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EFFECT OF DIETARY SOURCES AND LEVELS OF COPPER SUPPLEMENTATION ON GROWTH PERFORMANCE, BLOOD PARAMETERS AND SLAUGHTER TRAITS OF BROILER CHICKENS

O. A.H. El-Ghalid[1], Ghada Mostafa El Ashry[2], Soliman Mohamed Soliman[2] and A.M.Abd EL-Hady[1*]

[1]Poult. Prod. Dep., Fac. of Agric., Alexandria Uni. (21545), Alexandria, Egypt.

[2]Regional Centre for Food Feed, Agric. Res. Centre, Minis. of Agric., Dokki, Egypt.

***Corresponding author:** Ahmed Mohamed Abd HadyEL- E-mail: ahmed75atta@yahoo.com

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ABSTRACT: This research paper was carried to determine the effect of dietary supplementation of copper at levels 50 and100 ppm, from various sources, inorganic (copper sulfate, CuSO4) or organic (copper-methionine, Cu-Met and copper-glycine, Cu-gly) on the productive traits, blood parameters, carcass traits and cecal bacterial count of broiler chickens. Three hundred and fifty Cobb 500 broiler chickens at 7 days of age were randomly divided into 7 groups (each of 50 birds): the 1st group was fed a commercial basal diet without any supplementation (control), the 2nd and 3rd groups were fed control diet supplemented with 50 and 100 ppm of $CuSO_4$, the 4th and 5th groups were fed control diet supplemented with Cu-Met at 50 and 100 ppm and the 6th and 7th groups were fed basal diet supplemented with Cu-gly at 50 and 100 ppm.

Results showed that birds fed basal diet supplemented with inorganic or organic Cu had significantly better live body weight, weight gain, feed conversion ratio, economic efficiency and production index, while feed consumption was reduced compared with control group. However, the groups supplemented with organic Cu showed significantly improved on performance traits compared with the other groups. Supplementation of dietary Cu from different sources significantly decreased serum total lipids, triglycerides, cholesterol, low density lipoprotein, Aspartate aminotransferase, Alanine aminotransferase, creatinine and malondialdehyde. On the other hand supplementation of dietary Cu from different sources significantly increased the levels of red blood cells, hemoglobin, packed cell volume, glucose, globulin, alkaline phosphatase, triiodothyronine hormone, serum immunoglobulin (IgG and IgM) and total antioxidant capacity compared with the control group. Additionally, percentage of dressing and spleen were increased, while abdominal fat was decreased but not significant in Cu-supplemented birds. Moreover, Cu supplementation decreased total bacterial count (*Salmonella*, *E. coli* and *Proteus)* compared with the control. In conclusion, Cu supplementation with 100 ppm of Cu-gly or Cu-Met of diet were improved the growth performance, and physiological and immune response of broiler chickens. Broilers fed organic Cu had better growth and immune response than those fed inorganic Cu.

Key words: Copper; Performance; Hematology; Immunology; Broilers

INTRODUCTION

The quintessence of copper for chicken and animal has been well studied (Davis and Mertz, 1987). The prospect sources of copper used in the commercial feed industry should be investigated for biological availability as well as integrity. Copper is often added from various compounds to the poultry diet as an antimicrobial agent at different concentrations. Copper is an important component of various enzymes inside and outside cells like cytochrome oxidase, lysyl oxidase, ceruloplasmin and superoxide dismutase (Klasing, 1998). Copper sulfate ($CuSO_4$) supplementation at levels of 125-250 ppm increased growth performance and improved feed conversion (FCR) in broilers (Paik, 2001) and pigs (Cromwell *et al.*, 1989). Pesti and Bakalli (1996) noticed that add up to 125-250 ppm of Cu from cupric sulfate pentahydrate and cupric citrate decreased cholesterol concentration and breast muscle.

In another study, although, Cu-Met linearly increased level of serum cholesterol, but reduced serum triglycerides level (Chowdhury *et al.*, 2004). It was else noted that the addition of high concentrations of copper led to a high level of secretion of copper through the manures. Having a high proportion of Cu in the manures deters the regular fermentation process, their accumulation in soil reasons environmental problems. Copper in the shape of claw, complexes or proteins, used in animal diets, was considered as an alternative to inorganic sources to solve the above problems. This may be due to a better uptake, thus enhancing the efficient use of these sources Cu (Guo *et al*., 2001).

Most previous studies have shown that organic compounds contain some minerals in their composition that make them better used by animals. These compounds involve emulsifiers, consisting of ionic minerals associated with amino acids (Wang *et al*., 2007). The absorption of elements derived from metals and organic compounds is likely to be altered by the mucous membrane of the intestine by transferring amino acid and thus the body's ability to retain it substantially (Vieira, 2008). Amino acids with low molecular mass, such as glycine, are chemically collected from one to three fine elements, such as Cu or Fe, and have greater and clearer stability. Manner *et al*. (2006) studied that the establishment and availability of intestinal chelate based on the shortest amino acids, glycine, is 25% raise than methionine and lysine cache.

The vision of this research paper was to study the influence of different sources and levels of inorganic and organic copper on the productive performance, blood profile and immune response of broiler chickens.

MATERIALS AND METHODS

This study was conducted during the winter season (January to February, 2016) at the Poultry Research Center and Laboratories of the Poultry Production Department, Faculty of Agriculture (El-Shatby), Alexandria University, Egypt.

Birds and experimental design

A total number of 350 unsexed Cobb500 broiler chicks, aged 7days and averaged 167 gm body weight, were divided randomly into seven treated groups (50 birds each). Each group was subdivided into 5 replicates, each with 10 birds. Birds were kept under the same administrative, healthy and environmental conditions. The ingredients and calculated analysis of the experimental diets are shown in Table (1). Diet was formulated to cover the nutrient requirements of broiler chickens as urged by the (NRC, 1994). The seven treatment groups were fed as follows: The 1st group of birds was fed basal diet and served as control, birds of the 2nd and 3rd groups were fed the same basal diet supplemented with 50 and 100 ppm copper sulfate, birds on 4th and 5th groups were fed basal diet supplemented with 50 and 100 ppm copper methionine, and birds of the 6th and 7th groups were fed control diet supplemented with 50 and 100 ppm copper glycine. During the starter period the basal diet consisted of 22% crude protein and 3050 kcal/ kg ME, while during the grower period it contained 20% crude protein and 3150 kcal/ kg ME. The trial lasted 5 weeks.

Housing and husbandry

The chicks were stayed in the battery brooders in a semi-open room equipped with two tired fans to maintain normal ventilation. Chicks were fed *ad libitum* throughout the experiment. A light schedule similar to commercial conditions was used until seventh day (i.e. 23 hours of light), followed by 20 hours of light from day 8 until 35 days before slaughter (i.e. 8-35 days of age). The ambient temperature was maintained at thermal neutrality according to the bird's hippocampus; the mean outdoor minimum and maximum temperature and relative humidity during the broiler period were18 ^{o}C and 25 ^{o}C, and 66.7 %, respectively. The brooding temperature (internal) was 32, 30, 29 and 23-26^{o}C at 1-7, 8-14, 15-20 and 21-35 days of age, respectively (gradually decreased).

Collection of growth performance and efficiency data

Individual live body weight (LBW, g), body weight gain (BWG, g), and feed consumption (FC, g) were recorded weekly throughout the trial period (7-35 d of age). For each replicate within treatment groups, feed conversion ratio (FCR) was estimated according to the equation: FCR = FC (g) / BWG (g). Economic efficiency of experimental diets was estimated to be the ratio between income and feed cost consumed during the experimental growth period. All experimental diets prices were calculated according to the local market price at the same time of the experiment in 2016 by the Egyptian pound (L.E.). Economic efficiency (%) = (Net revenue/Total feed cost)*100. Net revenue = Total revenue - Total feed cost. European production efficiency index (EPEI, production index) was calculated throughout the experiment according to Hubbard broiler management manual as follows.

$$\mathbf{EPEI} = \frac{\mathbf{BW\ (kg)}\,x\ \mathbf{SR}}{\mathbf{PP}\ x\ \mathbf{FCR}}\,x\ \mathbf{100}$$

Where:

EPEI= European Production Efficiency Index, BW= Body weight (kg), SR= Survival rate (100% - Mortality rate), PP= Production period (days), FCR= Feed conversion ratio (kg feed / kg gain)

Blood collection and hemato-biochemical analysis

Finally of the trial period, ten fasted chicks from each group at 35 day of age were randomly assigned for slaughter. Blood specimens (about 3 ml) were assembled prior to slaughter of the wing vein to analyze hemato-biochemical parameters. Heparin was used as anticoagulant, but part of each sample was taken without heparin to obtain serum. Plasma or serum were separated by blood centrifugation at 3500 rpm for 20 minutes and stored at –20°C for later analysis. Part of each blood sample was used to evaluate blood hematological parameters including red blood cells (RBCs), white blood cells (WBCs) and lymphocytes were counted. Hemoglobin (Hb) concentration and the percentage of packed cells volume (PCV) were measured.

Serum total protein and albumin were measured by using a commercial kit from Sentinel CH (Milano, Italy) and a spectrophotometer (Beckman DU-530, Germany). The values of globulin were acquired by subtracting albumin values from the parallel values of total protein, because fibrinogen usually contained an insignificant fraction. Plasma glucose concentrations, total tri-iodothyronine (T3), serum total lipids, total cholesterol and triglyceride were confirmed by utilizing certain kits received from CAL-TECH Diagnostics, Inc., Chino, CA, USA. Serum low density lipoprotein (LDL), high density lipoprotein (HDL), the activities of aspartate amino transferase (AST), alanine amino transferase (ALT), creatinine were gauged using colorimetric method by commercial kits obtained from Reactivos GPL, Barcelona, Spain. Alkaline phosphatase (ALP) concentration was specified approving to the colorimetric method. Serum immunoglobulin (IgG and IgM) fractions, calcium and inorganic phosphorus concentrations were decided. The lipid peroxidation was fixed by measuring the activity of the biomarker total antioxidant capacity (TAC) and malondialdehyde (MDA) were deliberated in plasma.

Slaughter traits

Finally of trail period, 10 chicks from each group were casually selected for slaughter. Chicks were fasted 12 hours before slaughter at morning 8.00 O'clock and were weighed separately. After scalding, collect the feather and remove the viscera. Dressing and internal organs (liver, gizzard, heart, pancreas, abdominal fat, intestine, spleen, thymus gland and bursa) were weighted and percentages of dressing and organs were calculated based on live body weights.

Bacterial count

At the time of slaughter, 5 samples of cecal content for each treatment were taken for bacterial counting. The effect of dietary treatments on the microbial activity of the digestive system include: total bacteria count which was determined according to the method of (ICMSF, 1980), as well as the detection of Salmonella and Escherichia coli strains following the ISO-6579: 2002 food microbiology procedure employing the horizontal method of food and animal feeding stuffs (ISO Standards catalogue 07.100.30; WHO 2010).

Statistical analysis

Data were tested using IBM SPSS statistics for windows, version 23 (IBM Crop, 2015). Means and standard errors (SE) of the traits under study were computed. Percentage data of the studied traits were converted to stationary pocket or square root prior to analysis. Data were then analyzed of variance using the next model:

$Y_{ij} = \mu + T_i + e_{ij}$

Where:

Y_{ij} = Observation value of trait.

μ = Overall mean.

T_i = Treatment effect.

e_{ij} = The experimental error.

RESULTS

Data of the production performance, economical efficiency and production index are shown in Table (2). All sources and levels of Cu supplementation created significant ($p \leq 0.05$) increase in body weight (BW) at 35 d of age and body weight gain (BWG) from 7-35 d, when compared with the control group. However, the previous treats were superior for the groups supplemented with organic Cu compared with the other groups. Moreover, broilers that fed diets supplemented with different sources and levels of Cu displayed lower feed consumption (FC) and better feed conversion ratio (FCR) when compared with the control group, with significant differences shown by those fed organic Cu. They had significantly ($p \leq 0.05$) better economical efficiency and production index compared with the control group, while the best values were recorded for groups that fed on organic Cu.

Data showed also that feeding diets supplemented with different sources and levels of Cu significantly increased RBCs count, hemoglobin concentration, PCV, WBCs, and lymphocytes compared to control group (Table 3), with the higher values ($p \leq 0.05$) being recorded for organic Cu supplementation groups, except for WBCs count. Moreover, broilers fed basal diet supplemented with organic Cu had significantly higher RBCs, hemoglobin, PCV and lymphocyte than other groups. It is worthy to notice that, all supplementations of Cu had no significant effects on total protein and albumin, but significantly increased the levels of globulin, IgG, IgM, glucose, T_3 and TAC compared with the control group (Table 4). Broilers fed diets supplemented with organic Cu at different levels had significantly higher levels of IgG, IgM, glucose, T_3 and TAC than those fed diet supplemented with inorganic Cu and the control group. All Cu supplementations reduced serum total lipids, cholesterol, triglycerides and LDL, while increased HDL compared with control group. Furthermore, broilers fed basal diet supplemented with organic Cu had significantly low values of total lipids, cholesterol, triglycerides and LDL compared with other groups. Supplementations of Cu decreased creatinine, MDA, AST and ALT while increased ALP when compared with the control group. Broilers fed basal diet with organic Cu had significantly lower levels of MDA, AST and ALT than those fed diet with inorganic Cu.

All supplementations of Cu increased significantly the dressing percentage and numerically decreased abdominal fat compared with the control group, whereas the lowest values were recorded for organic Cu- fed groups compared by those fed inorganic and control diets (Table 5). No significant differences were detected among the various groups in the percentage of the primary lymphoid organs, bursa and thymus, while spleen percentage was significantly higher in the organic Cu-fed groups compared with the control one.

All supplementations of Cu decreased the total bacterial count, *Salmonella*, *E. coli* and *Proteus*, compared with the control group (Table 6). Broilers fed basal diet supplemented with organic Cu recorded significantly lower counts of *Salmonella*, *E. coli* and *Proteus* than the other supplemented groups. However, no significant differences were found among all supplemented groups regarding total bacterial count.

DISCUSSION

Growth performance and Economic efficiency

The current study indicates that copper supplementation, both inorganic and organic, to chicken diets improves the growth rate, FCR, economic efficiency, production index and reduces FC of broilers as compared to the non-complementary diet. Chickens fed diet with organic copper, i.e. Cu-Met or Cu-gly, showed better growth performance than other groups. The data of FC are consistent with those reported by Idowu *et al*. (2006), who noted that increasing Cu level significantly decreased feed intake. But, Metwally (2002) found no significant effect on the level of dietary copper on FI in chickens. Cu-Met at 50 ppm and Cu-gly at 100 ppm significantly improved FCR compared to $CuSO_4$. In agreement with the current resulting, Wang *et al.* (1987) observed that feeding high levels of methionine supplementation with copper gave the best response. Wedekind *et al.* (1992) suggested that metal-amino acid chelates or complexes furnish trace elements that absorb more efficiently from the intestine than those of an inorganic shape.

According to Zhou *et al.* (1994), the mechanisms by which Cu can enhance the productive traits may include: 1) effect on microflora population; 2) increased mitogenic activity; 3) increased growth hormone secretion of the pituitary gland; 4) increased secretion of nerve peptide; or 5) modified post-translational regulatory peptides.

Hematological parameters of blood

The higher number of RBCs recorded with dietary Cu-supplemented may be due to Cu involvement in hemoglobin synthesis. Studies conducted by Makaraski and Zdura (2006) shown that supplementing turkey's diet with Cu lysine chelate has a significant effect on the level of hematological indices. Addition of the antibiotic and Cu products performed in reduced levels of RBC and HCT paralleled with RBC and HCT in the control group. The MCV value was decrease in the Cu-supplemented groups paralleled with that in control group (Kim *et al*., 2011).

Blood biochemical parameters

The highest serum protein was recorded in chickens that received organic Cu. An increase in protein content may indicate faster biosynthesis of tissue protein, or a slowing down of protein metabolism. Complexes of elements with amino acids or proteins can be ingested in a non-altered form the intestine mucous membrane using the amino acid transportation system, which is higher absorbed by organisms. Copper-Met and Cu-gly had a positive effect on glucose, T_3, IgG, IgM, TAC levels, and reduced MDA, total lipids, cholesterol, triglycerides and LDL concentrations. Kim *et al*. (2011) showed that IgG constituted the bigger fraction of immunoglobulin in chicken serum, succeed by IgM. Treatment of broilers with Cu methionine and Cu glycine at 50-100 ppm increased IgG and IgM levels in the blood. Ferrari and Cagliero (1993) found a positive impact of amino acid chelates on immune system functions, improving the health state and vitality of chickens. The addition of Cu glycine to the feed ingredients reduced the total cholesterol and LDL levels, and increased the level of HDL, compared with the addition of $CuSO_4$ group. Sevcikova *et al*. (2003) noted that the cholesterol level was decreased by 24.9% with an extension of copper in the shape of glycine chelate paralleled to the control group. Also, Aksu *et al.* (2010) observed a decrease in cholesterol and the LDL value with high HDL level in the plasma of chickens fed diets added with Zn, Cu and Mn in an organic shape. Mondal *et al*. (2007) found a lowering in cholesterol in broiler chickens' blood at 200 mg/kg of Cu in the shape of protein diet, while an addition of 400 mg/ kg led to high level of HDL. Changes in the total cholesterol content, lipoprotein molecules have HDL and LDL and triglyceride, indicated many changes in lipid transformation, cholesterol progressive from internal and external lipoproteins is eradicated to HDL, and its molecule is involved in invert transport to the liver. High density lipoprotein (HDL) value should represent more than 40% of cholesterol value so it reduces in unfavorable (Ganong, 2005).

The adding of Cu chelate in the shape of methionine or glycine reduced the activity of the enzyme AST and ALT level compared with their activity when inorganic Cu is applied. Many research papers by Makaraski *et al.* (2009) showed that the utilize of both lysine and copper chelate improved the activity of ALT and AST of male turkeys, which appears to emphasize the condensation of the essential amino acids necessary for the synthesis of proteins. Copper supplementation in the form of methionine or glycine resulted in low MDA, an indicator for oxidative stress, because it is involved in the antioxidant defense system, leading to possible damage due to oxidative stress (Kato *et al.*, 2007).

Slaughter traits

Copper supplements from different sources have significantly increased the percentage of dressing, spleen and numerically lower abdominal fat compared with control. In addition, chickens fed control diet supplemented with organic Cu had significantly higher dressing and spleen percentage and lower abdominal fat than other groups. The results of this study indicate that Ellen *et al*. (2012) observed that dressing percentage was significantly rising in the feeding group with 2.50, 11.25, 15 and 18.75 g/ton of amino acid chelate of Cu, Zn, Mn and Fe, respectively. The results of this study are consistent with Vladimir *et al*. (2010) who found that nutrient groups with trace elements in the form of proteins restricted to 50% Cu, 20% Fe, Zn and Mn had same effect on carcass yield. Yang *et al*. (2011) investigated that supplementation of graded levels of trace minerals to broiler diet did not have a significant impact on relative weight of spleen.

Bacterial count

Our results showed significant reduction in the number of pathogenic bacteria, indicating the role of Cu as a good element to relieve bacterial disorders in the digestive tract of broiler chickens. It is well known that healthy and stable intestinal microbial community plays a useful role in maintaining the structural and functional characteristics of the mucosa, affecting the immune system, as well as preventing the development of intestinal disease in chickens (Chambers and Gang, 2011). In addition, Chowdhury *et al*. (2004) showed that copper has a significant impact on the regulation of growth rate in broiler chickens, pathogenic bacteria in the jejunum small intestine were prevented by incremented with Cu supported by our results.

CONCLUSION

The results can be summarized that the addition of organic and inorganic copper to broiler chicken diets improved productivities traits, economic efficiency and production index. Chickens fed diet with organic copper, Cu-Met or Cu-gly showed better growth performance than other groups. The use of copper chelates increases hemoglobin synthesis by higher number of RBCs recorded with Cu-supplemented chickens' diet. Cu-Met and Cu-gly had a positive effect on immune profile, antioxidant status and enhanced lipid profile. An increase in protein content may indicate faster biosynthesis of tissue protein, or a slowing down of protein metabolism. Our results showed significant reduction in the number of pathogenic bacteria (*Salmonella, E. coli* and *Proteus*), indicating the role of Cu as a good element to relieve bacterial disorders in the digestive tract of broiler chickens. Further research papers are needed to investigate the effect of copper-Met and glycine chelates on the immune role and local defense mechanisms of the digestive system, which helps improve absorption and disease resistance in chickens.

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Table (1): Composition and calculated analysis of experimental diets offered to broiler chickens from 1 to 35 days of age.

Ingredients	Starter diet (1 to 21 days of age)	Growing diet (22 to 35 days of age)
Yellow Corn	53.90	59.26
Soybean Meal (44%)	30.38	25.12
Corn gluten meal (60%)	8.50	8.0
Soy oil	2.85	3.5
Mono calcium Phosphate	1.5	1.35
Lime stone	1.65	1.52
L-lysine	0.32	0.32
DL –methionine	0.10	0.13
Salt (Na Cl)	0.30	0.3
Sodium Bicarbonate	0.20	0.20
Broiler Premix *	0.30	0.30
Total %	**100**	**100**
Calculated analysis		
Crude Protein %	22	20
ME (kcal/kg) **	3050	3150
Ether extract, %	6.30	7.15
Calcium, %	0.92	0.84
Phosphorus available%	0.45	0.42
Methionine %	0.51	0.51
Lysine %	1.32	1.19
Methionine +Cystine %	0.98	0.89

*Each 3 kg of vitamin and mineral premix contain: vitamin A 12000000 IU, vitamin D3 5000000 IU, vitamin E 50000 mg, vitamin K3 3000 mg, vitamin B1 2000 mg, vitamin B2 8000 mg, vitamin B6 3000 mg, vitamin B12 15 mg, biotin 120 mg, Choline Chloride 400000 mg; folic acid 2000 mg, pantothenic acid 12000 mg, manganese 100000 mg, zinc 100000 mg, iron 40000 mg, copper10000 mg, iodine 1000 mg, selenium 200 mg and cobalt 100 mg.

**ME= Metabolic Energy

Table (2): Effect of different copper sources and levels on productive performance, economical efficiency and productive efficiency index of broiler chickens at 35 days of age.

Traits		LBW (7d)	LBW (35d)	BWG (7-35d)	FC (7-35d)	FCR (7-35d)	EE	EPEI
Control	0 ppm	168.2	1743[c]	1575[c]	3345[a]	2.12[a]	41.1[c]	170[c]
$CuSO_4$	50 ppm	167.5	1830[b]	1662.5[b]	3151[b]	1.93[b]	66.9[b]	201[a]
	100 ppm	167.0	1891[b]	1724[b]	3164[b]	1.83[b]	70.3[b]	210[b]
Cu-Met	50 ppm	168.0	2090[a]	1922[a]	3000[c]	1.64[c]	97.3[a]	244[a]
	100 ppm	167.0	2000[a]	1833[a]	3021[c]	1.65[c]	98.1[a]	250[a]
Cu-gly	50 ppm	166.3	1990[a]	1824[a]	3007[c]	1.65[c]	90.3[a]	238[a]
	100 ppm	167.0	2010[a]	1843[a]	2974[c]	1.61[c]	98.8[a]	255[a]
P-Value		0.6521	0.0001	0.0001	0.0081	0.0001	0.008	0.001
SEM		2.66	5.98	5.99	10.11	0.013	4.55	5.09

[a,b,c] Means in the same column followed by different letters are significantly different at $p \leq 0.05$
SEM=Standard error of mean.
LBW= Live body weight; BWG= Body weight gain; FC= Feed consumption; FCR= Feed conversion ratio; EE= Economical efficiency; EPEI = European Productive Efficiency Index

Table (3): Effect of different copper sources and levels on blood hematological of broiler chickens.

Traits	Control	$CuSO_4$ mg/kg		Cu-Met mg/kg		Cu-gly mg/kg		*P-Value*	SEM
	0	50	100	50	100	50	100		
RBCs (10^6/cmm^3)	2.01[c]	2.57[b]	2.47[b]	2.84[a]	2.85[a]	2.80[a]	2.83[a]	0.006	0.083
Hb (g/100ml)	10.5[c]	11.9[b]	11.8[b]	12.5[a]	12.9[a]	13.0[a]	13.1[a]	0.007	0.189
PCV (%)	30.2[c]	32.9[b]	33.9[b]	39.3[a]	36.4[a]	35.8[a]	37.9[a]	0.023	0.642
WBCs (10^3/cmm^3)	10.1[b]	12.7[a]	12.3[a]	12.1[a]	12.9[a]	12.9[a]	13.2[a]	0.023	0.283
Lymphocytes (%)	53.7[c]	57.0[b]	56.2[b]	60.5[a]	61.0[a]	61.0[a]	62.5[a]	0.001	1.180

[a,b,c] Means in the same row followed by different letters are significantly different at $p \leq 0.05$
SEM=Standard error of the mean

RBCs= Red blood cells, Hb= Hemoglobin, PCV= Packed cells volume, WBCs= White blood cells,

Table (4): Effect of different copper sources and levels on blood hematological of broiler chickens.

Traits	Control	$CuSO_4$ mg/kg		Cu-Met mg/kg		Cu-gly mg/kg		*P-Value*	SEM
	0	50	100	50	100	50	100		
T. protein (g/dl)	3.71	4.06	4.07	4.14	4.20	4.18	4.25	0.4270	0.064
Albumin (g/dl)	2.04	2.11	2.12	2.13	2.24	2.21	2.23	0.9560	0.052
Globulin (g/dl)	1.67^{b}	1.96^{a}	1.95^{a}	2.01^{a}	1.96^{a}	1.96^{a}	2.02^{a}	0.0480	0.013
Glucose (mg/dl)	183^{c}	193^{b}	195^{b}	209^{a}	214^{a}	201^{a}	211^{a}	0.0320	2.830
Total Lipids (mg/dl)	346^{a}	306^{b}	299^{b}	249^{c}	234^{c}	235^{c}	226^{c}	0.0001	8.310
Cholesterol (mg/dl)	141^{a}	122^{b}	123^{b}	98.7^{c}	101^{c}	99.2^{c}	105^{c}	0.0001	3.090
Triglycerides(mg/dl)	101^{a}	72.0^{b}	69.2^{b}	68.0^{b}	61.0^{b}	63.2^{b}	57.5^{b}	0.0070	3.490
HDL (mg/dl)	42.0^{c}	55.0^{ab}	51.7^{b}	64.0^{a}	66.0^{a}	67.0^{a}	68.0^{a}	0.0180	2.130
LDL (mg/dl)	78.8^{a}	52.8^{b}	58.2^{b}	21.8^{c}	22.8^{c}	20.0^{c}	25.6^{c}	0.0001	8.310
AST (U/L)	70.5^{a}	49.5^{b}	48.5^{b}	45.5^{c}	43.7^{c}	44.5^{c}	45.2^{c}	0.0001	1.730
ALT (U/L)	27.5^{a}	23.0^{b}	22.0^{b}	18.7^{c}	18.7^{c}	18.7^{c}	19.0^{c}	0.0020	0.655
ALP (IU/l)	326^{a}	316^{b}	317^{b}	303^{c}	317^{b}	307^{c}	294^{c}	0.0280	5.730
Creatinine (mg/dl)	0.960^{a}	0.647^{b}	0.640^{b}	0.752^{b}	0.755^{b}	0.667^{b}	0.612^{b}	0.0070	0.026
Calcium (mg/dl)	9.12^{b}	11.6^{a}	11.8^{a}	12.5^{a}	13.2^{a}	12.2^{a}	13.1^{a}	0.0001	0.291
Phosphorus (mg/dl)	4.35^{b}	5.27^{a}	5.35^{a}	5.95^{a}	5.96^{a}	5.90^{a}	5.99^{a}	0.0001	0.146
T3 (ng/ml)	2.89^{c}	3.11^{b}	3.21^{b}	4.11^{a}	4.27^{a}	3.45^{a}	3.99^{a}	0.0001	0.055
IgG (mg/100 ml)	45.4^{c}	56.0^{b}	53.3^{b}	68.2^{a}	67.7^{a}	60.8^{a}	65.9^{a}	0.0001	1.650
IgM (mg/100 ml)	51.1^{c}	60.1^{b}	65.5^{b}	67.3^{a}	84.7^{a}	70.1^{a}	81.7^{a}	0.0270	3.210
TAC (mM/L)	1.42^{c}	1.76^{b}	1.72^{b}	1.90^{a}	1.95^{a}	1.96^{a}	1.98^{a}	0.0040	0.048
MDA (IU/L)	132^{a}	108^{b}	106^{b}	85.8^{c}	80.3^{c}	89.2^{c}	87.1^{c}	0.0001	3.590

^{a,b,c} Means in the same row followed by different letters are significantly different at $p \leq 0.05$
SEM=Standard error of the mean

HDL= High density lipoprotein, LDL= Low density lipoprotein, AST= Aspartate amino transferase, ALT= Alanine amino transferase, ALP= Alkaline phosphatase, T_3= Tri-iodothyronine, IgG= Immunoglobulin G, IgM= Immunoglobulin M, TAC= Total antioxidant capacity, MDA= Malondialdehyde

Table (5): Effect of different copper sources and levels on carcass characteristics and relative weight of immune organs to live body weight of broiler chickens.

Traits	Control	CuSO4 mg/kg		Cu-Met mg/kg		Cu-gly mg/kg		*P-Value*	SEM
	0	50	100	50	100	50	100		
Carcass characteristics									
Dressing (%)	58.94[c]	61.90[b]	62.70[b]	65.60[a]	66.70[a]	65.40[a]	63.60[a]	0.002	0.926
Liver (%)	1.65	1.62	1.62	1.65	1.62	1.52	1.65	0.532	0.019
Gizzard (%)	1.15	1.17	1.15	1.15	1.10	1.10	1.15	0.837	0.014
Heart (%)	0.725	0.750	0.775	0.750	0.800	0.750	0.750	0.596	0.098
Pancreas (%)	0.550	0.550	0.550	0.525	0.575	0.500	0.500	0.261	0.009
Abdominal Fat (%)	0.950	0.775	0.700	0.725	0.725	0.725	0.700	0.570	0.022
Intestine (%)	2.520	2.370	2.320	2.450	2.320	2.420	2.370	0.168	0.022
Immune organs									
Spleen (%)	0.375[b]	0.415[ab]	0.415[ab]	0.450[a]	0.435[a]	0.445[a]	0.445[a]	0.034	0.105
Thymus (%)	0.475	0.525	0.475	0.475	0.500	0.500	0.525	0.868	0.013
Bursa (%)	0.300	0.250	0.275	0.275	0.275	0.225	0.250	0.527	0.009

[a,b,c] Means in the same row followed by different letters are significantly different at $p\leq0.05$
SEM=Standard error of the mean

Table (6): Effect of different copper sources and levels on bacterial count of broiler chickens.

Traits	Control	$CuSO_4$ mg/kg		Cu-Met mg/kg		Cu-gly mg/kg		*P-Value*	SEM
	0	50	100	50	100	50	100		
T. bacterial ($x10^3$)	3.07[a]	1.92[b]	2.25[b]	1.95[b]	2.17[b]	2.07[b]	2.20[b]	0.0001	0.075
Salmonella ($x10^2$)	1.00[a]	0.800[b]	0.725[b]	0.675[c]	0.625[c]	0.650[c]	0.625[c]	0.0001	0.024
E. coli ($x10^3$)	1.17[a]	0.909[b]	0.900[b]	0.850[c]	0.775[c]	0.725[c]	0.795[c]	0.0001	0.033
Proteus ($x10^2$)	0.775[a]	0.610[b]	0.600[b]	0.450[c]	0.425[c]	0.425[c]	0.375[c]	0.002	0.036

[a,b,c] Means in the same row followed by different letters are significantly different at $p\leq 0.05$
SEM=Standard error of the mean

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الملخص العربى

تأثير المصادر والمستويات العلفية من النحاس على أداء النمو وتقديرات الدم وصفات الذبيحة لدجاج التسمين

أسامة أحمد حسن الغليض[1] ، غادة مصطفى العشري[2] ، سليمان محمد سليمان[2] ، أحمد محمد عبدالهادي[1]

[1] قسم إنتاج الدواجن ، كلية الزراعة ، جامعة الاسكندرية (21545) ، الأسكندرية ، جمهورهة مصر العربية
[2] المركز الإقليمي للأغذية والأعلاف، مركز البحوث الزراعية، وزارة الزراعة، الدقي، جمهورهة مصر العربية

أجرى هذا البحث لتحديد تأثير المكملات الغذائية للنحاس من مصادر مختلفة، غير عضوية (كبريتات النحاس ، CuSO4)أو عضوية (ميثيونين النحاس ، Cu-Met) أو (جلايسين النحاس ، Cu-gly) وبمستويات (50 - 100) جزء في المليون على الصفات الإنتاجية، وتقديرات الدم ، وصفات الذبيحة والعد البكتيري لأعور دجاج اللحم. تم تقسيم ثلاثمائة وخمسون دجاجة من دجاج التسمين عمر 7 أيام بشكل عشوائي إلى 7 مجموعات (50 طائر كل مجموعة) وغذيت المجموعة الأولى على عليقة تجارية أساسية بدون أي إضافات (ضابطة) ، وغذيت المجموعتين الثانية والثالثة على عليقة المجموعة الضابطة مضاف إليها 50 و 100 جزء في المليون من كبريتات النحاس، وغذيت المجموعتين الرابعة والخامسة على عليقة المجموعة الضابطة مضاف إليها 50 و 100 جزء في المليون من ميثيونين النحاس وغذيت المجموعتين السادسة والسابعة على عليقة المجموعة الضابطة مضاف إليها 50 و 100 جزء في المليون من جلايسين النحاس.
أظهرت النتائج أن الطيور التي تغذت على النحاس الغير عضوى أو العضوى اعطت نتيجة معنوية أفضل فى وزن الجسم الحي، وزيادة وزن الجسم المكتسب، والكفاءة الغذائية، والكفاءة الاقتصادية ، دليل الإنتاج ، ولكنها خفضت استهلاك العلف مقارنة مع المجموعة الضابطة. أظهرت مجموعة النحاس العضوية أن الأداء الانتاجى أفضل مقارنة بالمجموعات الأخرى. كل مجاميع النحاس خفضت مستويات الدهون الكلية، والدهون الثلاثية، والكولسترول، والبروتين الدهني منخفض الكثافة، وانزيمات الكبد (AST وALT)، الكرياتينين ومالوندهيد كمضاد اكسدة فى سيرم الدم؛ مع زيادة مستويات خلايا الدم الحمراء ، الهيموجلوبين ، حجم الخلايا المعبأة ، الجلوكوز ، الجلوبيولين ، أنزيم الألكالين فوسفاتيز، هرمون ثلاثي أيودوثيرونين ، الجلوبيولين المناعي في الدم (IgG و IgM) والسعة المضادة للأكسدة الكلية مقارنة مع مجموعة الضابطة. بالإضافة إلى ذلك، زيادة نسبة الاجزاء الماكولة للذبيحة والطحال، بينما انخفضت نسبة دهون البطن في مجاميع الطيور المعاملة بالنحاس. إضافة النحاس خفض عدد البكتريا الكلية (السلامونيلا والأى كولاي والبروتيوس) مقارنة مع المجموعة الضابطة.
يمكن تلخيص ذلك، أن إضافة النحاس بمعدل 100 جزء فى المليون سواء من جلايسين النحاس أو ميثيونين النحاس حسن أداء النمو ، والاستجابة الفسيولوجية والمناعية لدجاج اللحم. دجاج التسمين المغذى على النحاس العضوي أفضل فى النمو والاستجابة المناعية من تلك التي تمت تغذيتها بالنحاس الغير عضوي.