks) and large after 16 wks of production.
4-Local price of one egg (small = 0.25 , medium = 0.5 and large = 0.75 LE).
5- EEF = economic efficiency = (Net return LE / Total feed cost LE x100).

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تأثير إضافة كبريتات النحاس على الأداء الانتاجى في البط البكينى
٢ – أداء إنتاج البيض وصفات التفريخ

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أجرى هذا البحث لدراسة تأثير إضافة مستويات متدرجة من كبريتات النحاس إلى علائق البط البكينى في فترة النمو و إنتاج البيض على المظاهر الإنتاجية لإنتاج البيض وصفات التفريخ ومقاييس جودة البيض و التحليل الكيماوي له والكفاءة الاقتصادية . تم استخدام عدد ١٦٦ طائر بط بكيني عمر ١٤ أسبوع (١٤٤ بطة و ٢٤ ذكر) تم تقسيمهم إلى أربعة مجاميع تجريبية (٣٦ أنثى و ٦ ذكور لكل مجموعة تجريبية) ثم وزنت طيور كل مجموعة وتم توزيعها عشوائيا على ثلاث مكررات متساوية وتم استخدام علائق بياض انتاجي من ١٩ أسبوع حتى نهاية التجربة (٤٥ أسبوع) وتم تقسيم العليقة المستخدمة إلى أربعة أجزاء ليضاف إلى كل منها أحد المستويات المستخدمة من كبريتات النحاس (صفر ، ١٠٠ ، ٣٠٠ ، ٥٠٠ مجم / كجم عليقة) وتم تقديمها للمجموعات التجريبية الأربعة خلال فترة التجربة ، وتم وزن البط عند ١٤ ، ٢٢ ، ٤٥ أسبوع وتم تسجيل استهلاك العليقة والبيض الناتج من حيث العدد والوزن (لكل فترة ٢٨ يوم) وتم جمع البيض وتخزينه لمدة عشرة أيام على فترات مختلفة من التجربة لإجراء عملية تفريخ له وحساب نسبة الخصوبة والفقس للبيض الكلى والمخصب وحساب النفوق الجنينى المبكر والمتأخر وتم إجراء تقدير لبعض مقاييس جودة البيض الخارجية والداخلية عند عمر ٢٨ و ٤٠ أسبوع من العمر وتم أخذ عينات دم عند عمر ٤٥ أسبوع من البط لتقدير محتويات سيرم الدم من البروتين الكلى والجلسريدات الثلاثية والكولسترول الكلى وHDL كولسترول وإنزيمات الترانس أمينيز (GOT,GPT) وتم تقدير الكفاءة الاقتصادية خلال فترة إنتاج البيض و من التحليل الاحصائى يتضح الأتي:-

- تحسن معنوي نتيجة المعاملات التجريبية في عدد البيض وكتلة البيض الناتج لكل بطة وكذلك معدل إنتاج البيض اليومي وأيضا انخفضت كمية العليقة المستهلكة لكل بطة مع تحسن الكفاءة الغذائية لإنتاج البيض.
- تحسنت نسبة الفقس للبيض المخصب وكذلك انخفض معدل النفوق الجنينى المبكر معنويا بالمعاملات بينما لم تتأثر صفات الخصوبة والنفوق الجنينى المتأخر ووزن الكتكوت عند الفقس.
- لم تتأثر صفات الدم المدروسة معنويا بالمعاملات وان كانت قيم كل من الجلسريدات الثلاثية والكولسترول وإنزيمات الترانس أمينيز قد انخفضت .

- لم تتأثر معنويا مقاييس جودة البيض المختلفة عند عمر ٢٨ و ٤٠ أسبوع بينما تأثرت المادة الجافة والمستخلص الاثيرى لمحتويات البيضة الداخلية حيث زادت قيم المادة الجافة وانخفضت قيم المستخلص الاثيرى بالمعاملات .
- تحسنت الكفاءة الاقتصادية وصافى العائد لكل بطة بالمعاملات التجريبية

من النتائج السابقة يمكن الاستنتاج بأن إضافة كبريتات النحاس إلى علائق البط البياض بمعدلات تصل إلى ٥٠٠ مجم / كجم عليقة يؤدى إلى تحسن ملحوظ في مقاييس الأداء الانتاجى وصفات التفريخ والكفاءة الاقتصادية وبدون أي تأثير معاكس على هذه المقاييس.