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بسم الله الرحمن الرحيم

THE RESPONSE OF GROWING NEW ZEALAND WHITE RABBITS TO DIFFERENT DIETARY PROTEIN LEVEL AND SUPPLEMENTATION WITH COPPER AND VITAMIN C.

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ABSTRACT

One hundred eight New Zealand White rabbits of 35 day-old with an average weight of 872 to 882 g were divided into 18 treatment groups of 6 rabbits each. All rabbits were kept into an individual cage and reared under the same managerial and hygienic conditions.

A 2 X 3 X 3 factorial arrangement of treatments were used involving two protein levels (14 and 16 %) with three levels of copper sulfate ($CuSO_4.5H_2O$) to provide either zero, 250 or 750 mg/kg diet and graded levels of zero, 300 or 600 ppm coated ascorbic acid. Diets and water were offered to the rabbit *ad-libitum allover the* experimental period, which lasted for 15 weeks.

Eighteen digestion trials (3 rabbits each) were conducted for 5 days prelminary period followed by 4 days collection period using metabolism stainless steel cages, which allowed a quantitative collection of feces and urine.

Data showed that increasing either protein or vitamin C levels in diets increased CP, CF and EE digestibility, while supplementation of copper sulfate had no significant ($P<0.05$) effect on all nutrients digestibility except for CF. The interaction effect among protein, copper sulfate and vitamin C were similar to supplementation of copper sulfate and vitamin C each alone. The TDN values were not affected ($P<0.05$) due to protein level, copper sulfate and vitamin C, without interaction, also highly significant effect ($P<0.05$) was observed with DCP.

Balance of major and trace elements was influenced by protein level and supplementation of copper sulfate and vitamin C. Cobalt balances in all treatments were negative. While, all rabbits were in positive N-balances, which were not affected by protein levels but affected by copper sulfate and vitamin C supplementation.

Feeding trials showed that final body weight and weight gain were affected ($P<0.05$) by protein and vitamin C levels with increasing rate 11.83 - 13.45% and 28.88 - 22.52% for diets containing either 14 or 16 % CP, respectively. While feed consumption and feed efficiency were affected ($P<0.05$) by protein level, copper sulfate and vitamin C.

Keywords: Rabbits, protein level, copper, vitamin c

INTRODUCTION

Recently, several reports have indicated that rabbits productivity is the main target to solve the shortage gab of animal protein for human consumption, specially in tropical countries.

Contradictory reports exist in literature regarding protein requirements for growing rabbits (NRC,1977), which ranged from 16 to18% crude protein to meet the need of growing New Zealand White rabbits in tropical conditions.

Therefore, low protein diets resulted in depressed feed intake and feed utilization (Ayyat1991).

Copper is an essential element to animals for physiological functions, its supplementation in rabbit diets in different forms improved weight gain and feed efficiency (Bassuny, 1991 and Ayyat, 1994). While, rabbits may tolerate high copper feeding (McDowell, 1992). The response of rabbits to supplemental copper was influenced by dietary protein (Ayyat, 1994) and vitamin C. This response may improve the feed: gain of animals for human consumption (Van Den Berg et al 1990 and Van Den Berg and Beynen, 1992).

This experiment aimed to study the effects of varying dietary protein levels with graded levels of copper (as $CuSO_4.5H_2O$) and different levels of vitamin C (as coated ascorbic acid)on the growth performance of New Zealand white rabbits under the Egyptian conditions.

MATERIALS AND METHODS

This study was conducted at Sids Research Station, Beni-Sweef Governorate, Animal Production Research Institute, Agricultural Research Center, Egypt, during the period from January to April, 1997.

One hundred eight weaned un-sexed New Zealand White rabbits of 35 days of age with nearly equal body weight were randomly allocated to 18 treatment groups of 6 rabbits each in individual cages (stainless steel). All rabbits were kept under the same managerial and hygienic conditions.

A 2 X 3 X 3 factorial design was used involving two basal diets containing either 14 or 16% CP with three levels of $CuSO_4 .5H_2O$ which were added to the diets to provide either zero, 250 or 750 mg/kg diet and graded levels of Vitamin C (zero, 300 or 600 ppm) as coated ascorbic acid (Table 1) .

Table 1: Design of the experimental treatments.

Diet containing 14% CP (D1)			Diet containing 16 % CP (D2)		
Treatment no.	$CuSO_4 .5H_2O$ mg/kg diet	Vitamin C * (ppm)	Treatment no.	$CuSO_4 .5H_2O$ mg/kg diet	Vitamin C (ppm)
1		Zero	10		Zero
2	Zero	300	11	Zero	300
3		600	12		600
4		Zero	13		Zero
5	250	300	14	250	300
6		600	15		600
7		Zero	16		Zero
8	750	300	17	750	300
9		600	18		600

*** : Vitamin C was added as coated ascorbic acid (registered trade mark ROVIMIX, C) from Rovigypt Company, Hoffmann- La Roche Limited.**

The two basal diets with either 14% or 16% crude protein contained 2650 kcal DE / kg and their composition are shown in Table 2.

Diets and water were offered to the rabbit *ad-libitum* and feed consumption was recorded. Rabbits were weighed at weekly intervals during

10-weeks of the experimental period.

Table 2: Composition and calculated analysis of basal diets.

Ingredients (%)	Diets	
	14% CP (D1)	16% CP (D2)
Clover hay	40.82	40.46
Wheat bran	19.00	19.50
Yellow corn	15.35	9.51
Barley	15.00	15.00
Soybean meal (44%)	4.82	10.60
Molasses	3.00	3.00
Limestone	1.05	1.03
Table salt	0.50	0.50
Premix*	0.30	0.30
DL- methionine	0.16	0.10
Calculated values :		
CP (%)	14.20	16.20
DE (kcal / kg)	2650	2650
TDN (%)	58.77	58.77
CF (%)	14.00	14.00
EE (%)	2.66	2.51
Ca (%)	1.00	1.00
Total P (%)	0.46	0.47
Lysine (%)	0.75	0.87
Methionine+Cystine (%)	0.60	0.60

*** Premix: vitamin-mineral premix from Rovigyt Company, to provide kg of diet with Vit. A (4,000.000 IU); Vit. D_3 (500,000 IU); Vit. E (50 mg); Vit K_3 (2 mg), Vit. B_1 (2 mg); Vit. B_2 (6 mg) ; Vit. B_6 (2 mg); Vit. B_{12} (10 mcg); choline chloride (1200 mg); Biotin (200 mg); Niacin (50 mg); Pantothenic acid (20 mg); Folic acid (5 mg); Mg 400 mg ; Cu 5 mg ; I 0.75 mg ; Se 0.1 ; Fe 75 mg ; Mn 30 mg ; and Zn 70 mg .**

At the end of the feeding trial, eighteen digestion trials were conducted with 54 mature New Zealand White rabbits, divided into 18 groups of 3 rabbits each with the same body weight to determine the digestion coefficients of nutrients, feeding values, nitrogen and mineral balances of the experimental treatments.

Rabbits were kept individually in metabolism stainless steel cages, which allowed a quantitative collection of feces and urine. The rabbits were fed the experimental diets for 5 days as a preliminary period followed by 4 days as a collection period. Feces were dried at 60 ^oC for 24 hours then ground and thoroughly mixed. Urine was collected using sulfuric acid (10% solution) and then stored for chemical analysis. Proximate chemical analysis for samples of feed and feces were done according to A. O. A. C. (1980). Composite samples of feed, feces and urine were prepared for mineral determinations according to Fick et al (1979). Phosphorus was determined colorimetrically (A.O.A.C.1980) and the other minerals were determined using Shimatzu atomic absorption-flame spectrophotometer (model AA - 640 - 13).

Data were analyzed by computer program of SAS user guide 1986, using

General Linear Models (GLM) procedure. All characteristics were performed in conformity by factorial analysis model:

$Y_{ijkl} = \mu + P_i + Cu_j + V_k + PCu_{ij} + PV_{ik} + VCu_{jk} + PVCu_{ijk} + E_{ijkl}$, where

μ = the overall mean.

P_i = the fixed effect of i^{th} dietary protein levels (i = 1, 2),

Cu_j = the fixed effect of j^{th} copper sulfate levels (j = 1, 2 and 3),

V_k = the fixed effect of k^{th} vitamin C levels (k = 1, 2 and 3),

PCu_{ij} = the interaction between dietary protein levels and copper sulfate levels,

PV_{ik} = the interaction between dietary protein levels and vitamin C levels,

VCu_{jk} = the interaction between vitamin C levels and copper sulfate levels,

$PVCu_{ijk}$ = the interaction between dietary protein levels, vitamin C level and copper sulfate levels,

E_{ijkl} = random error.

Significant differences between treatments means were separated by Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Data in Table 3 showed that increasing dietary protein level in the diets from 14 to 16%, increased the CP, CF and EE digestibility by about 8.0, 35.8 and 10.8%, respectively. These results agree with those reported by Hintz *et al.* (1978); Cheeke *et al.* (1986) and Ayyat et al (1995) who reported that nutrient digestibility was affected by protein level in the diets. Adding nitrogen or increasing CP level in the basal diets of either high or low starch content resulted in an increase of apparent nitrogen digestion coefficients (Mathius *et al.* 1988). The DM, OM, CF and NFE digestibility values for rabbits fed diet containing 18.67% CP were better than those of diets either containing 16.0 or 21.33% CP. (El-sayaad, 1985). Bassuny (1991) found the addition of copper sulfate to rabbit diet (300 ppm) improved digestibility of all nutrients. On the other hand, Combs *et al.* (1966) found that the apparent digestion coefficient of DM was not influenced by protein or copper levels, while protein digestibility was higher and significantly influenced by protein level in pig diets.

Supplementing the diets with copper sulfate had no effect on all nutrient digestibility except for CF (Table 3). Similar trend was observed with vitamin C levels in which the CF digestibility was higher ($P<0.05$) with the diet containing 300ppm ascorbic acid. These results are matching to those reported by Mahan and Saif (1983) who found that vitamin C supplementation to young swine diet did not improve gain and feed utilization. Similar results were reported by Van den Berg and Beynen (1992) who found that high dietary concentration of ascorbic acid may influence copper metabolism. The present result may be due to the effect of vitamin C, which had impaired the effect of copper sulfate for improving the nutrient digestibility.

The interaction effect of protein , $CuSO_4$ and vitamin C are presented in Table 3. Data showed significant differences for CP, CF and EE digestibility.

The highly significant effect due to protein level was noticed with group 2 (P14 X Cu0 X 300V) and group16 (P16 X Cu750 X V0) and the lowest effect

was observed with group 5 (P14 X Cu250 X V300). While the CF digestibility was higher ($P<0.05$) being 37.43% for group fed P16 X Cu0 X V300 than for the other treatments and the lowest value was 15.45% for those fed (P14X Cu0 X V300). These results were higher than those reported by Hintz *et al.* (1978) who found that CF digestibility for rabbit did not exceed 15%.

The effect of interaction on EE digestibility (Table 3) showed the highest ($P<0.05$) value with group 17 (P16 X Cu750 X V300) being 92.03% and the lowest value was recorded with group 9 (P14 X Cu750 X V600) being 57.39% with no significant differences among the other groups.

The feeding value expressed as TDN was insignificantly varied among groups due to protein, copper sulfate and vitamin C levels. While the dietary protein and copper levels affected significantly DCP values. Therefore, the highest and lowest significant effect due to the interaction, were similar for CP digestibility. These results may be due to CP content diets or due to copper sulfate addition.

The nitrogen and mineral element contents for the experimental diets fed to rabbits are shown in Table 4 .The nitrogen content was varying between the two basal diets due to the protein content (14% and 16%). While, mineral element contents were nearly similar for the two basal diets except for Cu, which was added in different levels (zero, 250 or 750 ppm).

Table 5 showed the effect of copper sulfate and vitamin C supplementation on balances of major elements as percentage of intake. Retention of Ca, P and Mg % was highly positive for groups fed diets containing P14 X Cu250 X V300 and P16 X Cu0 X V600. These results showed that high level of copper sulfate (750 ppm) with high level of vitamin C (600 ppm) in diet containing 14% CP decreased the retention of Ca, P and Mg, while the high level of copper sulfate with 300 ppm vitamin C in diet containing 16% CP decreased of percentage retention Ca, P and Mg % of intake. These data are not matching those reported by Dove (1995) who found that retention of Ca, P, Mg was not affected by addition of Cu to the diet. Sodium and potassium balances were highly retained for groups fed P14 X Cu250 X V600 and P16 X Cu250 X V0. These results indicated that mineral balances are influenced by dietary protein, copper sulfate and vitamin C supplementation in the diet. These results are in agreement with those for Dove (1995) who suggested that addition of 250 ppm Cu to the diet increased the retention percentage of sodium and potassium.

Data in Table 6 showed the effect of supplemented diets containing 14 or 16% CP with copper sulfate, vitamin C on trace element balances. The retention of all trace elements was higher with group fed P14 X Cu750 X V0 except manganese and cobalt which had negative balances, and groups fed P16 X Cu0 X V300 except Co . Cobalt balance was negative in all treatments and it may be due to the antagonism between Cu and cobalt (Kornegay *et al.*, 1995). Data indicated that trace element balances were affected by protein, copper sulfate and vitamin C in the diet . These results were similar to those reported by Dove (1995) for Zn, Cu, Mn and Fe % of intake. Van Den Berg and Beynen (1992) who found that apparent absorption of Cu was significantly decreased by dietary ascorbic acid and low intake of Cu which increased the apparent efficiency of Cu absorption. While, Van Campen and

Table 5: Effect of dietary protein, copper sulfate and vitamin C levels on major element balances with rabbits during metabolism trials.

Item	Level of $CuSO_4.5H_2O$	Ration containing 14% CP level of Vitamin C (ppm)			Ration containing 16% CP level of Vitamin C (ppm)		
	mg/kg	zero	300	600	zero	300	600
(Ca) Intake (g/h/d)	Zero	0.85	1.26	1.19	1.48	1.81	1.33
% of intake*		63.76	72.70	71.72	66.77	78.81	81.80
Intake (g/h/d)	250	1.17	1.31	1.30	1.22	1.29	1.18
% of intake		60.16	74.75	68.04	75.51	76.07	61.08
Intake (g/h/d)	750	0.49	1.50	1.52	1.22	1.45	1.18
% of intake		59.87	70.73	69.81	68.06	67.77	64.95
(P) Intake (g/h/d)	Zero	0.42	0.46	0.46	0.63	0.59	0.55
% of intake		16.59	39.41	14.26	37.85	52.87	55.10
Intake (g/h/d)	250	0.48	0.48	0.53	0.54	0.54	0.49
% of intake		17.58	42.07	33.32	43.84	36.88	37.42
Intake (g/h/d)	750	0.21	0.56	0.61	0.55	0.65	0.52
% of intake		41.17	34.75	33.28	35.46	30.95	19.10
(Mg) Intake (g/h/d)	Zero	0.49	0.54	0.46	0.66	0.53	0.54
% of intake		36.87	37.93	35.01	39.49	30.83	41.05
Intake (g/h/d)	250	0.44	0.64	0.57	0.45	0.55	0.32
% of intake		15.86	40.78	39.42	35.03	15.17	10.80
Intake (g/h/d)	750	0.22	0.53	0.55	0.43	0.52	0.50
% of intake		17.17	20.57	17.28	4.53	12.59	4.58
(Na) Intake (g/h/d)	Zero	1.22	1.04	0.98	0.73	1.40	1.00
% of intake		34.83	26.58	34.40	17.27	35.44	21.73
Intake (g/h/d)	250	1.69	1.25	1.38	1.42	1.13	1.41
% of intake		29.28	30.95	62.30	49.63	43.39	27.39
Intake (g/h/d)	750	0.54	1.47	1.99	1.07	1.29	1.37
% of intake		13.55	36.19	37.78	9.75	31.24	15.71
(K) Intake (g/h/d)	Zero	1.33	1.46	1.42	2.41	2.57	1.87
% of intake		40.89	16.72	52.25	42.95	48.44	44.82
Intake (g/h/d)	250	1.63	1.55	1.65	1.66	1.92	1.53
% of intake		10.91	27.08	52.86	48.65	41.24	18.22
Intake (g/h/d)	750	1.67	1.77	2.42	1.89	2.25	2.19
% of intake		16.57	35.68	46.23	10.93	39.73	26.14

- **% of intake: element retention as percentage of intake.**

Table 6: Effect of dietary protein, copper sulfate and vitamin C levels on trace element balances with rabbits during metabolism trials.

Item	level of $CuSO_4.5H_2O$	Ration containing 14% CP level of Vitamin C (ppm)			Ration containing 16% CP level of Vitamin C (ppm)		
	mg/kg	**zero**	**300**	**600**	**zero**	**300**	**600**
(Zn) Intake (mg/h/d)	Zero	5.38	7.49	6.86	10.19	12.25	9.19
% of intake*		-15.23	22.92	4.48	24.69	49.90	32.99
Intake (mg/h/d)	250	8.03	7.37	8.39	8.27	8.90	7.80
% of intake		4.99	15.70	3.88	27.23	14.93	12.31
Intake (mg/h/d)	750	8.35	9.14	9.15	8.98	11.79	8.80
% of intake		24.47	14.81	-5.45	2.72	27.91	-17.25
(Cu) Intake (mg/h/d)	Zero	1.61	2.03	1.74	2.36	3.66	1.84
% of intake		2.56	21.75	9.45	4.05	39.94	-25.92
Intake (mg/h/d)	250	6.56	6.29	8.82	7.27	8.69	8.06
% of intake		-16.58	14.19	1.68	7.71	14.57	6.81
Intake (mg/h/d)	750	18.85	21.26	19.71	25.53	32.19	20.60
% of intake		32.77	13.35	1.57	13.53	33.38	19.27
(Mn) Intake (mg/h/d)	Zero	5.13	6.21	5.70	8.01	8.42	7.09
% of intake		-22.33	-4.96	-46.00	5.13	15.63	4.98
Intake (mg/h/d)	250	5.87	5.95	6.96	6.59	7.74	5.92
% of intake		-48.83	-7.97	-21.24	-7.68	8.47	-18.31
Intake (mg/h/d)	750	2.81	6.72	7.31	7.24	9.99	6.83
% of intake		-1.14	-23.88	-28.69	-14.10	9.89	-36.79
(Fe) Intake (mg/h/d)	Zero	35.27	49.37	45.85	66.35	74.92	63.65
% of intake		39.79	53.34	39.00	49.73	68.16	61.39
Intake (mg/h/d)	250	53.81	49.93	56.17	56.05	61.60	49.81
% of intake		40.03	53.05	39.54	54.48	58.86	51.43
Intake (mg/h/d)	750	24.16	59.36	61.96	56.92	75.94	57.42
% of intake		56.47	42.60	36.93	48.98	56.02	40.81
(Co) Intake (mg/h/d)	Zero	0.15	0.23	0.32	0.29	0.62	0.32
% of intake		-164.14	-172.81	-53.77	-124.39	-0.03	-91.94
Intake (mg/h/d)	250	0.45	0.30	0.20	0.40	0.29	0.42
% of intake		-86.89	-82.30	-184.35	-56.60	-63.79	-39.76
Intake (mg/h/d)	750	0.09	0.37	0.42	0.22	0.48	0.27
% of intake		-345.41	-63.32	-35.74	-249.19	-67.74	-187.74

*** % of intake: element retention as percentage of intake.**

Gross (1995) indicated that ascorbic acid can depress the intestinal absorption of copper if the two materials are administered together.

Nitrogen retention percentage was not affected by dietary protein and copper sulfate levels. All rabbits in different treatments were in positive N-balances (Table 7). Therefore, the highest interaction regarding protein, copper sulfate and vitamin C level was recorded with groups fed (P14 X Cu0 X V300) and (P16 X Cu750 X V300) and the lowest value was observed with groups fed (P14 X Cu750 X V0) and (P16 X Cu750 X V0), otherwise, no significant differences were obtained among the other treatments . The high level of (750 ppm) copper sulfate alone in diet containing either 14 or 16 % CP depressed N-retention %. These results did not agree with those reported by Dove (1995) who suggested that addition of Cu in pig diets increased N retention and it may be due to the behaviour and physiological status of rabbits. Spreadbury (1978) found that growing rabbits can maintain their protein requirements from soft feces throughout coprophagy when given a good quality diet.

The N-retention in this study ranged from 16.96% to 56.65% of intake which was higher than those (16.40 - 31.43 %) estimated by Mathius *et al.* (1988), when using different sources of nitrogen in rabbit diets without any supplementation of either Cu or vitamin C.

Feeding trials showed that final body weight (FBW) was (P<0.05) affected significantly by dietary protein level and supplementaion of vitamin C but not by copper sulfate (Table 7). These results agree with those reported by Harris *et al.* (1984) who noticed that supplementing rabbit diets with 250 ppm copper sulfate did not affect significantly daily gain.

The highest values of FBW were observed for diets supplemented with 750 ppm copper sulfate and 300 ppm ascorbic acid regardless the CP content. They were heavier than the control by 11.83 and 13.45 % with 14 or 16% CP, respectively. The lowest value was recorded with diet (P14 X Cu750 X V0) where it was less by 12.42% than to the control one in this respect.

The body weight gain (BWG) during the experimental period showed similar trend as for final body weight (Table 7). The rabbit of P14 x Cu750 x V300 and P16 x Cu 750 x V300 showed better values of weight gain than the control groups by 28.9 and 23.3%, respectively. Yen and Pond (1981) found that dietary vitamin C, failed to improve daily gain, while supplementation of Cu improved weight gain.

Feed consumption was significantly (P<0.05) affected by protein, copper sulfate and vitamin C levels (Table 7). Regarding interaction effect, data showed similar trend as observed for FBW. These results are similar to those reported by Mahan and Saif (1983) who found that there is no improvement in feed intake and feed efficiency when pigs fed different combinations of vitamin C and Cu levels.

The feed conversion was not affected significantly by protein level and supplementation with either copper sulfate or vitamin C. The interaction for treatments showed the highest value with groups fed (P14 X Cu0 X V300) and (P16 X Cu750 X V300) , which seems to be related to N-intake which in turn affected weight gain and feed efficiency.

It is important to point out that an increase in feed intake will not stimulate growth rate, but also improve feed efficiency. Edmonds *et al.* (1985) noticed that feed efficiency was not affected by feeding Cu in their experiments, which indicated that increased feed intake accounted for all the growth stimulation.

It could be concluded that supplementation of 750 ppm copper sulfate and 300 ppm vitamin C to the diet containing either 14 or 16 % CP improved feed intake, weight gain and feed efficiency and the diet containing 14 % CP is more practical to maintain nitrogen requirement of growing rabbits. Further studies with mineral balances are needed to determine mineral requirements of rabbits during different stages of production.

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استجابة أرانب النيوزيلاندى الأبيض النامية لمستوى البروتين فى علائق مضاف إليها مستويات مختلفة من عنصر النحاس وفتامين ج.

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أجريت التجربة باستخدام ١٠٨ أرنب نيوزيلندى أبيض عمره ٣٥ يوم متوسط وزن يتراوح بين ٨٧٢ إلى ٨٨٢ جرام قسمت إلى ١٨ معاملة اشتملت كل مجموعة على ٦ أرانب فرادى فى أقفاص منفصلة وتحت نفس الظروف من الرعاية .

صممت التجربة فى نظام إحصائى ٢×٣×٣ باستخدام مستويين من البروتين الخام (١٤، ١٦%) مع ثلاث مستويات من كبريتات النحاس (صفر ، ٢٥٠ ، ٧٥٠ مللجرام لكل كيلو جرام علف) وثلاث مستويات من فيتامين ج (صفر ، ٣٠٠، ٦٠٠ جزء فى المليون) مع تقديم الغذاء والماء بنظام التغذية الحرة (المفتوحة) طوال فترة التجربة التى استمرت ١٠ أسابيع وفى نهاية فترة التجربة أجريت ١٨ تجربة هضم اشتملت كل تجربة على ثلاث أرانب منفردة فى أقفاص هضم من الاستانلس ستيل وتم جمع كل من الروث والبول كمياً.

أظهرت النتائج أنه بزيادة كل من مستويات البروتين وفيتامين ج بالعلائق أدى إلى زيادة معامل هضم البروتين الخام والألياف والدهن الخام بينما لم يكن هناك تأثير لإضافة كبريتات النحاس على معاملات هضم المركبات الغذائية المهضومة فيما عدا الألياف الخام. كان تأثير التداخل بين ا لبروتين وكبريتات النحاس وفيتامين ج مشابها للنتائج المتحصل عليها نتيجة لإضافة كبريتات النحاس وفيتامين ج كلا على حدة. ولم يكن هناك تأثير لمستويات كل من البروتين وكبريتات النحاس وفيتامين ج على مجموع المركبات الغذائية المهضومة بينما أظهرت تأثيراً عالى المعنوية على المهضوم من البروتين الخام.

تراوح معامل الاختلاف لاختلاف العليقة من العناصر المعدنية بين ١ إلى ١,٥٤% أى فى الحدود الطبيعية بينما يرجع الإرتفاع العالى لمعامل الاختلاف لعنصر النحاس إلى إضافة كبريتات النحاس وأيضا الى التداخل المتضاد لعنصر الكوبالت مع النحاس.

تأثر ميزان العناصر المعدنية الكبرى والصغرى بإختلاف مستوى البروتين، كبريتات النحاس ، ا فيتامين ج . وأظهرت كل المعاملات ميزانا سالبا لعنصر الكوبالت والمنجنيز بينما أظهرت ميزانا موجبا لعنصر النتروجين الذى لم يتأثر بمستوى البروتين بالعليقة ولكن التأثير كان راجعا إلى إضافة كل من كبريتات النحاس وفيتامين ج إلى العلائق.

أظهرت تجارب التغذية زيادة معنوية لوزن الجسم النهائى وكذا وزن الجسم المكتسب تراوحت بين ١١,٨٣ – ١٣,٤٥% ، ٢٨,٨٨ – ٢٢,٥٢% على التوالى نتيجة لزيادة كل من مستويات البروتين من ١٤ إلى ١٦% وفيتامين ج بينما أظهر كل من البروتين وكبريتات النحاس وفيتامين ج تأثيرا معنوياً على كل من معدل الكفاءة التحويلية ومقدار الغذاء المستهلك.

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Table 3: Effect of dietary protein, copper sulfate and vitamin C levels on digestion coefficients and feeding values (%) of experimental treatments.

Item	Digestion coefficients (%) (X ± SE)						Feeding values (%)	
	DM	OM	CP	CF	EE	NFE	TDN	DCP
Protein level, % (P)								
(14)	62.78 ± 1.0	63.79 ± 1.2	65.43 ± 1.6 b	17.71 ± 0.6 b	75.12 ± 2.1 b	73.75 ± 1.1	61.60 ± 1.1	10.15 ± 0.3 b
(16)	63.44 ± 0.6	64.12 ± 0.6	70.66 ± 0.8 a	24.05 ± 1.7 a	83.20 ± 1.7 a	71.92 ± 0.6	62.57 ± 0.6	12.22 ± 0.2 a
$CuSO_4.5H_2O$ level,mg/kg diet (Cu)								
(Zreo)	64.02 ± 1.0	64.60 ± 0.9	69.58 ± 1.3	23.88 ± 2.6 a	78.44 ± 1.0	72.76 ± 1.0	62.79 ± 0.8	11.44 ± 0.3 a
(250)	61.89 ± 1.2	62.67 ± 1.2	65.48 ± 2.1	18.32 ± 0.2 c	79.10 ± 2.2	72.14 ± 1.2	60.78 ± 1.1	10.67 ± 0.5 b
(750)	63.42 ± 1.3	64.42 ± 1.2	69.07 ± 1.6	20.44 ± 1.2 b	79.93 ± 3.9	73.59 ± 1.1	62.66 ± 1.3	11.39 ± 0.4 a
Vit.C level, PPm (V)								
(Zreo)	63.37 ± 1.4	64.25 ± 1.5	68.22 ± 1.5	20.65±1.7 ab	81.12 ± 1.5	72.89 ± 1.3	63.01 ± 1.3	11.09 ± 0.3
(300)	64.52 ± 1.2	64.94 ± 1.2	69.03 ± 2.4	22.64 ± 2.4 a	80.42 ± 2.5	73.14 ± 0.9	62.99 ± 1.1	11.40 ± 0.5
(600)	61.44 ± 0.8	62.67 ± 0.7	66.89 ± 1.2	19.49 ± 1.2 b	75.93 ± 3.3	72.47 ± 1.1	60.23 ± 0.7	11.05 ± 0.4
Interactions								
P14 x Cu 0 x V0	64.87 ± 1.5	65.61 ± 1.5	68.81± 0.3 abc	16.20 ± 0.1 f	80.55±1.2abcd	75.44 ± 0.5	64.51 ± 1.4	11.00±0.4bcde
P14 x Cu 0 x V300	68.35 ± 0.2	68.34 ± 0.5	75.35 ± 0.4 a	15.45 ± 0.2 f	79.96 ± 2.7 abcd	76.86 ± 0.9	64.99 ± 0.3	12.06 ± 0.0 abc
P14 x Cu 0 x V600	60.15 ± 4.1	61.14 ± 3.6	63.57± 3.1 abc	16.37 ± 0.9 f	77.90 ± 1.7 abcd	70.08 ± 2.4	59.61 ± 3.4	9.76 ± 0.5 def
P14 x Cu 250 x V0	57.72 ± 2.4	58.76 ± 2.3	61.58 ± 1.6 bc	17.87 ± 2.1 ef	77.76 ± 0.1 abcd	67.62 ± 2.5	57.87 ± 2.2	9.46 ± 0.3 ef
P14 x Cu 250 x V300	61.79 ± 5.6	62.02 ± 5.8	57.92 ± 9.4 c	16.56 ± 1.5 f	72.81 ± 7.8 d	70.76 ± 4.2	59.62 ± 5.7	8.65 ± 1.6 f
P14 x Cu 250 x V600	61.44 ± 0.8	62.38 ± 5.8	63.38± 5.8 abc	18.47 ± 1.2 ef	77.54 ± 7.0 abcd	76.09 ± 3.1	60.89 ± 1.2	9.72 ± 0.2 ef
P14 x Cu 750 x V0	68.94 ± 6.7	69.79 ± 6.4	69.69± 5.6 abc	20.06±1.2def	78.52±4.9abcd	78.35 ± 4.7	67.62 ± 6.1	10.71 ± 0.9 cde
P14 x Cu 750 x V300	59.89 ± 0.3	60.73 ± 0.5	63.35± 4.5 abc	15.60 ± 0.3 f	73.57 ± 1.2 cd	72.24 ± 1.5	60.19 ± 0.5	9.95 ± 0.6 def
P14 x Cu 750 x V600	61.91 ± 3.1	65.23 ± 0.7	64.22± 3.7 abc	22.77±0.9cde	57.39 ± 9.5 e	75.68 ± 0.3	59.17 ± 3.1	10.03 ± 0.6 def
P16 x Cu 0 x V0	63.51 ± 0.1	64.30 ± 0.1	66.78 ± 2.9 abc	31.43 ± 4.5 b	76.94 ± 0.5 abcd	71.91 ± 2.4	63.11 ± 0.1	11.00 ± 05 bcde
P16 x Cu 0 x V300	66.17 ± 0.2	66.59 ± 0.5	72.43 ± 0.2 ab	37.43 ± 0.6 a	77.02 ± 6.4 abcd	73.36 ± 0.2	63.94 ± 0.8	12.63 ± 04 ab
P16 x Cu 0 x V600	61.09 ± 0.9	61.66 ± 0.9	70.45 ± 0.9 ab	26.37 ± 0.8 c	78.28±1.1abcd	68.95 ± 2.0	60.64 ± 0.9	12.41 ± 0.2 abc
P16 x Cu 250 x V0	61.09 ± 0.9	61.77 ± 1.1	67.64± 1.6 abc	17.52± 1.8 ef	84.22 ± 4.2 abcd	70.25 ± 0.5	60.61 ± 1.3	11.51 ± 0.3 abc
P16 x Cu 250 x V300	66.27 ± 3.9	67.00 ± 3.9	71.73 ± 4.6 ab	24.16 ± 1.0 cd	87.11 ± 3.7 abcd	74.12 ± 2.7	65.32 ± 3.5	12.29 ± 0.9 abc
P16 x Cu 250 x V600	63.03 ± 0.2	63.89 ± 0.2	70.68 ± 0.4 ab	15.34 ± 1.8 f	75.09 ± 3.7 bcd	73.39 ± 3.7	60.45 ± 0.3	12.41 ± 0.1 abc
P16 x Cu 750 x V0	64.10 ± 1.2	65.29 ± 1.1	74.77 ± 0.9 a	20.80 ± 3.6 ef	88.66 ± 0.8 abc	73.08 ± 0.6	64.45 ± 0.9	12.87 ± 0.2 a
P16 x Cu 750 x V300	64.66 ± 0.7	64.99 ± 0.7	72.36 ± 0.9 ab	25.36 ± 3.1 cd	92.03 ± 0.0 a	71.36 ± 0.6	63.93 ± 0.3	12.82 ± 0.2 ab
P16 x Cu 750 x V600	61.02 ± 2.7	61.56 ± 2.5	69.03 ± 0.8 abc	17.64 ± 0.0 ef	89.40 ± 2.8 ab	70.13 ± 3.4	60.64 ± 2.1	12.01 ± 0.1 abc

a, b, c, d, e and f: Means in the same column with different letter(s) are significantly different ($P<0.05$).

Table 4: Nitrogen and mineral element contents of the experimental diets.

Item	N	Ca	P	Mg	Na	K	Zn	Cu	Mn	Fe	Co
D1 Treat.	(%)	<------------------------------(%)---------------------------------->					<--------------------(mg / 100 gm)-------------------------->				
1	2.56	0.895	0.439	0.514	1.29	1.40	5.66	1.69	5.40	37.13	0.16
2	2.56	1.168	0.412	0.479	0.93	1.30	6.66	1.80	5.52	43.88	0.20
3	2.46	1.079	0.420	0.422	0.89	1.30	6.24	1.58	5.18	41.68	0.29
4	2.46	0.967	0.393	0.365	1.40	1.35	6.64	5.42	4.85	44.47	0.37
5	2.39	1.179	0.448	0.533	1.18	1.45	6.92	5.91	5.59	46.88	0.28
6	2.45	1.087	0.442	0.533	1.15	1.37	6.99	7.35	5.80	46.81	0.17
7	2.46	1.038	0.455	0.463	1.14	1.43	7.50	18.82	5.98	51.41	0.19
8	2.51	1.900	0.440	0.424	1.16	1.40	7.25	17.87	5.33	47.11	0.29
9	2.50	1.051	0.417	0.376	1.37	1.67	6.31	18.59	5.04	42.73	0.29
Av.	2.48	1.152	0.430	0.457	1.17	1.41	6..69	8.78	5.41	44.68	0.25
D2 Treat.											
10	2.63	1.024	0.437	0.453	0.98	1.67	7.03	1.63	5.53	45.76	0.20
11	2.79	1.259	0.413	0.359	0.98	1.79	8.54	2.55	5.87	52.21	0.43
12	2.81	1.147	0.477	0.467	0.86	1.61	7.92	1.59	6.11	59.48	0.28
13	2.72	1.050	0.465	0.386	0.63	1.43	7.13	6.27	5.68	48.32	0.34
14	2.74	0.970	0.404	0.416	0.85	1.45	6.72	6.56	5.84	46.49	0.22
15	2.81	1.072	0.442	0.286	1.28	1.39	7.06	7.29	5.36	45.08	0.38
16	2.17	0.959	0.341	0.337	0.84	1.48	7.04	20.02	5.68	44.64	0.17
17	2.84	0.912	0.410	0.327	0.87	1.42	7.44	20.31	6.30	47.91	0.29
18	2.78	0.853	0.378	0.362	0.99	1.59	6.38	20.93	4.95	41.61	0.20
Av.	2.70	1.027	0.429	0.378	0.92	1.54	7.25	9.68	5.70	47.94	0.28

Table 7: Effect of dietary protein, copper sulfate and vitamin C levels on weight gain, feed efficiency and N-balances (Mean ± SE).

Item	IBW (g/h) at 35 days old	FBW (g/h) at 15 weeks of age	BWG (g/h) at 5-15 weeks of age	Feed consumption (g/h) at 5-10 weeks of age	Feed conversion (feed / gain)	N-intake (g/h/d)	N-retention (%)
Protein level, % (P)							
(14)	882.16 ± 31.4	2117.13 ± 43.8 b	1234.98 ± 36.1 b	7849.2 ± 122.8 b	6.54 ± 0.2	2.71 ± 0.19 b	44.52 ± 2.9
(16)	878.38 ± 31.6	2293.62 ± 51.1 a	1415.2 ± 39.8 a	8763.4 ± 106.8 a	6.35 ± 0.2	3..56 ± 0.18 a	42.12 ± 2.9
$CuSO_4.5H_2O$ level, mg/kg diet (Cu)							
(Zreo)	886.70 ± 41.4	2214.81 ± 65.8	1328.11 ± 53.7	8315.6 ± 171.9 ab	6.43 ± 0.2	3.18 ± 0.2	50.27 ± 1.9 a
(250)	880.34 ± 39.0	2169.72 ± 59.2	1289.38 ± 47.7	8081.5 ± 157.6 b	6.48 ± 0.2	3.05 ± 0.2	42.50 ± 1.8 b
(750)	874.58 ± 36.0	2233.97 ± 57.7	1359.39 ± 47.5	8491.0 ± 154.1 a	6.43 ± 0.2	3.17 ± 0.4	37.20 ± 5.0 b
Vit.C level, PPm(V)							
(Zreo)	882.23 ± 40.5	2101.16 ± 65.9 b	1218.94 ± 49.8 b	8042.4 ± 162.5 b	6.86 ± 0.2 a	2.72 ± 0.2 b	36.25 ± 4.3 b
(300)	883.52 ± 39.7	2298.70 ± 50.4 ab	1415.34 ± 46.7 a	8485.7 ± 149.4 a	6.13 ± 0.2 b	3.45 ± 0.2 a	48.25 ± 2.1 a
(600)	875.10 ± 35.9	2222.70 ± 58.3 ab	1347.60 ± 45.2 a	8365.1 ± 167.1 ab	6.33 ± 0.2 ab	3.24 ± 0.3 ab	45.48 ± 3.2 a
Interactions							
P14 x Cu 0 x V0	966.5 ± 116.1	2090.00 ± 196.4 ab	1123.5 ± 95.3 de	7869.5 ± 120.2 cd	7.10 ± 0.5 ab	2.43 ± 0.5 bc	51.76 ± 2.6 ab
P14 x Cu 0 x V300	853.7 ± 70.5	2216.00 ± 131.0 ab	1362.3 ± 80.1 abcd	7836.0 ± 525.2 cd	5.60 ± 0.2 b	2.88 ± 0.0 abc	56.65 ± 0.7 a
P14 x Cu 0 x V600	894.0 ± 100.0	2054.80 ± 136.7 ab	1160.8 ± 114.1 cde	7445.8 ± 354.1 d	6.60 ± 0.6 ab	2.68 ± 0.0 abc	53.97 ± 6.2 ab
P14 x Cu 250 x V0	842.3 ± 116.5	2080.50 ± 86.5 ab	1238.2 ± 133.0 abcde	7409.7 ± 299.1 d	6.30 ± 0.6 ab	2.97 ± 0.2 ab	39.20 ± 0.1 ab
P14 x Cu 250 x V300	944.8 ± 89.5	2202.20 ± 75.8 ab	1257.4 ± 74.1 abcde	7965.4 ± 211.2 bcd	6.40 ± 0.5 ab	2.54 ± 0.3 bc	42.73 ± 6.3 ab
P14 x Cu 250 x V600	872.4 ± 96.8	2091.00 ± 124.3 ab	1218.6 ± 96.9 abcde	7836.6 ± 363.1 cd	6.50 ± 0.3 ab	2.94 ± 0.7 abc	46.03 ± 5.4 ab
P14 x Cu 750 x V0	834.0 ± 93.9	1818.00 ± 165.2 b	984.0 ± 199.5 e	7304.2 ± 331.5 d	7.70 ± 0.7 a	1.15 ± 0.1 c	18.54 ± 5.4 cd
P14 x Cu 750 x V300	889.2 ± 117.5	2337.20 ± 99.5 a	1448.0 ± 69.3 abcd	8752.2 ± 248.7 abc	6.10 ± 0.4 ab	3.16 ± 0.4 ab	38.67 ± 7.0 ab
P14 x Cu 750 x V600	865.0 ± 90.5	2174.70 ± 134.1 b	1309.7 ± 83.5 abcde	8237.2 ± 436.4 abcd	6.30 ± 0.3 ab	3.63 ± 1.0 ab	45.17 ± 9.5 ab
P16 x Cu 0 x V0	887.0 ± 107.6	2158.40 ± 157.5 ab	1271.4 ± 83.5 abcde	8592.4 ± 274.8 abc	6.80 ± 0.4 ab	3.81 ± 0.3 ab	43.84 ± 5.8 ab
P16 x Cu 0 x V300	872.0 ± 126.6	2419.00 ± 192.6 a	1547.0 ± 189.9 ab	9097.0 ± 237.6 a	6.20 ± 0.7 ab	4.00 ± 0.1 ab	46.76 ± 6.3 ab
P16 x Cu 0 x V600	848.7 ± 126.9	2353.70 ± 149.3 a	1505.0 ± 43.0 abc	9008.0 ± 323.9 bc	5.99 ± 0.3 b	3.26 ± 0.3 ab	48.65 ± 4.4 ab
P16 x Cu 250 x V0	859.8 ± 131.0	2035.80 ± 237.7 ab	1176.0 ± 140.9 bcde	8223.0 ± 594.2 abcd	7.30 ± 0.8 ab	3.15 ± 0.3 ab	47.20 ± 4.3 ab
P16 x Cu 250 x V300	858.5 ± 87.0	2202.70 ± 124.3 ab	1344.2 ± 93.4 abcde	8217.7 ± 340.4 abcd	6.20 ± 0.4 ab	3.63 ± 0.2 ab	44.64 ± 0.5 ab
P16 x Cu 250 x V600	916.2 ± 84.8	2417.40 ± 192.8 a	1501.2 ± 144.7 abc	8943.8 ± 210.1 abc	6.10 ± 0.5 ab	3.09 ± 0.1 ab	35.24 ± 4.4 bc
P16 x Cu 750 x V0	920.8 ± 68.8	2372.00 ± 100.6 a	1451.2 ± 78.6 abcd	8798.0 ± 138.2 abc	6.10 ± 0.3 ab	2.77 ± 0.6 abc	16.96 ± 0.9 d
P16 x Cu 750 x V300	881.5 ± 130.8	2448.80 ± 59.6 a	1567.7 ± 113.2 a	9090.3 ± 276.8 a	5.90 ± 0.5 b	4.50 ± 0.3 a	52.04 ± 6.1 ab
P16 x Cu 750 x V600	851.0 ± 82.4	2280.40 ± 102.7 ab	1429.4 ± 89.3 abcd	8873.6 ± 217.0 abc	6.30 ± 0.3 ab	3.83 ± 1.5 ab	43.83 ± 6.4 ab

a,b,c,d and e: Means in the same column with different letters are significantly different ($P<0.05$).