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COPPER-PROTEIN NUTRITION OF NEW ZEALAND WHITE RABBITS UNDER EGYPTIAN CONDITIONS

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ABSTRACT : One hundred and twenty male New Zealand White (NZW) rabbits of 35 days of age were randomly allotted to twelve groups. Rabbits of six groups were fed a low protein diet (16.44 % crude protein) and the other six were fed a high protein diet (18.5 % crude protein). Within each dietary protein level, three groups were supplemented with copper sulfate to supply either 0, 100 or 200 ppm copper/kg diet, while the other three were supplemented with copper chloride to supply the same levels of copper. Most of the studied traits were affected positively with the increase in each of protein and copper levels in the diets of NZW rabbits without interaction. The affected traits were : live body weight and daily gain (Protein high *vs* low : 28.2 *vs* 23.4 g/d ; Cu 0-100-200 ppm : 22.1-25.9-29.2 g/d ; P<0.001), feed conversion, protein efficiency, nutrient digestibility and final margin, as well as, concentration of serum protein, albumin (Protein high : + 12 % *vs* low ; Cu 100 and 200 ppm : 8 % and 17 % *vs* 0 ppm ; P<0.001), urea, creatinine (P<0.01) and SGOT (P<0.05). Feed cost, serum globulin level, SGPT and some carcass and non-carcass components were insignificantly affected by levels of either protein or copper. Dressing percentage increased slightly with the increase of dietary protein and copper levels, while empty gut percentage (relatively to live body weight) decreased with addition of copper in rabbit diets. The effects of copper source and the interaction between protein level and each of copper level and source on the traits studied, did not show any significance.

RÉSUMÉ : Cuivre et protéines dans la nutrition de lapins NZW élevés en Egypte.
Cent vingt lapins mâles NZW âgés de 35 jours ont été répartis au hasard en 12 groupes. Six groupes ont reçu un régime pauvre en protéine (16,44 % de protéine brute) et les 6 autres un régime riche en protéines (18,5 % de protéines brutes). Dans chacun des groupes de niveau protéique, 3 groupes ont été supplémentés avec du sulfate de cuivre à raison de 0, 100 ou 200 ppm de cuivre/kg aliment, tandis que les 3 autres étaient supplémentés avec du chlorure de cuivre tel que les taux de cuivre soient identiques. La plupart des caractéristiques étudiées on été affectées positivement par le taux de protéines et les additions sans interactions de cuivre. Les caractères améliorés ont été le poids vif et la vitesse de croissance (Protéines riches vs protéines pauvres : 28,2 vs 23,4 g/j ; Cu 0-100-200 ppm : 22,1-2,9-29,2 g/j ; P<0.001), l'indice de consommation, l'efficacité protéique, la digestibilité de l'aliment. Ont également été améliorés le bénéfice financier, le taux de protéines sanguin, l'albumine (Protéines riches : + 12 % vs pauvres ; Cu 100 ppm et 200 ppm : + 8 % et 17 % vs 0 ppm ; P<0.001), urée, la créatinine (P<0.01) et SGOT (P<0.05). Le coût de l'aliment, le taux sanguin de globuline, SGPT et quelques composants du rendement à l'abattage n'ont pas été affectés significativement ni par le niveau de protéine ni celui du cuivre. Le rendement de la carcasse augmente légèrement avec l'augmentation des taux de protéine et de cuivre, tandis que le pourcentage représenté par le tube digestif vide, par rapport au poids vif, diminue avec l'apport de cuivre dans l'alimentation des lapins. L'effet de la source de cuivre et l'interaction entre le taux de protéines et chacun des taux de cuivre et de sa provenance, sur les caractéristiques étudiées, n'étaient pas significatifs.

INTRODUCTION

High dietary level of cooper has shown to act as a growth promoter in rabbits. OMOLE (1977) found that feeding diets with high copper (200 ppm) – low protein (14 or 18 %) was more effective as growth promoter than with a low copper (150 ppm) – high protein (22 %) diet. However, AYYAT (1994) reported that a diet with low copper (200 ppm) – high protein (16.8 %) was more effective than high copper (300 ppm) – low protein (13.2 %) diet. QUATERMAN (1967) reported that rabbits maintain normal health and growth on diets containing up to 500 ppm copper.

With regard to the source of copper, several investigators have reported that the copper sulfate was effective in this respect (OMOLE 1977, 1979 ; PATTON *et al.*, 1982 ; FEKETE *et al.*, 1988 ; BASSUNY, 1991 ; AYYAT, 1994), while others (BUNCH *et al.*, 1964) reported that addition of copper carbonate, copper–methionine and copper sulfate in diets improved growth rate.

The present experiment was conducted to study the growth performance of New Zealand White rabbits as affected by varying dietary protein levels (16.44 and 18.5 %) graded with different levels of copper (0, 100 and 200 ppm/kg diet) from different sources (copper sulfate and copper chloride) under Egyptian sub–tropical conditions.

MATERIALS AND METHODS

One hundred and twenty male New Zealand White rabbits of 35 days old with nearly equal live body weights at the beginning of the experiment, were randomly allotted to twelve groups. Rabbits of six groups were fed a low protein diet containing 16.44 % crude protein, 13.1 % crude fibre and 2665 kcal/kg dry matter digestible energy calculated according to NRC (1977). The constituents of the diet were 30 % alfalfa hay, 24 % corn, 13 % soybean meal, 28 % wheat bran, 3 % molasses, 1.4 % limestone, 0.3 % sodium chloride and 0.3 % vitamin and mineral premix. The other six groups were fed a high protein diet containing 18.5 % crude protein, 13.1 % crude fibre and 2670 kcal/kg dry matter digestible energy. The constituents of the diet were 32 % alfalfa hay, 20 % corn, 19 % soybean meal, 24 % wheat bran, 3 % molasses, 1.4 % limestone, 0.3 % sodium chloride and 0.3 % vitamin and mineral premix. Within each dietary protein level, three groups were supplemented with copper sulfate to supply either 0, 100 or 200 ppm copper/kg diet, while the other three groups were supplemented with copper chloride to supply the same levels of copper (0, 100 or 200 ppm). Feed and water were available *ad libitum* all time.

All rabbits were kept under the same managerial and hygienic conditions at the Rabbitry Farm of the Department of Animal Production, Faculty of Agriculture, Zagazig University, Zagazig, Egypt. The rabbits were housed in batteries provided with feeders and automatic drinkers. The batteries were located in a conventional confined and windowed building.

Rabbits were weighed an feed consumption was recorded at weekly intervals. At the end of experimental period, five rabbits from each group were randomly taken for slaughter test, after being fasted for 12 hours. After complete bleeding, the carcass and some non–carcass components were weighed. Blood samples were taken at the time of slaughter to estimate blood components.

At the end of the feeding treatments, four rabbits from each group were housed in individual metabolism cages. Faeces were quantitatively collected for 6 days. Samples were taken and dried for chemical analysis. Chemical composition of the rations and faeces were analysed according to A.O.A.C. (1980).

Data of the body weight and gain and blood traits were statistically analysed by (2 x 2 x 3) factorial design (SNEDECOR and COCHRAN, 1982) according to the following model :

$$Y_{ijkl} = \mu + P_i + S_j + L_k + PS_{ij} + PL_{ik} + SL_{jk} + PSL_{ijk} + E_{ijkl} \quad (1)$$

where :

μ = the overall mean
P_i = the fixed effect of i^{th} dietary protein level ($i = 1, 2$)
S_j = the fixed effect of j^{th} copper source ($j = 1, 2$)
L_k = the fixed effect of k^{th} dietary copper level ($k = 1, 2, 3$)
PS_{ij} = the interaction between i^{th} dietary protein level and j^{th} copper source
PL_{ik} = the interaction between the i^{th} dietary protein and k^{th} copper levels
SL_{jk} = the interaction between j^{th} copper source and k^{th} copper level
PSL_{ijk} = the interaction between i^{th} dietary protein level, j^{th} copper source and k^{th} copper level
E_{ijkl} = random error.

Slaughter data were analyzed by analysis of covariance according the following model :

$$Y_{ijkl} = \mu + P_i + S_j + L_k + PS_{ij} + PL_{ik} + SL_{jk} + PSL_{ijk} + b\,(X-x) + E_{ijkl} \quad (2)$$

where
μ, P_i, S_j, L_k, PS_{ij}, PL_{ik}, SL_{jk}, PSL_{ijk}, E_{ijkl} = were as defined in the previous model 1,
b = regression coefficients of Y on X (slaughter weight) and x is the arithmetic means of the X's (slaughter weight).

RESULTS AND DISCUSSION

The increase in each of protein and copper levels was accompanied with the increase ($P<0.001$) in rabbits body weight and gain (Table 1), feed conversion and protein efficiency ratio (Table 2). OMOLE (1977 and 1979), FEKETE *et al.* (1988), BASSUNY (1991) and AYYAT (1994) reported similar results. Moreover, LADETTO *et al.* (1984) found that addition of copper sulfate or copper oxide in rabbit diets insignificantly increased growth rate or feed utilization.

Nutrient digestibility was improved by the increase in each of dietary protein and copper levels (Table 3) similar to that reported by ANUGWA *et al.* (1984), FEKETE *et al.* (1988) and BASSUNY (1991). Feed cost was not affected, while return from live body gain and final margin increased with the increase in protein and copper levels in rabbit diets (Table 4). Addition of 100 or 200 ppm copper in rabbit diets increased the final margin with 27.0 and 51.7 %, respectively, than in the control diet, similar to that obtained by AYYAT (1994).

Concentration of serum protein, albumin, urea, creatinine and SGOT increased significantly, while serum globulin and SGPT insignificantly increased by the increase of each of protein and copper levels (Table 5). BASSUNY (1991) and AYYAT (1994) reported similar results.

Table 1 : Averages of live body and gain weights (g) of New Zealand White rabbits as affected by dietary protein and copper levels and sources.

Items	Body weight (g)			Gain weight (g)		
	5 weeks	9 weeks	13 weeks	5–9 weeks	9–13 weeks	5–13 weeks
Dietary protein level :						
Low	810 ± 15	1465 ± 22	2119 ± 27	23.4 ± 0.7	23.3 ± 0.5	23.4 ± 0.5
High	815 ± 18	1599 ± 24	2396 ± 31	28.0 ± 0.7	28.5 ± 0.6	28.2 ± 0.6
Significance	NS	***	***	***	***	***
Copper level :						
0 ppm	807 ± 20	1405 ± 22	2047 ± 28	21.3 ± 0.7	22.9 ± 0.6	22.1 ± 0.5
100 ppm	808 ± 19	1552 ± 24	2256 ± 31	26.6 ± 0.8	25.1 ± 0.6	25.9 ± 0.6
200 ppm	821 ± 21	1633 ± 30	2455 ± 37	29.0 ± 0.9	29.4 ± 0.7	29.2 ± 0.6
Significance	NS	***	***	***	***	***
Copper source :						
$CuSO_4$	820 ± 17	1533 ± 23	2248 ± 33	25.5 ± 0.7	25.5 ± 0.7	25.5 ± 0.6
CuCl	805 ± 16	1530 ± 26	2265 ± 36	25.9 ± 0.9	26.2 ± 0.6	26.1 ± 0.7
Significance	NS	NS	NS	NS	NS	NS

*** P<0.001 ; NS : not significant ; All interactions between factors studied were not significant.

Analysis of covariance of carcass and some non–carcass components relatively to live body weight at slaughter did not show any significant effect of the dietary treatments (Table 6). Dressing percentage increased slightly with the increase in dietary protein and copper levels, while percentage of the empty gut (relatively to live body weight) decreased with addition of copper in rabbit diets (Table 7). BASSUNY (1991) found no effect of copper sulfate supplementation on carcass yield.

BOWLAND *et al.* (1961) clarified that the absorbed copper is bound with plasma protein, probably albumin. ADELSTEIN and VALEE (1962) confirmed that albumin–bound copper serves as an intermediate form to transport and distribute widely copper from the gut through the blood to the tissues especially the parenchymal cells of the liver and kidney. In the liver, copper is synthesized into ceruloplasmin or other copper–protein complexes. In other words, addition of copper in rabbit diets increased the liver function and protein synthesis in the liver. In addition, the effect of copper can be attributed to the antibiotic–like action of copper on the intestinal micro–organisms (HAWBACKER *et al.*, 1961). KING (1975) and OMOLE (1977, 1979) clarified that addition of copper sulfate in rabbits diets caused thinning of caecum and small intestine, that may facilitate the uptake of essential nutrients from gut tract.

The copper source did not show any significant effect on any of the traits studied (Tables 1 to 7). Similarly, BUNCH *et al.* (1965) observed a close similarity in the performance of animals receiving supplementations of copper from different chemical forms.

Table 2 : Feed intake (g/day) and conversion (g food/g gain) and protein efficiency (g gain/g protein intake) of New Zealand White rabbits as affected by dietary protein and copper levels and sources.

	Feed intake			Feed conversion			Protein efficiency		
	5–9 weeks	9–13 weeks	5–13 weeks	5–9 weeks	9–13 weeks	5–13 weeks	5–9 weeks	9–13 weeks	5–13 weeks
Dietary protein level :									
Low	73.67	124.00	98.83	3.20	5.41	4.31	1.95	0.95	1.44
High	64.83	115.17	90.00	2.36	4.11	3.24	2.33	1.03	1.68
Copper level :									
0 ppm	68.50	121.50	95.00	3.26	5.48	4.37	1.79	0.88	1.33
100 ppm	70.00	120.50	95.25	2.67	4.80	3.72	2.19	0.89	1.54
200 ppm	69.25	116.75	93.00	2.42	4.03	3.23	2.41	1.19	1.80
Copper source :									
$CuSO_4$	69.00	120.67	94.83	2.78	4.87	3.82	2.12	0.93	1.52
CuCl	96.50	118.50	94.00	2.79	4.65	3.72	2.14	1.04	1.59

Table 3 : Digestibility coefficients of New Zealand White rabbits as affected by dietary protein and copper levels and sources.

Items %	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	Nitrogen free extract
Dietary protein level :						
Low	63.14	66.92	72.83	76.75	29.80	73.41
High	63.30	68.18	75.94	75.54	32.17	75.18
Copper level :						
0 ppm	62.10	66.57	72.61	75.18	29.20	72.29
100 ppm	62.91	67.54	74.65	75.67	31.09	73.84
200 ppm	64.65	68.55	75.90	77.59	32.67	76.75
Copper source :						
$CuSO_4$	63.31	67.54	74.49	76.34	30.94	74.43
CuCl	63.14	67.56	74.29	75.95	31.03	74.15

Table 4 : Profit analyses for New Zealand White rabbits as affected by dietary protein and copper level and source.

Items	Feed intake (kg)	Body gain (kg)	Feed cost** (L.E.)	Return from body gain*** (L.E.)	Margin* (L.E.)	Mortality (%)
Dietary protein level :						
Low	5.535	1.309	2.934	8.509	5.575	3.33
High	5.040	1.581	2.923	10.277	7.354	5.00
Copper level :						
0 ppm	5.320	1.239	2.948	8.054	5.106	5.00
100 ppm	5.334	1.452	2.953	9.438	6.485	7.50
200 ppm	5.208	1.635	2.884	10.628	7.744	0.00
Copper source :						
$CuSO_4$	5.311	1.425	2.941	9.263	6.322	3.33
CuCl	5.264	1.460	2.915	9.490	6.575	5.00

* Final margin ; ** Price of one kg diets from high and low crude protein levels were 0.58 and 0.53 L.E. respectively ; *** Selling price of one kg live body weight rabbit was 6.5 L.E. ; L.E. : Egyptian pound (0.3 USA $).

Table 5 : Blood components of New Zealand White rabbits as affected by dietary protein and copper level and source.

	Protein (g/100 ml)	Albumin (g/100 ml)	Globulin (g/100 ml)	Urea-N (mg/100 ml)	Creatinine mg/100 ml)	SGPT (μ/l)	SGOT (μ/l)
Dietary protein level :							
Low	6.51 ± 0.08	3.35 ± 0.07	3.16 ± 0.05	15.60 ± 0.40	1.07 ± 0.02	24.7 ± 0.6	10.5 ± 0.3
High	7.05 ± 0.14	3.75 ± 0.09	3.30 ± 0.10	16.82 ± 0.42	1.16 ± 0.20	25.6 ± 0.6	11.0 ± 0.4
Significance	***	***	NS	**	**	NS	*
Copper level :							
0 ppm	6.41 ± 0.12	3.28 ± 0.09	3.13 ± 0.43	16.25 ± 0.43	1.12 ± 0.02	25.0 ± 0.6	10.9 ± 0.3
100 ppm	6.75 ± 0.12	3.54 ± 0.08	3.21 ± 0.26	17.23 ± 0.26	1.11 ± 0.02	25.3 ± 0.5	10.2 ± 0.2
200 ppm	7.17 ± 0.16	3.83 ± 0.12	3.34 ± 0.23	17.77 ± 0.23	1.18 ± 0.03	27.9 ± 0.6	12.5 ± 0.2
Significance	***	***	NS	**	**	NS	**
Copper source :							
$CuSO_4$	6.78 ± 0.13	3.56 ± 0.10	3.22 ± 0.09	16.18 ± 0.42	1.11 ± 0.02	25.2 ± 0.6	10.6 ± 0.3
CuCl	6.78 ± 0.12	3.54 ± 0.09	3.24 ± 0.07	16.25 ± 0.43	1.12 ± 0.02	25.0 ± 0.6	10.9 ± 0.3
Significance	NS	NS	NS	NS	NS	NS	NS

* : $P<0.05$; ** : $P<0.01$; *** : $P<0.001$. All interactions between factors studied were not significant.

Table 6 : Live weight means (g) and least squares means for carcass and some non-carcass components of New Zealand White rabbits as affected by dietary protein and copper levels and sources.

Weights (g) :	Live body	Carcass	Gut	Liver	Kidney	Kidney fat
Dietary protein level :						
Low	2145 ± 41	1266.2 ± 7.5	223.0 ± 6.2	72.3 ± 1.6	15.4 ± 0.4	20.5 ± 1.2
High	2188 ± 46	1272.8 ± 7.5	220.0 ± 6.2	69.7 ± 1.6	15.0 ± 0.4	20.7 ± 1.2
Copper level :						
0 ppm	1985 ± 22	1242.7 ± 8.1	236.4 ± 8.3	68.3 ± 2.2	14.9 ± 0.6	21.1 ± 1.6
100 ppm	2241 ± 50	1258.0 ± 7.3	214.7 ± 7.5	73.8 ± 2.0	15.2 ± 0.5	21.0 ± 1.5
200 ppm	2274 ± 56	1307.9 ± 7.5	213.4 ± 7.7	71.0 ± 2.0	15.6 ± 0.5	19.6 ± 1.5
Copper source :						
$CuSO_4$	2148 ± 46	1272.2 ± 7.5	220.8 ± 6.2	72.3 ± 1.6	15.3 ± 0.4	19.0 ± 1.1
CuCl	2185 ± 41	1266.8 ± 7.5	222.2 ± 6.2	69.7 ± 1.6	15.2 ± 0.4	22.2 ± 1.1

Analysis of covariance did not show any significance as affected with factors studied.

Table 7 : Percentages of carcass and some non–carcass components relatively to live body weight of New Zealand White rabbits as affected by dietary protein and copper levels and sources.

Items	Dressing % *	Gut %	Liver %	Kidney %	Kidney fat %
Dietary protein level :					
Low	58.29	10.51	5.72	1.23	1.64
High	58.72	10.17	5.48	1.18	1.60
Copper level :					
0 ppm	56.89	11.74	5.54	1.28	1.68
100 ppm	58.23	9.71	5.86	1.18	1.69
200 ppm	60.40	9.58	5.41	1.16	1.50
Copper source :					
$CuSO_4$	58.55	10.42	5.68	1.22	1.49
CuCl	58.46	10.26	5.53	1.20	1.75

* Including the head.

The interactions between the protein level and each of copper level and source, did not show any significant effect on the traits studied, indicating that the studied factors act additively, contrarily to that reported by other investigators (OMOLE, 1977 ; AYYAT, 1994).

In conclusion, addition of 200 ppm copper sulfate or chloride into rabbit diets containing either 16.4 or 18.5 % crude protein improves each of growth rate, feed efficiency ratio and nutrient digestibility and it seems that each of copper and protein acts independently.

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