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Full Length Research Paper

Growth response and carcass quality of broiler chickens fed on diets supplemented with dietary copper sources

F. A. Igbasan* and S. K. Akinsanmi

Department of Animal Production and Health, School of Agriculture and Agricultural Technology, Federal University of Technology, P. M. B. 704, Akure, Nigeria.

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An experiment was conducted to determine the effects of dietary sources of copper on growth performance and carcass characteristics of broiler chickens. Three dietary sources of copper (Cu) namely: copper sulphate ($CuSO_4$), copper oxide (CuO) and copper acetate were added to a corn-soy basal diet, which was formulated to meet the nutrient requirements of broilers, at 150, 200 and 250 ppm. The control diet had no supplemental Cu. There were ten dietary treatment groups. One hundred and sixty ANAK 2000 broiler chicks were randomly divided into these treatment groups of 16 birds each. Each treatment group was further subdivided into four replicates of 4 birds per replicate. The experimental design was completely randomized with 3 × 3 factorial arrangements of treatments and the trial lasted for 42 days, after a pre-trial period of 14 days. The final body weight, body weight gain, feed intake and feed conversion ratio (FCR) of the birds were determined on weekly basis. At the end of the experiment, two birds per replicate were randomly selected and slaughtered for the evaluation of carcass quality traits. The average final body weight and body weight gain of the birds fed with Cu supplemented diets were significantly ($P \leq 0.05$) different from those fed with the control diet. The birds on Cu supplemented diets gained more body weight than birds on the control diet. Birds fed with 200 ppm Cu gained ($P \geq 0.05$) more weight than those on other levels of inclusion. Although not significant ($P \geq 0.05$), those birds fed with CuO gained more weight than birds on $CuSO_4$ and Cu acetate. There was no significant ($P \geq 0.05$) difference in the average feed intake of birds fed Cu supplemented diets compared to the birds on the control diet. The FCR of the birds fed with supplemented diets was significantly ($P \leq 0.05$) lower than that of the birds on the control diet. Those birds fed with Cu supplemented diets utilized feed better than birds on the control diet. Among those fed with dietary Cu salts, those birds on CuO utilized feed better ($P \leq 0.05$) than the birds on $CuSO_4$ and Cu acetate. Dietary Cu supplementation had no significant ($P \geq 0.05$) effect on carcass quality traits determined. It can be concluded from this study that dietary copper supplementation up to 250 ppm from $CuSO_4$, CuO and Cu acetate can substantially improve the growth performance and feed utilization of broilers.

Key words: Copper, supplemented diets, broiler chickens, growth performance, carcass quality.

INTRODUCTION

Researchers have intensified efforts to manipulate scarce and expensive feed materials in such a way that would make birds utilize them maximally for meat production.

These manipulations include the use of feed additives such as enzymes, vitamins and certain organic and inorganic mineral salts as growth promoters. While the enzymes may have hydrolytic effect on the hardly digested portion of feeds, the organic and inorganic salts either stimulate increased feed intake or act as growth promoters through their antimicrobial activities (McKinnon, 1985).

Copper is an important micro-mineral in poultry nutrition

*Corresponding author. E-mail: francisigbasan@yahoo.com.

used in normal bone formation, particularly cartilage formation. Lilburn and Leach (1980) showed that cartilage from copper deficient chicks oxidized less glucose than normal, and at a rate comparable to that seen in situations of tibial dyschondroplasia. Copper is also needed by animals to prevent microcytic hypochromic anaemia, thus, emphasizing its role in iron metabolism (Leeson and Summers, 2001). The element also plays a role in many other enzyme systems such as cytochrome oxidase, amino oxidase and poly-phenoloxidase (Kim and Hill, 1996; Leeson and Summers, 2001).

Copper requirement of poultry has been reported as 3 to 5 mg/kg dry feed (Georgievskii, 1979). Pesti and Bakalli (1996) also reported that the nutritional require-ment of copper for poultry is 10 mg/kg. The National Research Council (NRC, 1994) recommended between 8 and 10 ppm copper for broiler diets. Copper is normally fed to broiler chickens at levels above the nutritional requirement as a growth promoter and antimicrobial agent. However, there are conflicting reports about the growth stimulating effects of Cu on broiler chickens. Bakalli et al. (1995), Pesti and Bakalli (1996), Bakalli and Pesti (1996), Ewing et al. (1998), Luo et al. (2005), Arias and Koutsos (2006), Lu et al. (2010) and Kim et al. (2011) have shown that feeding dietary Cu in excess of the basal level that satisfied the nutritional requirement (10 ppm) improved the growth performance and feed conversion efficiency of broilers. Others have also shown that supplemental copper has little or no effect on growth performance and feed utilization of boiler chickens (Chiou et al., 1999; Nys, 2001; Skrivan et al., 2002; Sevcikova et al., 2003; Waldroup et al., 2003; Blanks et al., 2004; Pang et al., 2009; Xiang-Qi et al., 2009; Karimi et al., 2011). Higher levels of supplementation (above 250 mg/kg) have even been reported to decrease weight gain and feed utilization (Xiang-Qi et al., 2009; Karimi et al., 2011).

Dietary sources of copper affect the biological availability of copper to animal for absorption and utilization. Copper may exist as compounds of salt, such as, copper sulphate ($CuSO_4$), copper oxide (CuO), copper citrate, copper acetate, and copper carbonate or as complexes such as copper-methionine chelate, copper lysine complex, copper-soyproteinate and tribasic copper chloride. Copper sulphate and copper oxide have been the two predominant sources of supplemental copper used in animal feeds. Pesti and Bakalli (1996) found copper citrate to be more efficient as growth promoter than cupric sulphate pentahydrate. Koh et al. (1996) reported that though $CuSO_4$ and CuO gave similar increases in gain but $CuSO_4$ was more effective at increasing ceruloplasmin level, which implies that copper is more biologically available from $CuSO_4$ than CuO. Copper oxide is poorly absorbed from the gut and therefore should not be used as a supplement (Cromwell et al. 1989; Ledoux et al., 1991; Aoyogi and Baker, 1993). It has also been reported that Cu in the form complexes is more available and effective than the Cu in Cu sulphate (Luo et al., 2005; Lu et al., 2010; Kim et al., 2011).

Many nutritionists and feed manufacturers are concerned about the contradictory reports on the growth promoting effect of different sources of supplemental copper. Therefore, the present study was carried out to re-assess the effects of dietary copper sources on the growth performance and carcass quality of broiler chickens.

MATERIALS AND METHODS

The experiment was carried out at the Teaching and Research Farm of the Federal University of Technology, Akure, Nigeria. All animals received humane care and the principles outlined in the Helsinki declaration were adhered to strictly. A corn-soybean meal basal diet was formulated to meet the nutrient requirements (NRC, 1994) of growing broilers. The composition of the basal diet is presented in Table 1. The three sources of copper used in the trial were copper sulphate, copper oxide and copper acetate and they were obtained from Lixoy-K, Nig. Ltd., Akure, Nigeria. While $CuSO_4$ and CuO were in inorganic form, Cu acetate was in organic form. Each copper source was included in the basal diet at 150, 200 and 250 ppm levels. So there were ten dietary treatments. feed and water were provided for *ad libitum* consumption throughout the experimental period.

A total of 200 day-old ANAK 2000 broiler chicks were purchased from a reputable commercial hatchery (Chi Hatchery, Ajanla Farms, Ibadan, Nigeria). The birds were fed on commercial broiler starter ration for two weeks and starved for 4 h before they were randomly distributed amongst treatments based on the body weight. Out of these 200 chicks, 160 healthy ones were randomly assigned to 10 dietary treatments of 16 birds per treatment and four birds per replicate. There were four replicates per treatment and experiment lasted for six weeks. The experimental design was completely randomized with 3 × 3 factorial arrangement of treatments, that is, three sources of copper ($CuSO_4$, CuO and Cu acetate) and three levels of inclusion (150, 200 and 250ppm).

The growth performance data were determined between 14 and 56 days. During this period, weekly body weight and feed consumption were recorded. Feed conversion ratio was calculated from the body weight and feed consumption data. At the end of the experiment, two birds per replicate were randomly selected, weighed and tagged. Slaughtering was performed by severing the jugular vein with sharp surgical knife without anaesthetizing. The slaughtered birds were de-feathered using hot water and the dressed weights were recorded. After removal of viscera, the eviscerated weights were recorded and the abdominal fat pads and organs (liver, heart, kidney, spleen, lung, bursa, gizzard and pancreas) were removed and weighed. Carcasses were cut into basic parts (breasts, thighs, drumsticks, wings, shanks, heads, chests, backs and necks) and weighed.

The proximate composition of the basal diet was carried out according to the Official Method of Analysis (AOAC, 2005). The data collected were subjected to one way analysis of variance (ANOVA) according to the General Linear Model Procedures of SAS (2008). When analysis of variance indicated a significant treatment effect, Duncan's multiple range test (Duncan, 1955) was used to compare treatment means.

RESULTS

The initial body weight, final body weight, body weight

Table 1. Composition of the basal diet.

Ingredient	Amount (%)
Corn	51.75
Soybean meal	27.50
Fish meal	5.00
Wheat offal	10.00
Palm oil	3.00
Bone meal	2.00
DL-Methionine	0.10
L-Lysine	0.20
Premix[1]	0.25
Salt	0.20
Total	**100.00**

Nutrient	Calculated analysis (%)	Proximate (%)
Crude protein	23.19	22.51
Crude fibre	3.71	2.71
Lysine	1.37	-
Methionine	0.47	-
Ca	1.1	-
Avail. P	0.6	-
Ether extract	-	3.89
Ash	-	6.68
Nitrogen free extract	-	67.46
Metabolizable energy (kcal/kg)	3,089.22	-

[1]Broiler finisher premix per 1 kg used in the composition of the diet consist of the following: Vit A (500,000 iu), Vit D3 (1000,000 iu), Vit E (1,400 iu), Vit K (0.8 g), Thiamine B1 (0.8 g) Riboflavin B2 (2 g), Nicacin B3 (16g), D-calpan B5 (4.4 g), Pyridoxine B6 (1.6 g), Biotin (0.04 g), Folic acid (Vit B12) (0.006 g), Manganese (28 g), Copper (2.4 g), Iron (16 g), Iodine (0.4 g), Cobalt (0.1 g), Selenium (0.06 g), Sodium Chloride (200 g), BHT (200 g, BHT (50 g) per kg.

gain, feed intake and feed conversion ratio (FCR) are presented in Table 2 while Table 3 shows the effects of dietary Cu sources and levels on weight gain, feed intake and FCR. The average final body weight and average body weight gain of the birds fed with Cu supplemented diets were significantly ($P \leq 0.05$) different from those fed the control diet (Table 2). Among those birds fed with Cu supplemented diets, there was no significant ($P \geq 0.05$) effect of dietary Cu sources and levels on body weight gain (Table 3). However, those birds fed diets supplemented with CuO appeared to gain more weight numerically than those birds fed diets supplemented with $CuSO_4$ and Cu acetate.

There was no significant ($P \geq 0.05$) difference in the average feed intake of birds fed Cu supplemented diets as compared to other birds fed the control diet. The average feed intake (Table 3) of broilers fed diet containing Cu acetate was numerically higher than broilers fed other Cu supplemented diets. The FCR of the birds fed the control diet (Table 2) was significantly ($P \leq 0.05$) higher than the birds fed diets supplemented with Cu sources. Among those birds fed dietary Cu salts, those birds fed CuO utilized feed better ($P \leq 0.05$) than their counterparts (Table 3). The FCR of those birds fed dietary CuO was significantly ($P \leq 0.05$) lower than their counterparts fed dietary $CuSO_4$, so also those of the birds that were fed $CuSO_4$ were significantly ($P \leq 0.05$) lower than those birds fed dietary Cu acetate (Table 3).

The summary of the carcass characteristics of the broilers fed different dietary copper sources is shown in Table 4. There were no significant ($P \geq 0.05$) differences in the dressing weight (as percentage of live weight) of the broilers fed the control diet when compared with other broilers from dietary copper sources. Also there was no significant ($P \geq 0.05$) difference in the eviscerated weights (percentage of live weights) of the broilers from control diet and those from other supplemented diets. The treatment contrast among birds on copper supplemented diets also revealed that there was no significant ($P \geq 0.05$) difference in both dressed weights and eviscerated weights (Table 5).

The analysis of parts (as percent eviscerated weight) of the broilers as affected by dietary copper sources is presented in Table 6. With the exception of the heads, all

Table 2. The influence of dietary copper sources on performance of broiler chickens.

Dietary copper source	Level of inclusion (ppm)	Initial weight (g/bird)	Final weight (g/bird)	Weight gain (g/bird)	Feed intake (g/bird)	Feed conversion ratio
Control	0	115.0	1637.1[a]	1537.1[a]	3910.2	2.54[a]
	150	112.0	1914.6[bc]	1902.1[bc]	3925.0	2.18[bcd]
$CuSO_4$	200	116.7	1862.5[b]	1745.8[b]	3914.6	2.25[bc]
	250	114.2	1954.2[bc]	1840.0[bc]	3874.0	2.10[bd]
	150	113.3	1863.1[b]	1749.8[b]	4018.0	2.29[bc]
Cu acetate	200	115.8	2070.1[c]	1954.3[c]	4176.0	2.13[bd]
	250	120.0	1892.0[bc]	1771.7[bc]	4174.0	2.37[c]
	150	118.3	1982.0[bc]	1864.0[bc]	3968.8	2.14[bd]
CuO	200	116.7	2041.7[bc]	1925.0[bc]	3887.5	2.02[d]
	250	120.8	1992.1[bc]	1871.3[bc]	3979.6	2.00[bd]
SEM		2.71	56.13	55.49	114.93	0.06

Means with different superscripts within the same column for the parameter were significantly ($P \leq 0.05$) different; $CuSO_4$: Copper sulphate; CuO: Copper oxide.

Table 3. Factorial analysis of the performance of broiler chickens fed different dietary copper sources (means comparison).

	Average final weight (g)	Average weight gain (g)	Average feed intake (g)	Feed conversion ratio
Copper source				
$CuSO_4$	1910.40	1796.00	3904.60	2.18[a]
Cu acetate	1941.60	1825.20	4122.70	2.26[b]
CuO	2005.20	1886.60	3945.00	2.10[c]
Copper level (ppm)				
150	1919.90	1805.10	3970.00	2.21
200	1991.40	1875.00	3992.70	2.13
250	1946.00	1827.60	4009.30	2.20
Statistical significance				
Cu source	NS	NS	NS	*
Cu level	NS	NS	NS	NS
Cu source × Cu level	NS	NS	NS	*

Means with different superscripts within the same column for the same parameter were significantly different ($P \leq 0.05$); NS: Not significantly different at $P \geq 0.05$; * Significantly different at $P \leq 0.05$; $CuSO_4$: Copper sulphate; CuO: Copper oxide.

other parameters showed no significant ($P \geq 0.05$) differences. Also the wet weights (g/kg live weight) of organs as shown in Table 7 were not significantly ($P \geq 0.05$) affected by the supplemented copper diets.

DISCUSSION

The results of the final body weight and the weight gain by the birds on supplemental copper were significantly higher than that of birds fed basal diet. This suggests that copper may have growth promoting influence on broiler chickens. This finding was in agreement with those of Bakalli et al. (1995), Pesti and Bakalli (1996), Bakalli and Pesti (1996), Ewing et al. (1998), Skrivan et al. (2000), Luo et al. (2005), Arias and Koutsos (2006), Lu et al. (2010) and Kim et al. (2011) who reported that broilers given copper grew faster and utilized feed better than those on control diets. However, our results are in contrast with those of Chiou et al. (1999), Nys, (2001),

Table 4. The influence of dietary copper source on carcass characteristics of broiler chickens (% of live weight).

Dietary copper source	Level of inclusion (ppm)	Live weight (kg)	Dressing weight (% live weight)	Eviscerated weight (% live weight)
Control	0	1.76	89.70	83.90
	150	1.80	90.00	83.50
$CuSO_4$	200	1.80	98.40	96.50
	250	1.96	86.30	82.30
	150	1.78	88.40	83.40
Cu acetate	200	2.05	90.60	85.70
	250	1.73	89.70	83.60
	150	1.94	89.80	83.30
CuO	200	1.76	93.70	84.78
	250	1.82	88.60	83.00
SEM	-	1.10	1.18	1.19

The means were not significantly ($P \geq 0.05$) different; $CuSO_4$: Copper sulphate; CuO: Copper oxide.

Table 5. Factorial analysis of carcass characteristics of broiler chickens fed different dietary copper sources (means comparison).

	Live weight (g)	Dressed weight (% live weight)	Eviscerated weight (g)
Copper source			
$CuSO_4$	1852.10	88.54	1552.10
Cu acetate	1852.10	89.54	1550.00
CuO	1837.50	90.67	1541.70
Copper level (ppm)			
150	1837.90	89.38	1535.40
200	1868.70	91.19	1595.80
250	1835.40	88.18	1512.50
Statistical significance			
Cu source	NS	NS	NS
Cu level	NS	NS	NS
Cu source × Cu level	NS	NS	NS

The means were not significantly ($P \geq 0.05$) different; NS: Not significant at $P \geq 0.05$; $CuSO_4$: Copper sulphate; CuO: Copper oxide.

Skrivan et al. (2002), Sevcikova et al. (2003), Waldroup et al. (2003), Blanks et al. (2004), Pang et al. (2009), Xiang-Qi et al. (2009) and Karimi et al. (2011), who found no positive effect of copper supplementation on broiler performance. In the present study, the capacity of the three sources of Cu to promote weight gain and feed conversion efficiency was not similar. Copper oxide was found to be a better source of copper because those birds fed on dietary copper oxide numerically gained more weight and utilized feed better than those on other sources. This implies that copper oxide was more efficient in promoting growth and feed utilization than other two sources. This finding did not confirm the results presented by Cromwell et al. (1989), Ledoux et al. (1991), and Aoyogi and Baker (1993) which showed copper oxide as a poor source of copper. The results of broilers fed supplemental copper acetate at 200 ppm was numerically higher than that of copper oxide while copper oxide at the same level of inclusion was numerically higher than that of $CuSO_4$. This suggests that 200 ppm

Table 6. The influence of dietary copper sources on carcass characteristics (parts) of broiler chickens (as percentage of eviscerated weights).

Level of inclusion (ppm)	Head	Shank	Drumstick	Chest	Breast muscle	Abdominal fat	Back	Neck	Wing	Thigh
Control	3.47[a]	2.30	5.24	17.29	6.86	1.50	15.34	5.65	4.97	6.14
$CuSO_4$										
150	3.36[ab]	2.65	5.54	16.31	6.11	1.50	16.14	6.11	5.09	5.72
200	3.37[ab]	2.49	5.26	18.04	6.17	0.83	13.72	5.37	4.72	5.82
250	3.25[b]	2.46	5.43	16.62	5.82	2.64	15.64	5.22	4.14	5.40
Cu acetate										
150	2.96[cd]	2.47	5.16	17.28	5.82	1.94	16.05	6.43	4.77	5.42
200	2.89[cd]	3.60	5.83	17.71	6.36	1.56	14.98	5.94	4.67	5.88
250	2.95[cd]	3.12	5.81	17.71	6.02	1.50	14.58	5.89	4.36	5.50
CuO										
150	2.86[d]	2.37	5.38	17.07	7.03	1.43	17.25	5.14	4.74	5.75
200	3.10[bc]	2.55	5.44	17.31	6.84	1.70	16.34	5.91	4.36	5.81
250	2.96[cd]	2.53	5.60	17.88	6.06	1.36	15.03	6.03	4.19	5.75
SEM	0.16	0.19	0.27	1.10	0.51	0.30	0.71	0.34	0.27	0.26

Means with different superscripts within the same column for the same parameter were significantly ($P \leq 0.05$) different; $CuSO_4$: Copper sulphate; CuO: Copper oxide.

Table 7. The influence of dietary copper sources on organ weight of broiler chickens (g/kg live weights).

Dietary copper source	Level of inclusion (ppm)	Liver	Heart	Kidney	Spleen	Lung	Bursa	Gizzard	Pancreas
Control	0	17.10	4.40	6.10	0.96	5.48	1.36	40.31	1.81
	150	16.10	4.20	5.01	1.00	5.32	1.86	40.68	1.69
$CuSO_4$	200	17.09	4.32	6.70	1.38	5.77	2.36	38.71	2.03
	250	13.80	4.41	6.21	1.08	5.39	3.44	32.30	1.64
	150	16.18	5.10	5.69	1.26	5.57	2.01	38.00	1.78
Cu acetate	200	14.51	4.50	5.22	0.84	5.17	2.10	33.00	1.76
	250	16.32	4.71	5.58	1.05	5.22	2.81	37.41	1.92
	150	14.78	3.80	5.50	0.85	5.97	3.10	37.30	1.84
CuO	200	14.89	4.10	5.40	0.70	6.35	2.32	38.60	1.84
	250	14.30	4.60	5.89	0.81	5.53	2.48	39.61	1.79
SEM		0.74	0.27	0.49	0.13	0.73	0.55	2.70	0.08

The means were not significantly ($P \geq 0.05$) different; $CuSO_4$: Copper sulphate; CuO: Copper oxide.

level of inclusion was better than other levels. This was in agreement with the findings of Omole (1980) who reported that 200 ppm was more effective when 14 or 18% dietary protein was fed. Although, the protein level used in this study was higher. He further reported that 200 ppm was more effective than 250 ppm for growth promotion regardless of the source of dietary fat.

The exact mechanism through which copper promotes growth performance of animals has not been fully elucidated. Certainly the excreta colour of the birds changes markedly, and it is presumed that there may be some changes to the microbial gut flora. Evidence that copper produces a growth promoting effect through modification of microbial gut flora is supported by the results of Shurson et al (1990) and Kim et al. (2011) who observed a positive effect of high concentration of copper in the diet on gut microbial populations in pigs and chickens, respectively. Aoyagi and Baker (1995) suggest that the beneficial effect of copper may result from improved digestion of hemicelluloses. After feeding 250 mg/kg Cu diet, they recorded a 15% increase in hemicelluloses digestion and a substantial increase in apparent metabolizable energy (AMEn) of the diet. In explaining their results, Aoyagi and Baker (1995) suggest that excess copper stimulates clearing of liver copper into bile through exocytosis of hepatocellular lysosymes. A side effect of such action is increased bile secretion of glucosidases, which could be available for carbohydrate digestion. Omole (1979) has also suggested that the enhanced growth as a result of supplemental copper could be attributed to improved nutrient utilization.

The average feed intakes of the birds fed supplemental diets were not significantly different from the birds fed basal diets. However, birds fed diets supplemented with Cu tended to consume more feed than the control. The inclusion of copper salts in the feed gives such a characteristic aroma and birds are believed to possess very sensitive sensory organs that can easily pick up the aroma emanating from their feed and thus may encourage them to eat more (McKinnon, 1985). It can therefore be said that copper salts did stimulate feed intake as suggested by Biobaku et al. (1999). The fact that broilers fed copper supplemented diets tended to consume more feed than those on the control diet was in agreement with the findings of Kings (1975) and Luo et al. (2005). The birds fed supplemental copper acetate diet appeared to have higher feed intake. This might probably be attributed to the fact that copper acetate is an organic salt while others were inorganic salts which, makes copper acetate more palatable to stimulate higher feed consumption than others.

Chowdhury et al. (2004) and Luo et al. (2005) have reported that birds fed organic Cu-methionine chelate and tribasic copper chloride consumed more feed than birds fed inorganic $CuSO_4$.

A post-mortem measurement of the birds in the treatments shows that average carcass yields were not influenced by copper supplementation. These results confirmed the results obtained by Waldroup et al. (2003), Arias and Koutsos (2006) and Xiang-Qi et al. (2009), who reported that addition of Cu in excess of the minimum needs (NRC, 1994) had no significant influence on carcass yields. The differences in weight gains of the birds fed Cu supplemented diets over birds fed control diet observed in this study might have been spread among the carcass parts thereby making the gains less pronounced on individual parts. The thigh muscle weights of the birds fed basal diet were numerically higher than those of the birds fed supplemental diets. This may be due to the fact that thigh muscles are known to accumulate lipid. It has been shown by Miles et al. (1998) that copper can act as pro-oxidant, potentially destroying the fat and fat-soluble compounds thereby aiding the production of lean meat.

Conclusions

The results from this study suggest that, dietary copper supplementation can substantially influence the growth performance and feed utilization of broilers. Dietary copper from these sources can be incorporated in to broiler ration up to 250 ppm without any noticeable adverse effects on the performance of the birds and quality of their meat products. The birds appeared to perform better at 200 ppm level of incorporation. One can therefore, recommend that copper from either copper oxide, copper acetate or copper sulphate can be safely incorporated into broiler diet up to 250 ppm without any noticeable adverse effect on performance and the health of the animal.

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