J.Animal and Poultry Prod., Mansoura Univ., Vol.7(5): 163-171,2016

Effect of Copper Supplementation with Different Energy Levels on Broilers: (A) - Productive Performance

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ABSTRACT

An experiment was conducted to determine the effect of dietary supplementation of two Cu sources: inorganic (copper sulfate) and organic (copper yeast) with different levels of metabolizable energy on productive performance of broiler chickens. Three dietary metabolizable energy levels were used in starter period from 1 to 28 days old (2900, 2800 and 3000 kcal/kg); the corresponding values in finisher period (29 to 42 days old) were 3000, 2900 and 3100 kcal/kg, respectively. One-day-old Cobb broiler chicks were randomly assigned into nine experimental groups, each with three replicate groups. Diets containing 2900 and 3000 kcal ME were used as controls for the starter and finisher periods, respectively. In the starter diets (2800 and 3000 kcal ME/kg) Cu was supplemented at 50 and 100 mg/kg as copper yeast and at 50 and 100 mg/kg as copper sulfate. In the finisher diets (2900 and 3100 kcal ME/kg) the same sources and levels of Cu were added. During the whole experimental period, dietary supplementation with organic and inorganic copper caused a significant increase in LBW of birds compared with their controls. Birds fed the high ME diets plus Cu yeast consumed significantly less feed compared with the control group, but chicks fed the low ME diets plus copper consumed approximately similar amounts of feed compared with the control. Birds fed the high ME diets plus organic or inorganic copper displayed significantly better FCR than the control. Dietary Cu supplementation had no significant effect on carcass yield of broilers, expect those fed the high ME diet plus 100 ppm Cu yeast which exhibited significantly higher carcass yield compared with their control group. Birds fed the low ME diets plus 50 ppm Cu yeast or 100 ppm CuSO4 and those fed the high ME diets plus 100 ppm Cu yeast and those given diets plus 50 or 100 ppm CuSO4 displayed significantly higher total edible parts compared with the control group. Broiler fed diets containing the high ME diets supplemented with 50 or 100 mg/kg organic copper had higher means of net revenue and economic efficiency compared with the control birds. It can be concluded that birds fed the high ME diets plus 100 ppm organic copper can improve productive performance of broilers.

Keywords: Copper Yeast, Dietary Energy, Performance, Broiler Chickens

INTRODUCTION

Copper is one of the essential trace minerals for poultry and livestock (Davis and Mertz, 1987). Two forms of copper (inorganic or organic) are used. In commercial poultry diets the majority of trace minerals are provided in inorganic forms such as oxide, chloride, carbonate, citrate and sulfate salts. Copper sulfate ($CuSO_4.5H_2O$) is the most commonly inorganic form that is used as dietary copper supplementation. Copper in the form of Cu sulfate improves growth rate and feed efficiency in broilers (Baker *et al*., 1991) and in pigs (Cromwell *et al*., 1989). Growth promoting effect of dietary copper has been attributed to its antimicrobial action (Burnell *et al*., 1988). Supplementation of copper chelates, complexes or proteinates can safely be used in animal diets as alternatives to inorganic sources. In this regard, Ammerman *et al*. (1995) reported that relative bioavailability estimates of organic copper sources ranged from 88 to 147% of the response to cupric sulfate in poultry, swine, sheep and cattle.

Copper plays a vital role in many physiological and biochemical processes in the organism. Copper is an important component of many enzymes which are critical to the maturation of hematopoietic cells. It is required for normal red blood cell formation by allowing iron absorption from small intestine and release of iron in tissue into the blood plasma. Copper is also required for bone formation by maintaining structural integrity of bone collagen and for normal elastin formation in the cardiovascular system. The immune system requires copper to perform several functions, of which little is known about the direct mechanism of action (Percival, 1998). Several studies had indicated that copper plays an important role in productive performance for poultry. The role of copper in animal body results mainly from its presence in the structure of many enzymes that take part in oxidative and reductive processes such as cytochrome oxidase, lysyl oxidase, superoxide dismutase, ceruloplasmin, and in the formation of metallothioneins (Klasing, 1998). Also, Cu has been added to poultry diets as an antimicrobial agent at a concentration in excess of its established requirement 8 ppm by the NRC (1994). Dietary copper significantly increased the body weight and carcass weight of broiler chicks Arias and Koutsos (2006).

Copper deficiency can result in an inadequate iron utilization in organism (Reeves and DeMars, 2004). Some studies have focused on the mechanism by which copper deficiency induces hypercholesterolemia. Evidence indicated that liver copper regulates cholesterol biosynthesis by reducing hepatic glutathione concentrations (Hong *et al*., 2002). Also, copper deficiency has a detrimental effect on numerous organs and tissues including the hematopoietic system, cardiovascular system, central nervous system and integument (Ammerman *et al*., 1995).

Dietary energy levels have a major effect on the voluntary feed intake and productive performance of poultry. Dietary energy level is the most important factor in determining feed intake of poultry which consume feed to satisfy their energy requirements (Leeson *et al*., 2001).

Objective of this study was to investigate the effect of supplementation with inorganic and organic copper to diets with different energy levels on productive, performance of broiler chickens.

MATERIALS AND METHODS

Birds and Experimental Design:

Four hundred and five (405) one-day-old unsexed Cobb broiler chicks, purchased from a commercial hatchery, were used in this experiment. Chicks were individually weighed to the nearest gram and randomly assigned into nine experimental groups. One group served as a control, other groups divided into two groups according to the metabolism of energy level in the diet, each main group subdivided into two subgroups according to the source of copper (organic/inorganic), subgroups divided into two treatments according to the levels of organic/inorganic copper, each treatment contained 3 replicates, 15 birds in each replicate.

Housing and Management:

Chicks were housed in floor pens bedded with wood shavings which were cleaned thoroughly with formaldehyde and potassium permanganate solution three days prior to arrival of birds. House ambient temperature was maintained at 32-34^{o}C. for the first 5 days and then gradually reduced according to normal management practices. Birds were kept at a 23 hrs. constant light schedule. All chicks were subjected to similar managerial, hygienic and environmental conditions throughout the entire experimental period that lasted for 6 weeks.

The Experimental Diets:

The chicks were offered two corn–soybean meal basal mash diets that were formulated to serve as controls for the starter and finisher periods. The feeding period in the current investigation consists of two periods; the first (starter period), its basal diet contained 22.5 % crude protein (CP), this period lasted for four weeks. The second was finisher period; its basal diet contained 20 % CP and lasted for two weeks. Within each protein level used two dietary metabolizable energy levels (2800 and 3000 kcal/kg diet) were used during starter period and two ones (2900and 3100 kcal/kg diet) were used during finisher period, were tested with two Cu sources [organic vs. inorganic ($CuSO_4$)] and two levels (50, 100 mg of copper/kg diet). While the control diets containing the same protein levels with 2900 and 3000 kcal of metabolizable energy (ME) during starter and finisher periods, respectively, without copper supplementation. The compositions and calculated analysis of the diets are detailed in Table 1.

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

Ingredients	Starter period			Finisher period		
	2900 kcal / kg diet (control)	**2800 kcal / kg diet ¤**	**3000 kcal /kg diet ¤**	**3000 kcal / kg diet (control)**	**2900 kcal / kg diet ¤¤**	**3100 kcal /kg diet ¤¤**
Yellow corn	55.5	56.6	56.4	62.0	63.6	60.0
Soybean meal (44% CP)	35.0	36.7	35.1	28.0	28.7	28.0
Yeast	2.0	2.0	2.5	2.0	2.0	2.0
Corn gluten meal	3.5	1.0	2.5	2.7	2.0	2.9
Limestone	1.1	1.1	1.1	1.1	1.1	1.1
Dicalcium phosphate	1.2	1.2	1.2	1.2	1.2	1.2
DL-Methionine	0.3	0.3	0.3	0.3	0.3	0.3
L-lysine. Hcl	0.2	0.2	0.2	0.2	0.2	0.2
Choline chloride	0.3	0.3	0.3	0.3	0.3	0.3
Corn oil	0.3	-	0.3	1.6	-	3.4
Salt	0.3	0.3	0.3	0.3	0.3	0.3
(Premix)*	0.3	0.3	0.3	0.3	0.3	0.3
Total	100	100	100	100	100	100
Calculated analysis						
ME (kcal/kg)	2908	2803	3000	3003	2907	3100
Crude protein (%)	22.5	22.5	22.5	20	20	20
Calcium (%)	0.79	0.79	0.79	0.77	0.77	0.77
Available phosphorus (%)	0.37	0.38	0.37	0.36	0.36	0.36
Lysine (%)	1.3	1.36	1.33	1.16	1.18	1.2
Methionine + Cystine (%)	1.1	1.1	1.1	1	1	1
Crude fibre (%)	3.5	3.6	3.5	3.4	3.5	3.4
Ether extracte (%)	3.4	3.2	3.3	3.8	3.6	4.1

***Each 3 kg premix contains: Vit. A, 12000 IU; Vit. D3, 22000 IU; Vit. E, 10 mg; Vit. K, 2000mg, Thiamin, 1000 mg; Riboflavin, 5000 mg; Pyridoxine,1500 mg; Cyanocobalamin, 10 mg; Folic acid, 1000 mg; Biotin, 50 mg; Pantothenic acid, 10 mg; Niacin, 30 mg; Iron, 30 mg; Copper, 10 mg; Selenium, 100 mg; Zinc, 50 mg; Manganese, 60 mg; Cobalt, 100 mg; Iodine, 1000 mg Choline chloride, 300mg and $CaCo_3$ to 3g.**

¤ Diets containing 2800 and 3000 kcal ME/kg diet were supplemented with (50 and 100 mg/kg diet) copper yeast as an organic source and (50 and 100 mg/kg diet) copper sulfate as an inorganic source of copper.

¤¤ Diets having 2900 and 3100 kcal ME/kg diet were supplemented with (50 and 100 mg/kg diet) copper yeast as an organic source and (50 and 100 mg/kg diet) copper sulfate as an inorganic copper source.

Measurements:

Body weight, weight gain, feed consumption, feed conversion ratio and mortality rate were estimated throughout the experimental period from day-old to 6 weeks of age. At the end of the experimental period, three birds from each replicate were taken randomly, for slaughter test, fasted for twelve hrs. Birds were individually weighed and immediately slaughtered by slitting the jugular vein of the birds in the morning. Just after slaughter and complete bleeding they were scalded and defeathered. Carcasses were eviscerated manually and weighed. Bursa, thymus, spleen, liver, heart, and gizzard were separately weighed. All organs weights were expressed as percentage of live body weight.

Economical Efficiency:

Economic efficiency was calculated from the following equation:

Economic efficiency (%) = [Net revenue (LE) /Total feed cost (LE)] x100

Where, Net revenue = Total revenue – Total feed cost

Total revenue (LE) =Total weight gain x price of kg of live body (LE)

Total feed cost = Total feed consumption/bird x price of kg feed.

Statistical Analysis:

Data were statistically analyzed by one-way analysis of variance using the General Linear Models (GLM) procedure of SPSS (1997). Tests of significance for the differences among means of different variables were done according to Duncan's new multiple range test (Duncan, 1955).

The following statistical model is used to estimate the effects of different levels of dietary copper and energy.

$$X_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + e_{ijk}$$

Where, Xijk = observation; μ = overall mean; α_i = effect of energy; βj = effect of copper; β_{ij} = interaction between energy and copper; E_{ijk} = random error.

RESULTS AND DISCUSSION

Broiler performance and feed efficiency:

Performance of broiler chicken supplemented with two sources of Cu (CuSO4 and Cu-Proteinate) during the starter and finisher periods are presented in Tables 2 and 3, respectively.

Starter period:

From these results, it can be noticed that there were no significant differences in the initial body weights of chickens among the experimental groups; indicating an efficient well randomization process. However, body weights of broilers at 4 weeks of age (at the end of starter period) were a significantly ($p \leq 0.05$) higher for the copper supplemented groups than that of the control.

Table 2: Effect of copper supplementation to diets with different energy levels on performance traits of broiler chicks during the starter period (1 to 28 days old)

Dietary treatments ¶	Cu sources and levels	Initial LBW[1](g)	Final LBW[1](g)	Total BWG[2](g)	Total FI[3] (g)	FCR[4] (g feed: g gain)
(Control)ME (2900 kcal/kg)	Without copper supplemented	46.4	1381^{d}	1334^{d}	2291^{a}	1.717^{a}
	50 ppm Cu yeast	46.4	1452^{ab}	1404^{ab}	2204^{a}	1.569^{ab}
Low ME	100 ppm Cu yeast	46.5	1499^{a}	1452^{a}	2081^{b}	1.433^{ab}
(2800 kcal/kg)	50 ppm CuSO4	46.5	1402^{bc}	1355^{c}	2204^{a}	1.626^{a}
	100 ppm CuSO4	46.4	1428^{bc}	1382^{bc}	2245^{a}	1.624^{a}
	50 ppm Cu yeast	46.3	1487^{a}	1451^{a}	1894^{c}	1.305^{c}
High ME	100 ppm Cu yeast	46.4	1509^{a}	1462^{a}	1879^{cd}	1.285^{c}
(3000 kcal/kg)	50 ppm CuSO4	46.4	1446^{b}	1399^{b}	1964^{b}	1.403^{abc}
	100 ppm CuSO4	46.4	1457^{b}	1411^{ab}	1904^{c}	1.349^{bc}
SEM§		± 0.31	± 18.59	± 56.39	± 45.89	± 0.09
Significance		NS	*	*	*	*

a-d: Means within the same column bearing different superscripts differ significantly (P<0.05). NS = not significant. * = P<0.05

§: Standard error of the means.

1-4: Refers to live body weight, body weight gain, feed intake and feed conversion ratio, respectively.

¶: Three dietary metabolizable energy levels used in starter period (1 to 28 days old) diets were referred to as control, low and high (2900, 2800 and 3000 kcal/kg).

At the end of starter period, birds fed the high ME diet (3000 kcal) with 100, 50 mg organic copper/kg diet recorded heavier body weights by 9.3,7.7%, followed by those fed the low ME diet (2800 kcal) with 100, 50 mg organic copper/kg diet by 8.5, 5.1%, then birds fed the high ME diet (3000 kcal) with 100, 50 mg inorganic copper/kg diet) by 5.4, 4.7% and finally those fed the low ME diet (2800 kcal) with 100, 50 mg inorganic copper/kg diet by 3.4, 1.5% compared to the control birds.

Generally, at the end of the starter period, birds fed the high ME diets plus 100 or 50 ppm Cu yeast exhibited significantly higher body weight gains (BWG) compared with that of the control group, with significant between the two groups. Compared with the control group the percent increases in BWG of these two groups were 9.54 and 8.73%, respectively. Similar positive growth response was achieved by birds fed the low ME diets plus 100 or 50 ppm Cu yeast compared with that of the control chicks. The relative increases in BWG of these two groups were 8.83 and 5.23%, respectively compared with the control group. In addition, birds fed the high ME diets plus 100 or 50 ppm $CuSO_4$ displayed significantly higher ($p<0.05$) BWG compared with the control group, with no significant differences between the two groups. Compared with the control group the percent increases in BWG of these two groups were 5.76 and 4.87%, respectively. However, BWG of chicks fed the low ME diets plus 100 or 50 ppm of copper in the form $CuSO_4$ was not significantly different from that of the control birds.

Feed consumption (g) of broilers fed diets containing either low or high ME (2800 or 3000 kcal/kg diet) supplemented with 100 or 50 mg organic and inorganic copper/kg diet had a significant difference of the first week of age. At the end of starter period feed consumption of broilers fed diets containing 3000 kcal metabolizable energy supplemented with 100 or 50 mg either organic or inorganic copper/kg diet was significantly ($P\leq0.05$) decreased compared with the control and other treatment groups.

As a result , for the reduction in feed intake and weight gain the improvement of fed conversion ratio recorded in broilers fed the high ME (3000 kcal) supplemented with100 and 50 mg either organic or inorganic copper/kg diet by 25.2 and 23.9 % or by 21.4 and 18.3%, respectively, followed by birds fed diets supplemented with 100 and 50 mg organic copper/kg diet and contains the low ME (2800 kcal) improved by 16.5 and 8.6%, respectively, compared to the control, while birds fed diet supplemented with inorganic copper with the low ME (2800 kcal/kg diet) had insignificant ($P\leq0.05$) affected compared to control.

Finisher period:

At the end of finisher period, birds fed the high ME diet (3100 kcal) with 100, 50 mg organic copper/kg diet recorded heavier body weights by 16.3, 13.1%, followed by those fed the same ME diet with 100, 50 mg inorganic copper/kg diet by 9.9, 7.6%. Followed by birds fed the low ME diet (2900 kcal) plus 100 ppm organic copper by 6.5 %. In addition, birds fed the low ME diets plus 50 ppm yeast or 100 and 50 $CuSO_4$ displayed significantly higher ($p<0.05$) LBW compared with the control group, with no significant differences between the three groups. Compared with the control group the percent increases in LBW of these three groups were 3.8 or 3.5 % and 1.8%, respectively. However, LBW of chicks fed the low ME diets plus 100 or 50 ppm of copper in the form $CuSO_4$ was not significantly different from that of the control birds.

Table 3: Effect of copper supplementation to diets with different energy levels on performance traits of broiler chicks during finisher period (29 to 42 days old)

Dietary treatments ¶	Cu sources and levels	Initial LBW[1](g)	Final LBW[1](g)	Total BWG[2](g)	Total FI[3] (g)	FCR[4] (g feed: g gain)
(Control)ME (3000 kcal/kg)	Without copper supplemented	1381^{d}	2128^{d}	747^{d}	1829^{a}	2.448^{a}
	50 ppm Cu yeast	1452^{ab}	2209^{bc}	757^{d}	1737^{ab}	2.294^{ab}
Low ME	100 ppm Cu yeast	1499^{a}	2266^{bc}	767^{cd}	1670^{b}	2.177^{c}
(2900 kcal/kg)	50 ppm CuSO4	1402^{bc}	2167^{d}	765^{cd}	1757^{ab}	2.296^{ab}
	100 ppm CuSO4	1428^{bc}	2202^{c}	774^{bc}	1688^{b}	2.180^{c}
	50 ppm Cu yeast	1487^{a}	2407^{ab}	920^{ab}	1794^{a}	1.950^{e}
High ME	100 ppm Cu yeast	1509^{a}	2474^{a}	965^{a}	1718^{ab}	1.780^{f}
(3100 kcal/kg)	50 ppm CuSO4	1446^{b}	2290^{b}	844^{b}	1798^{a}	2.130^{cd}
	100 ppm CuSO4	1457^{b}	2338^{ab}	881^{ab}	1739^{ab}	1.973^{e}
SEM§		± 18.59	± 31.35	± 0.31	± 45.48	± 0.10
Significance		*	*	*	*	*

a-g: Means within the same column bearing different superscripts differ significantly (P<0.05). NS= not significant. *= P<0.05
§: Standard error of the means.
1-4: Refers to live body weight, body weight gain, feed intake and feed conversion ratio, respectively.
¶: Three dietary metabolizable energy levels used in starter period (1 to 28 days old) diets were referred to as a control, low and high (2900, 2800 and 3000 kcal/kg); the corresponding dietary energy levels used in finisher period (29 to 42 days old) were 3000, 2900 and 3100 kcal/kg, respectively.

Generally, at the end of the finisher period, birds fed the high ME diets plus 100 or 50 ppm Cu yeast exhibited significantly higher body weight gains (BWG) compared with that of the control group, with significant between the two groups. Compared with the control group the percent increases in BWG of these two groups were 29.1 and 23.2%, respectively. Similar positive growth response was achieved by birds fed the same ME diets plus 100 or 50 ppm $CuSO_4$ compared with that of the control chicks. The relative increases in BWG of these two groups were 17.9 and 12.9, respectively compared with the control group. In addition, birds fed the low ME diets plus 100 or 50 ppm yeast displayed significantly higher ($p<0.05$) BWG compared with the control group, with no significant differences between the two groups. Compared with the control group the percent increases in BWG of these two groups were 2.7 and 1.3 %, respectively. However, BWG of chicks fed the low ME diets plus 100 or 50 ppm of copper in the form $CuSO_4$ was not significantly different from that of the control birds.

Feed consumption (g) of broilers fed diets containing either low or high ME (2900 or 3100 kcal/kg diet) supplemented with 100 or 50 mg organic and inorganic copper/kg diet had a significant difference at the end of starter period. At the end of starter period feed consumption of broilers fed diets containing 2900 kcal metabolizable energy supplemented with 100 organic or inorganic copper/kg diet was significantly ($P \leq 0.05$) decreased compared with the control and other treatment groups.

From these results, for the reduction in feed intake and weight gain the improvement of fed conversion ratio recorded in broilers fed the high ME (3100 kcal) plus100 and 50 mg either organic or inorganic copper/kg diet by 27.3 and 20.9 % or by 19.4 and 12.9%, respectively, in addition, birds fed the low ME diets plus 100 ppm Cu yeast or $CuSO_4$ displayed significantly higher ($p<0.05$) FCR compared with the control group, with no significant differences between the two groups. Compared with the control group the percent improving in of these two groups were 11.1 and 10.9%, respectively. However, birds fed the low ME diets plus 50 ppm Cu yeast or $CuSO_4$ displayed significantly higher ($p<0.05$) FCR compared with the control group, with no significant differences between the two groups. Compared with the control group the percent improving in of these two groups were 6.3 and 6.2%, respectively. While birds fed diet supplemented with organic and inorganic copper with the low ME (2900 kcal/kg diet) had significant ($P \leq 0.05$) affected compared to control.

Whole experimental period:

Performance of broiler chicken supplemented with two sources of Cu (CuSO4 and Cu-Proteinate) during the whole experimental are presented in Tables 4. Through the whole experimental period (0-6 wks. of age) the present results pointed out that, birds fed diets containing the high ME (3000 and 3100 kcal) during starter and finisher periods plus 100, 50 mg organic copper/kg diet) recorded heavier body weight gain by 16.6, 13.3% and also, recorded the lowest feed consumption by 12.6 and 10.5 accordingly improved FCR by 25.1 and 21.0%, respectively.

Table 4: Effect of copper supplementation to diets with different energy levels on performance traits of broiler chicks during whole experimental period (1 to 42 days old)

Dietary treatments ¶	Cu sources and levels	Initial LBW[1](g)	Final LBW[1](g)	Total BWG[2](g)	Total FI[3] (g)	FCR[4] (g feed: g gain)
(Control)ME	Without copper supplemented	46.4	2128^{d}	2082^{b}	4120^{a}	1.978^{a}
Low ME	50 ppm Cu yeast	46.4	2209^{bc}	2160^{ab}	3941^{a}	1.824^{ab}
	100 ppm Cu yeast	46.5	2266^{bc}	2220^{ab}	3851^{ab}	1.734^{abc}
	50 ppm CuSO4	46.5	2167^{d}	2120^{b}	3961^{a}	1.868^{ab}
	100 ppm CuSO4	46.4	2202^{c}	2156^{ab}	3933^{ab}	1.824^{ab}
High ME	50 ppm Cu yeast	46.3	2407^{ab}	2360^{ab}	3688^{bc}	1.562^{d}
	100 ppm Cu yeast	46.4	2474^{a}	2427^{a}	3597^{c}	1.482^{d}
	50 ppm CuSO4	46.4	2290^{b}	2243^{ab}	3762^{ab}	1.677^{bcd}
	100 ppm CuSO4	46.4	2338^{ab}	2293^{ab}	3643^{bc}	1.588^{cd}
SEM§		± 0.31	± 31.35	± 84.59	± 63.35	± 0.97
Significance		NS	*	*	*	*

a-e: Means within the same column bearing different superscripts differ significantly (P<0.05). NS= not significant. *= P<0.05
§: Standard error of the means.
1-4: Refers to live body weight, body weight gain, feed intake and feed conversion ratio, respectively.
¶: Three dietary metabolizable energy levels used in starter period (1 to 28 days old) diets were referred to as a control, low and high (2900, 2800 and 3000 kcal/kg); the corresponding dietary energy levels used in finisher period (29 to 42 days old) were 3000, 2900and 3100 kcal/kg, respectively.

The current results indicated that organic copper supplemented at 100 mg/kg diet with diets containing 2900 or 3100 kcal/kg diet could successfully be used as a growth promoter in broilers diet. This positive effect of copper supplementation is partially due to its ability to modify the pH of the small intestine, leading to improving its bioavailability to the chicks. Therefore, it is possible that copper can enhance protein utilization and nitrogen retention by stimulating secretion of pituitary growth hormone in broiler chickens. Addition of copper may also increase the metabolizability of energy, indicating that copper played a role in the utilization of vegetable oil. This may indicate that birds needed additional copper in the diet to efficiently utilize supplemental vegetable fat. The improved fat metabolizability resulting from copper (Cu) addition would lead to an increased absorption of fatty acids and fat-soluble vitamins, and perhaps other essential nutrients and therefore can stimulate the growth of broiler chickens. These results are supported by Burnell *et al.* (1988), who reported that growth promoting of dietary copper has been attributed to its antimicrobial action. Ammerman *et al.* (1995), reported that relative bioavailability estimates of organic copper sources ranged from 88 to 147% of the response to cupric sulfate in poultry, swine, sheep and cattle. Improvement of fat metabolizability in response to copper (Cu) addition may be partially due to an increase in lipase and phospholipase activity in the small intestine as reported by Nahashon *et al.* (2005), Mondal *et al.* (2007) and Das *et al.* (2010).

In addition, the present results are also in harmony with the findings of by Lim and Paik (2006) and Hong *et al.* (2002), who reported that there was a higher weight gain for broiler chickens when they fed diet supplemented with 100 ppm copper in methionine chelate (Cu-Met) compared to the control group. They cited that this beneficial effect is partially due to its high antimicrobial activity.

The current results are in the same direction with those of Prajapati *et al.* (2012), who noted that body weights of broilers given a combination of copper sulfate penta-hydrate at 125 mg/kg diet were significantly heavier compared with their control group. In addition, ducks that received tribasic copper chloride (TBCC) at 150 mg copper/kg diet had higher body weights than those fed non –supplemented diet (Wang *et al.* 2010). Also, the results are in agreement with the findings of Xia *et al.* (2004), Lu *et al.* (2010), Samanta *et al.* (2011) and Igbasan and Akinsanmi (2012), who reported that there was a significant increase in body weight gain of broiler chickens with the supplementation of copper. In this respect, Das *et al.* (2010) concluded that Cu-proteinate resulted in better growth performance and nutrient utilization in broiler chicks as compared to $CuSO_4$. More bioavailability of organic copper is probably due to better absorption, which enhances its efficiency (Guo *et al.*, 2001).

Generally, throughout the whole experimental period, it was noticed that birds fed the control diet recorded the highest ($P \leq 0.05$) feed consumption 4120 g, while birds fed 3100 kcal supplemented with 100 and 50 mg organic copper/kg diet recorded the lowest ($P \leq 0.05$) feed consumption value 3597 and 3688 g, respectively. While birds fed 3100 kcal supplemented with 100 and 50 mg/kg diet of inorganic copper consumed 3643 and 3762 g, respectively. The results also indicated that feed intake of broiler chicks groups fed the diets containing 2900 kcal supplemented with 50 or 100mg organic or inorganic copper was not significantly different from that of the control group.

The lack of significantly differences in feed intake of birds may be attributed to the low dose of copper, applied herein and to the fact that birds were kept in similar hygienic conditions where there were no challenging factors affecting the gastrointestinal health of the birds. Copper is routinely added to poultry diets at pharmacological concentrations for its growth-promoting effects (Pesti and Bakalli, 1996). The present results agree with the findings of Balevi and Coskun (2004), Luo *et al.* (2005), Aksu *et al.* (2011), and Samanta *et al.* (2011), who indicated that dietary supplementation of birds with organic or inorganic copper led to a significant decrease in feed consumption when compared with the control group. On the other hand, these results are in contrast with the other findings of Banks *et al.* (2004), Lim and Paik (2006) and Das *et al.* (2010), who found that dietary supplementation of birds with copper organic or inorganic copper had no significant effect on feed consumption when compared with the control group.

During the whole experimental period (0 to 6 weeks), feed conversion ratios (FCR) of birds fed the high ME diets plus organic or inorganic copper were significantly better than that of the control birds. However, FCR of birds fed the low ME diets supplemented with Cu yeast or $CuSO_4$ were slightly higher but insignificantly different from that of the control group. It was estimated the percent improvement in FCR of chicks feed the high ME diet plus 100 or 50 ppm of Cu yeast were 25.0 and 21.0 %. While FCR of birds fed the high ME diet plus 100 or 50 ppm of $CuSO_4$ was improved by 19.7 or 15.2 %, respectively, when compared with that of their control counter parts. The improvement in feed conversion ratio may be related partially to the lower feed consumption and higher growth rate of the groups fed diet supplemented with copper or to the important role of copper as a growth promoter compared to the control group. Another possible reason for the improved FCR may be due to an increased utilization of dietary the energy as a result of adding copper and especially organic copper, where it might be more bioavailable than the inorganic source of Cu.

The current results harmonize with the results obtained by experimental work of Das *et al.* (2010), who noticed that feed conversion ratio improved with when the diet was supplemented copper proteinate as compared to copper sulfate. This effect is due to high content of healthy conditions of birds fed copper. In line with the present results, Wang *et al.* (2010) observed an improvement in feed conversion ratio after the application of tribasic copper chloride in the diet of duck. These results revealed the growth promoting effect of copper. A similar response was observed by Baker *et al.* (1991), who found that copper in the form of copper sulfate improved growth rate and feed efficiency in broiler chicks.

Mortality rate of birds was not related to the effects of dietary treatments; only three birds from the control group, two from the experimental group fed the low ME diet plus 50 ppm $CuSO_4$ and one bird from the experimental group fed he low ME diet plus 100 ppm $CuSO_4$ were died during the experimental period, from day-old to 42 days of age

The absence of deaths in most dietary treatments and the presence of some accidental mortality in others may indicate that the chicks had good health status. The immune response of birds fed dietary copper can be improved as a result of antimicrobial and antiviral properties of copper. The present results are in agreement with the findings of Wang *et al.* (2010), who showed that the dietary supplementation of birds with copper had a positive effect on mortality rate of duckling.

On other hand, Karimi *et al.* (2001) and Morias *et al.* (2001), reported that the dietary supplementation of birds with copper did not significant affect mortality rate of broiler chickens.

Carcass traits:

The results of carcass traits and relative weights of edible and lymphoid organs are given in Table 5.

Table 5: Effect of copper supplementation to diets with different energy levels on relative weights (% of LBW[1]) of carcass traits and lymphoid organs of 6-wk-old broiler chicks

Dietary treatments ¶	Cu sources and levels	CY[2]	Liver	Heart	Gizzard	TEP[3]	Thymus	Bursa	Spleen
(Control	Without copper supplemented	72.25[b]	2.66[c]	0.42[b]	2.31[b]	77.64[b]	0.30[b]	0.12[b]	0.16[b]
Low ME	50 ppm Cu yeast	74.50[ab]	2.71[b]	0.54[ab]	2.64[a]	80.40[a]	0.33[ab]	0.15[ab]	0.19[ab]
	100 ppm Cu yeast	73.20[ab]	2.91[ab]	0.54[ab]	2.31[b]	78.97[ab]	0.35[a]	0.15[ab]	0.20[a]
	50 ppm CuSO4	72.92[b]	2.89[ab]	0.47[b]	2.35[b]	78.86[ab]	0.31[b]	0.13[b]	0.16[b]
	100 ppm CuSO4	74.34[ab]	3.02[a]	0.48[b]	2.21[bc]	80.00[a]	0.31[b]	0.14[b]	0.17[b]
High ME	50 ppm Cu yeast	73.94[ab]	2.68[bc]	0.62[a]	2.22[bc]	79.47[ab]	0.36[a]	0.15[ab]	0.21[ab]
	100 ppm Cu yeast	76.34[a]	2.75[b]	0.52[ab]	2.39[ab]	82.02[a]	0.38[a]	0.18[a]	0.26[a]
	50 ppm CuSO4	74.93[ab]	2.81[ab]	0.53[ab]	2.13[c]	80.38[a]	0.31[b]	0.14[b]	0.18[b]
	100 ppm CuSO4	74.90[ab]	3.31[a]	0.51[ab]	2.35[b]	80.87[a]	0.32[ab]	0.14[b]	0.18[ab]
SEM §		± 1.18	± 0.08	± 0.01	± 0.05	± 2.38	± 0.01	± 0.04	± 0.01
Significance		*	*	*	*	*	*	*	*

a-c: Means within the same column bearing different superscripts differ significantly (P<0.05). NS= not significant. *= P<0.05
§: Standard error of the means.
1-3: Refers to live body weight, carcass yield and total edible parts, respectively.
¶: Three dietary metabolizable energy levels used in starter period (1 to 28 days old) diets were referred to as normal, low and high (2900, 2800 and 3000 kcal/kg); the corresponding dietary energy levels used in finisher period (28 to 42 days old) were 3000, 2900 and 3100 kcal/kg, respectively.

As given in table 5, dietary Cu supplementation had no significant effect on carcass yield of broiler chicks, expect those fed the high ME diet plus 100 ppm Cu yeast which exhibited significantly higher ($P \leq 0.05$) carcass yield compared with their control counter parts. In addition, birds fed the low ME diets plus 50 ppm Cu yeast or 100 ppm $CuSO_4$ and those fed the high ME diets plus 100 ppm Cu yeast and those given diets plus 50 or 100 ppm $CuSO_4$ displayed significantly higher ($P \leq 0.05$) total edible parts compared with the control group. Birds fed the copper-supplanted diets had significantly higher ($P \leq 0.05$) relative weights of liver compared with that of the control group but relative liver weight of chicks fed the high ME diet plus 50 ppm Cu yeast was not significantly different from that of the control birds. However, chicks fed the high ME diet plus 50 ppm Cu yeast had significantly higher ($P \leq 0.05$) relative weight of heart compared with the control group but relative heart weight of other experimental groups were not significantly different from that of the controls. Birds fed the low ME diet plus 50 ppm Cu yeast had significantly higher ($P \leq 0.05$) relative gizzard weight as compared to that of the control group. But fed the high ME diet plus 50 ppm $CuSO_4$ achieved significantly lower ($P \leq 0.05$) relative gizzard weight compared with the control group; however, relative gizzard weight of other experimental groups were not significantly different from that of the control birds.

Regarding the relative weights of lymphoid organs (thymus, bursa and spleen, significant increases were observed ($P \leq 0.05$) due to feeding the high ME diet plus 100 ppm Cu yeast as compared to those of the control group. Similar observation was found in relative weights of thymus and spleen of chicks fed the low ME diet supplemented with 50 ppm Cu yeast and in thymus relative weight of chicks fed the high ME diet plus 50 ppm Cu yeast as compared to those of their control counter parts.

The observed improvement in carcass yield and total edible parts may be related to increasing live body weight in response to dietary Cu supplementation to broiler diet. In line with the present results, several authors reported that body weight, weight gain and carcass yield of broiler chickens and ducklings were significantly increased by dietary inclusion of copper as compared to the control diet as reported by Arias and Koutsos (2006), Mondal *et al.* (2007) and Wang *et al.* (2010).

The increased relative weight of liver of chicks fed the supplemented diets, observed in the present study harmonizes with the obtained results by Karimi *et al.* (2011), who reported that liver weight was significantly higher in broilers fed diet supplemented with copper sulfate (250 ppm of copper/kg diet).

The observed increase in relative weights of lymphoid organs in increasing of lymphoid organs weight within the normal range. These results may be as response to dietary Cu supplementation can be considered an indicator of good health status of chicks. In this respect Virden *et al.* (2004) showed that dietary supplementation of Zinc manganese and copper increased relative weights of spleen and bursa of fabricius in progeny chicks.

Economic efficiency:

Results of economical efficiency of broilers fed the experimental diets are summarized in Table 6. Broiler fed diets containing the high ME (3000 and 3100 kcal) during starter and finisher periods supplemented with 100 mg/kg organic copper had higher net revenue compared with that of the control birds (25.56 vs. 19.95 LE). While the lowest value of net revenue was noticed on broilers fed the control diet (19.95 LE). Economical efficiency of broilers fed diets containing the high ME (3000 and 3100 kcal) during starter and finisher periods supplemented with 50 or 100 ppm organic copper attained the best values (154.46 and 151.12%) as compared to that of the control group (121.2%).

Table 6: Effect of dietary copper supplementation with different energy levels on economic efficiency of broilers.

Treatments / Parameters	Control	Low ME				High ME			
	Without Cu supplemented	50 ppm Cu yeast	100 ppm Cu yeast	50 ppm Cu SO_4	100 ppm Cu SO_4	50 ppm Cu yeast	100 ppm Cu yeast	50 ppm Cu SO_4	100 ppm Cu SO_4
Price /kg feed (LE)	4.00	4.25	4.50	4.12	4.24	4.40	4.70	4.25	4.45
Total FI /bird (kg)	4.120	3.941	3.851	3.961	3.933	3.688	3.597	3.762	3.643
Total feed cost (LE)	16.48	16.75	17.33	16.32	16.68	16.23	16.91	15.99	16.21
Total BWG (kg)	2.082	2.160	2.220	2.120	2.156	2.360	2.427	2.243	2.293
Total revenue (LE)	36.43	37.80	38.85	37.10	37.73	41.30	42.47	39.25	40.12
Net revenue (LE)	19.95	21.05	21.52	20.78	21.05	25.07	25.56	23.26	23.91
EEF, %	121.20	125.67	124.18	127.32	126.20	154.46	151.12	145.46	147.50
Relative EEF	100	107.22	112.75	103.53	106.84	125.69	131.89	114.92	119.51

Total feed cost = total FI/bird during the whole experimental period x price of kg feed
Price per kg live weight = 17.5 LE.
Net revenue = the difference between price of total revenue and total feed cost.
EEF= Economical efficiency of feeding = (Net revenue/ total feed cost) x 100.

CONCLUSION

Results from this study indicate that using diets containing 3000 and 3100 kcal ME during starter and finisher period supplemented with 100 mg organic copper/kg diet can improve broiler performance under Egyptian conditions.

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تأثير أضافة النحاس مع مستويات مختلفة من الطاقة على (أ)-الأداء الإنتاجي لدجاج التسمين

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أجريت هذه التجربة لتحديد تأثير الإضافات الغذائية من النحاس العضوي والمعدني مع مستويات الطاقة المختلفة على الأداء الإنتاجي لكتاكيت التسمين. في فترة البداية (١ الى ٢٨ يوم) استخدمت ثلاث مستويات من الطاقة هي ٢٩٠٠، ٢٨٠٠و٣٠٠٠ كيلو كالوري / كجم وفى فترة النهاية (٢٩ الى ٤٢ يوم) تم رفع المستويات الى ٢٩٠٠,٣٠٠٠و٣١٠٠ كيلو كالوري / كجم على الترتيب، تم توزيع الدجاج اللاحم (كوب)عمر يوم واحد عشوائيا إلى تسع مجموعات التجريبية، ولكل منها ثلاث مجموعات تكرارية. واستخدمت الوجبات الغذائية التي يحتوي الكنترول فيها على ٢٩٠٠ و٣٠٠٠ كيلو كالورى / كجم في فترة البداية والنهاية على التوالي. في فترة البداية (٢٨٠٠ و ٣٠٠٠ كيلو كالورى / كجم) واستكملت بالنحاس ٥٠ و١٠٠ ملغم / كغم من خميرة النحاس و٥٠ و١٠٠ ملغم / كغم على شكل كبريتات النحاس وفى فترة النهاية أضيفت نفس مصادر ومستويات النحاس مع مستويات (٢٩٠٠ و ٣١٠٠كيلو كالورى / كجم) من الطاقة، المكملات الغذائية من النحاس العضوي وغير العضوي تسبب في زيادة كبيرة في وزن الجسم في الطيور بالمقارنة مع الكنترول. الطيور المغداة على وجبات اضافية من النحاس العضوي تستهلك كمية غذاء أقل بكثير مقارنة مع مجموعة السيطرة، ولكن الدجاج التي غذيت على علائق منخفضة بالإضافة إلى النحاس العضوي أو غير العضوي تستهلك كميات مماثلة تقريبا من العلف مقارنة بالكنترول. تغذية الطيور وجبات عالية بالإضافة الى النحاس أفضل بكثير في معامل التحويل الغذائي من عنصر التحكم. المكملات الغذائية من النحاس ١٠٠جزء في المليون مع مستويات الطاقة المرتفعة لها تأثير كبير على محصول الذبيحة الفراريج، ونتوقع تلك التي تتغذى النظام الغذائي مرتفع بالإضافة إلى ١٠٠ جزء في المليون النحاس العضوي التي أظهرت أعلى عائد للذبيحة مقارنة مع مجموعة التحكم بهم. تغذية الطيور وجبات منخفضة بالإضافة إلى ٥٠ جزء في المليون النحاس العضوي أو ١٠٠ جزء في المليون من المعدني وتلك التي تتغذى على وجبات عالية بالإضافة إلى ١٠٠ جزء في المليون النحاس العضوي وتلك التي تعطى الوجبات الغذائية المنخفضة الطاقة بالإضافة إلى ٥٠ أو ١٠٠ جزء في المليون من النحاس العضوي والمعدني عرض أعلى بكثير مجموع الأجزاء الصالحة للأكل مقارنة مع مجموعة التحكم. الدجاج المغذي على الوجبات الغذائية عالية تستكمل مع ٥٠ أو ١٠٠ ملغم / كغم من النحاس العضوي أعلى من صافي الإيرادات والكفاءة الاقتصادية مقارنة مع الطيور السيطرة. ويمكن أن نخلص إلى أن الطيور التي غذيت على علائق عالية بالإضافة الى ١٠٠ جزء في المليون النحاس العضوي يمكن أن تحسن الأداء الإنتاجي للفراريج.