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RESPONSE OF GROWING RABBITS SUPPLEMENTED WITH COPPER SULFATE, ASCORBIC ACID OR DRINKING COOLED WATER UNDER EGYPTIAN SUMMER CONDITIONS

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ABSTRACT

This work was carried out to study the effect of adding drinking water with either, copper sulfate, ascorbic acid or drinking cooled water on growth performance (live body weight, body weight gain, feed intake, feed conversion and water consumption), digestibility coefficients of nutrients, carcass traits and economical efficiency of growing NZW rabbits under Egyptian summer conditions. Ninety six weanling New Zealand White (NZW) male rabbits at five weeks of age and nearly similar average body weight (650.3 ± 3.7 g) were randomly divided into eight treatment groups (twelve rabbits in each group), then each group was subdivided into four replicates, each of three rabbits. The rabbits were assigned to drinking water as follow: the 1st group was given fresh tap water as a control. The 2nd, 3rd and 4th groups were given tap fresh water supplemented with copper sulfate at levels of 40, 80 and 120 mg/L drinking water, respectively. The 5th, 6th and 7th groups were given tap fresh water supplemented with ascorbic acid at levels of 250, 500 and 750 mg/L drinking water, respectively. The 8th group was given cooled drinking water (CW) at 10-15°C. Results showed that supplementation of 40 or 80 mg copper sulfate/L or 500 mg ascorbic acid/L to heat-stressed rabbits drinking water improved final live body weight, body weight gain, daily water consumption, feed conversion ratio and economical efficiency. Hot carcass percentage was significantly ($P<0.01$) decreased with 80 mg/L copper sulfate and increased significantly ($P<0.01$) due to supplementation the drinking water with 250 mg ascorbic acid/L. Cooled water (10-15°C) improved significantly ($P<0.01$) each of final body weight, body weight gain, feed conversion ratio, economical efficiency and decreased significantly ($P<0.01$) each of hot carcass %, dressed weight %, heart and total giblets % feed intake, digestibility coefficients of nutrients and feeding values as TDN and ME were not significantly affected by either different levels of copper sulfate and ascorbic acid in drinking water or drinking cooled water. Finally, It could be use each of copper sulfate, ascorbic acid and cooled water as water supplements for NZW male rabbits to reduce the negative effects of heat stress, especially the levels of 40 mg/L of copper sulfate, 500 mg/L of ascorbic acid and cooled water which was the most efficient physical techniques for alleviation the heat stressed NZW male rabbits until marketing age in this study.

Key words: Copper sulfate, ascorbic acid, cooled water, heat-stressed rabbits, growth performance, digestibility coefficients, carcass traits.

INTRODUCTION

In recent years, the domestic rabbits have been recommended as a good alternative source of dietary protein for the increasing human population in developing countries (Lukefahr and Cheeke, 1991). Now there is evidence that some developing countries are beginning to utilize the rabbit as a main source of meat. In hot climate regions, where most of the developing

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countries are localized, rabbit production as any other animal production, is faced with many problems such as heat stress which is the most important one. At environmental temperature of 32°C and higher, heat stress occurs leading to production losses. When temperature of 35°C and higher persist, the greatest losses from heat stress may result. The thermo neutral zone of rabbits is around 18-21°C (Habeeb *et al.*, 1998).

In Egypt, the climate is characterized by a long hot period (from May to October). In this period, rabbits have difficult in elimination body heat due to their unfunctional sweat glands (Marai *et al.*, 1991, 1994a, b and 1996). Modification of the hot environment, reducing the animal's heat production and increasing its heat loss, help in keeping the animal within the range of its thermoneutral state that realize comfort. Alleviation of heat stressed animals can be carried out by either chemical (Ayyat *et al.*, 1997), physical (Habeeb *et al.*, 1994 and Marai *et al.*, 1994a) or nutritional techniques (Marai *et al.*, 1994a).

Vitamin C (ascorbic acid) is one of the most widely studied vitamins used to alleviate heat stress in rabbits. Amakye-Anim *et al.* (2000) and El-Ghaffar *et al.* (2000) showed that, vitamin C has a role in lowering viral pathogenic actions and in protecting animals from heat stress as well as in the enhancement of the immune system of infected rabbits. Vitamin C is not considered a required dietary nutrient, but under certain adverse environmental conditions, the metabolic need for this vitamin may exceed the inherent biosynthetic ability of ascorbic acid (Abou-Ashour *et al.*, 2004). However, many additives are recently added to rabbit feed or water as a way to help alleviate adverse effect during summer months and to enhance productive performance and immune response of rabbits. Copper sulfate ($CuSO_4$) has been recognized as a feed additives for rabbits to improve growth rate and reduce enteric disease (Lebas *et al.*, 1986 and Liang *et al.*, 1988). Different studies had been conducted to evaluate $CuSO_4$ as found by Yassein *et al.* (2011) who reported an improvement of growth performance for the $CuSO_4$ supplement in NZW rabbits and concluded that $CuSO_4$ in drinking water is more practical to alleviate heat load under the summer condition of Egypt. Also, the addition of 100 ppm copper (as CuO form) to the basal ration improved growth performance in the growing rabbits without accumulative effect of copper on liver tissues and did not adversely influence and kidney functions under subtropical conditions (Abd El-Samee and El-Masry, 1997).

Furthermore, providing cooled water was found to be effective in alleviating the heat load of rabbits. Treatment of heat-stressed rabbits by drinking cooled water (10-15 °C) showed the highest body weight, total body gain and margin percentage, as well as, improved feed intake, feed conversion and decreased water intake (Marai *et al.*, 1999).

Therefore, the objective of the present study was to investigate the effect of adding drinking water with copper sulfate, ascorbic acid or drinking cooled water on the performance of growing rabbits under Egyptian summer conditions.

MATERIALS AND METHODS

The present work was carried out at a private Rabbitry Farm, Zagazig, El-Sharkia Governorate, Egypt, from July to September 2011. The chemical analyses were performed in poultry department laboratories, faculty of Agriculture, Zagazig University.

Ninety six weanling New Zealand White (NZW) male rabbits at five weeks of age and nearly similar average body weight (650.3 ± 3.7 g) were randomly divided into eight treatment groups (twelve rabbits in each group), then each group was subdivided into four replicates, each of three rabbits. The rabbits were assigned to drinking water as follow: the 1st group was given fresh tap water as a control. The 2nd, 3rd and 4th groups were given tap fresh water supplemented with copper sulfate at levels of 40, 80 and 120 mg/L drinking water, respectively. The 5th, 6th and 7th groups were given tap fresh water supplemented with ascorbic acid at levels of 250, 500 and 750 mg/L water, respectively. The 8th group was given cooled drinking water (CW) at 10-15°C. Copper sulfate ($CuSO_4$-5H2O) was purchased from Movartis Agro Egypt, The industry area, Balteim, Kafr El-Sheikh Governorate, Egypt, while ascorbic acid (C6H8O6, 99% concentration) was purchased from S.D. FINE-

CHEM limited, India. Animals were housed in galvanized wire cages each cage was 40×30×25 cm in a well ventilated building. Fresh water was automatically available all the time by stainless steel nipples. The rabbits were fed *ad libitum* a basal diet that formulated to cover the nutrient requirements of growing rabbits from 5 to 13 weeks of age according to NRC (1977). The composition and chemical analyses of the experimental basal diet are presented in Table 1.

All rabbits were raised under the same managerial, hygienic and environmental conditions. Ambient temperature (°C) was measured by mercury thermometer and relative humidity by wet and dry thermometers. Average of air temperature and relative humidity at midday inside the rabbit building were 31.23±0.24 °C and 67.97±2.42 %, respectively. The temperature-humidity index (THI) was calculated using the equation modified by Marai *et al.* (2000) as follows: THI = db°C – [(0.31 – 0.31 (RH/100)) (db°C – 14.4)] where: db °C = dry bulb temperature in °C and RH = Air relative humidity expressed as a proportion. The obtained values of THI were classified as follows: THI < 27.8 show absence of heat stress, 27.8 ≤ 28.9 means moderate heat stress, 28.9 ≤ 30.0 means severe heat stress and 30.0 and more means very severe heat stress.

Individual live body weight, feed intake, water consumption, daily weight gain, feed conversion ratio and mortality rate were recorded biweekly during the experimental period. Economic efficiency (EE) was calculated as the ratio between income (price of weight gain) and cost of feed consumption during the experimental period (Abd-Ella *et al.*, 1988). The price of each Kg of the experimental diet was calculated according to the price of ingredients in the local market at the time of the experiment (2.3 L.E).

$$\text{EE \%} = \frac{\text{Gain price} - \text{total cost}}{\text{Total cost}} \times 100$$

where: gain price = weight gain × price of Kg meat (18 L.E) and total cost = feed intake × cost of Kg feed (2.3 LE); cost of water additives did not calculated because of its very tiny price.

At the end of the experimental period, at 13 weeks of age, three rabbits were randomly chosen from each treatment. Assigned rabbits were fasted for 16 hours before slaughtering and were individually weighted as pre-slaughtering weight. Animals were slaughtered by cutting the jugular veins of the neck. When complete bleeding was achieved slaughter weight was recorded. After skinning, the carcass was opened down and all entrails were removed and the empty carcass, heart, liver, kidney and spleen were separately weighted, each of them was proportioned to live pre-slaughtering weight. Dressing percentage was calculated according to Ayyat *et al.* (1995).

Also, at the end of the experimental period, one metabolism trail was conducted to estimate the digestibility coefficients of the eight groups. Three rabbits from each group were housed individually in metabolic cages. Digestibility trail lasted 15 days (10 days as a preliminary period and 5 days as a collection period. Coprophagy was not prevented. Samples from both feed offered and dried faeces of each animal were taken daily during the collection period for chemical analyses (crude protein, crude fiber, ether extract and ash) which was carried out according to A.O.A.C. (1990). The total digestible nutrients (TDN) % was calculated according to Cheeke *et al.* (1982). The digestible energy (DE) values (Kcal/Kg diet) of the experimental diets were calculated according to the equation of Schiemann *et al.* (1972) as follows:

DE (Kcal/Kg diet) = [(5.28×(DCP g/Kg))+ (9.51 × (DEE g/Kg)+ (4.2 (DCF+DNFE g/Kg) /0.3]

Where: DCP, DEE, DCF and DNFE = digestible CP, EE, CF and NFE, respectively.

Data of the previous parameters were statistically analysed using the completely randomized (one way ANOVA) design according to Snedecor and Cochran (1982). The following model was used: $Y_{ij} = \mu + T_i + E_{ij}$ where: Y_{ij} = the observation, μ = general mean, T_i = fixed effect of i^{th} treatment levels (i = 40; 80 or 120 ppm/L of $CuSO_4$, 250; 500 or 750 ppm/L of ascorbic acid and cooled water at 10-15°C and E_{ij}= error of the model. Differences among treatments were tested statistically with New Multiple Range test method according to Duncan (1955).

RESULTS AND DISCUSSION

Temperature-Humidity Index

Temperature-humidity index value estimated was exceeded than 28.9, indicated animals exposure to sever heat stress during the hot period (Table 2). These results were similar to those of Marai *et al.* (1996) and Marai *et al.* (2000) under the same Egyptian climate conditions.

Growth Performance

Results in Table 3 showed that the addition of copper sulfate in the drinking water of the heat stressed NZW growing rabbits up to 40 mg/L water, significantly ($P<0.01$) improved all traits concerning growth performance (live body weight at 13 weeks of age, weight gain through 5-13 weeks, daily water consumption and feed conversion) comparatively with those receiving unsupplemented one except daily feed intake during 5-13 weeks of age in which the effect of copper sulfate was not significant. However, the supplementation of 40 mg copper sulfate/L water seemed to be the optimum level owing to the best performance obtained when compared with that of 80 mg copper sulfate/L water. It is worth noting that increasing copper sulfate level from 80 to 120 mg/L water showed no significant effect on the aforementioned traits comparatively with control.

These results coincided with those of Patton *et al.* (1982); Anugwa *et al.* (1984); Grobner *et al.* (1986); Abo El-Ezz *et al.* (1996); Abd El-Samee and El-Masry (1997); Ayyat *et al.* (2000); Attia (2003); Adu *et al.* (2010) and Yassein *et al.* (2011) who reported that growth performance of rabbits improved as a consequence of copper supplement in the diet or drinking water under tropical conditions. The different beneficial effect of copper supplementation to growing rabbits in the tropics possibly is explained through the action on the gut flora which might produce different levels of growth depressing infection and had a role in metabolism and absorption of the iron and haemoglobin (Underwood and Suttle, 1999). Other investigators (King, 1975 and Omole, 1977) had suggested that the mode of action of copper is by reducing the wall thickness of the caecum of rabbits that facilitates the uptake of nutrients and consequently improves daily and final gains. In addition, Anugwa *et al.* (1984) indicated that the beneficial effect of supplemental dietary copper to growing rabbits in the tropics may be partly due to improved fiber utilization which increases energy availability. Conflicting with that King (1975) reported no increase in growth rate when 200 ppm copper was added/kg diet.

With regard to ascorbic acid supplementation, it could be noticed from Table 3 that supplementation heat-stressed rabbits drinking water with 500 mg ascorbic acid/L water improved significantly ($P<0.01$) final body weight (13 weeks), body weight gain and feed conversion when compared with the control group. While final body weight, body weight gain and feed conversion were insignificantly improved by the supplementation with 250 and 750 mg ascorbic acid/L water. Daily feed intake insignificantly increased with 250 mg ascorbic acid/L and insignificantly decreased with 500 and 750 mg ascorbic acid/L. Daily water consumption was increased significantly ($P<0.01$) by the supplementation with different levels of ascorbic acid (250, 500 and 750 mg/L) as compared with the control group.

Improvement of the growth performance result of ascorbic acid supplementation to the drinking water of heat-stressed growing rabbits may be attributed to the animal increased resistance during physiological stress and enhancement of the total antioxidant (Selim *et al.*, 2004) or may be due to that ascorbic acid helps to control the increase in body temperature and plasma corticosteron concentration. It also protects the immune system and it has an important role in bone formation through the growth rate (Rama-Rao *et al.*, 2002).

In general, the present study agrees with that reported by Abd El-Hamid and El-Adway (1999) who found that supplementing heat-stressed rabbit diet with either 300 or 600 mg vit.C/kg diet significantly improved live body weight and feed conversion and decreased feed intake. Al-Shanty (2003) showed that ascorbic acid (1.0 g/L water) significantly improved averages of daily gain and final weight but, numerically decreased daily feed intake by 1.81 and 1.15%, respectively when compared with the control group. Selim *et al.* (2004) cleared that rabbits had access to extra levels of ascorbic acid beyond recommendation level achieved ($P<0.01$) better performance in

Table 1. Composition and chemical analyses of the experimental basal diet

Ingredients	(%)
Clover hay	42.50
Wheat bran	24.00
Yellow corn	15.00
Soybean meal (44% CP)	10.00
Molasses	5.00
NaCl	0.55
Limestone	0.90
Calcium carbonate	0.70
Di Calcium phosphate	1.00
Vitamins and Minerals mixture*	0.35
Total	**100**
Chemical analyses	
a- Calculated analyses**	
Crude protein (%)	18.00
Ether extract (%)	2.8
Crude fiber (%)	12.0
Digestible energy (kcal DE/kg diet)	2415
b- Determined analyses	
Crude protein (%)	18.9
Crude fiber (%)	16.08
Moisture (%)	8.04
Ash (%)	9.53

* Each 3 Kg of vitamins and minerals mixture contains: vit. A 10000 IU; vit D3 2000 IU; vit E 50 mg; vit K3 1000 mg; vit B1 1000 mg; vit B2 5000 mg; vit B6 1500 mg; vit B12 10 mg; Pantothenic acid 60 mg; Niacin 150 mg; Folic acid 1000 mg; Biotin 50 mg; Choline 12000 mg; Iodine 20 mg; Manganese 90 mg; Zinc 210 mg; Copper 10 mg; Iron 30 mg; Iodine 1000 mg; Selenium 100 mg; Cobalt 100 mg and Magnesium 40 mg.

**Calculated analyses according to NRC (1977).

Table 2. Averages ($\overline{X}$ ± SE) of air temperature, relative humidity and temperature-humidity index during the experimental period

Experimental periods	Air temperature (°C)	Relative humidity (%)	Temperature humidity index (THI)*
July 2011	32.12 ± 0.31	71.83 ± 3.17	30.56 ± 0.80
August 2011	30.84 ± 0.26	67.58 ± 2.26	29.17 ± 0.21
September 2011	30.72 ± 0.15	64.5 ± 1.83	28.93 ± 0.30

*THI values obtained were classified as follows: < 27.8 = absence of heat stress, $27.8 \leq 28.9$ = moderate heat stress, $28.9 \leq 30.0$ = severe heat stress and 30.0 and more = very severe heat stress (Marai *et al.,* 2000).

Table 3. Growth performance ($\overline{X}$ ± SE) of NZW growing rabbits as affected by addition of copper sulfate ($CuSO_4$), ascorbic acid (AA) in drinking water and drinking cooled water during the experimental period (5-13 weeks of age)

Items	Final body weight (g)	Daily weight gain (5-13 weeks) (g)	Daily feed intake (g)	Daily water consumption (L)	Feed conversion (g feed/ g gain)	Mortality rate (%)	Economic efficiency (%)
Sig.	**	**	N.S.	**	**	N.S.	-
Unsupplemented (Control)	1703.0^{bc}±31.84	18.84^{bc}±0.54	80.32±3.36	0.427^{c}±0.01	4.26^{a}±0.06	24.99±8.33	83.90
Copper sulfate mg/L water							
40	1905.4^{a}±37.87	22.32^{a}±0.67	78.72±2.08	0.530^{a}±0.02	3.54^{bc}±0.19	16.67±9.62	122.80
80	1886.0^{a}±24.56	22.04^{a}±0.40	82.26±2.47	0.485^{ab}±0.03	3.74^{abc}±0.17	16.67±9.62	110.51
120	1639.3^{c}±16.4	17.62^{c}±0.25	70.50±0.41	0.468^{bc}±0.01	4.00^{ab}±0.07	33.33±19.24	95.66
Ascorbic acid mg/L water							
250	1747.1^{b}±31.98	19.58^{b}±0.58	81.25±3.46	0.511^{ab}±0.00	4.16^{a}±0.20	0.00	89.61
500	1885.6^{a}±31.27	22.01^{a}±0.61	79.76±4.34	0.511^{ab}±0.02	3.62^{bc}±0.12	8.333±8.33	117.00
750	1784.7^{b}±24.81	20.32^{b}±0.43	77.68±1.59	0.531^{a}±0.02	3.83^{abc}±0.14	0.00	105.14
Cooled water	1923.0^{a}±14.34	22.82^{a}±0.29	78.00±6.67	0.422^{c}±0.01	3.41^{c}±0.26	8.333±8.33	132.92

Means in the same column within each classification bearing different letters are significantly different.
N.S. = not significant and ** ($P \leq 0.01$).

growth terms (live weight gain and feed conversion ratio) compared to the control group. Sallam *et al.* (2005) reported that ascorbic acid had significant ($P<0.05$) increase in water intake and a favorable effect on final body weight in growing rabbits. Selim *et al.* (2004) reported that using of ascorbic acid did not significantly affect feed intake. Contrasted with these results Sallam *et al.* (2005) and Shehata (2005) showed that ascorbic acid supplementation caused significant increase in feed intake. Selim *et al.* (2004) reported no further response to supplemental ascorbic acid on growth performance of rabbits.

Regarding to the treatment with drinking cooled water, results in Table 3 showed that cooled water improved significantly ($P<0.01$) each of final body weight at 13 weeks of age, body weight gain and feed conversion ratio when compared with the control group. There are no significant differences were found in feed and water consumption due to drinking cooled water comparatively with control. Drinking cooled water acts through cooling the animal body core by conduction as a result to the difference between temperatures of the drinking water and urine, mediated by cooling the area of the hypothalamus. This is altogether with the high specific heat of water, as well as, body water retention with drinking cooled water that help to alleviate the rise in body temperature which are reflected in reduction of rectal temperature and respiration rate. Reduction of water intake by drinking cooled water may be due to increase in the dissipated heat (Marai *et al.,* 1994a, 1999 and Habeeb *et al.,* 1994). Moreover, drinking cool water is an excellent cooling agent because of its high latent heat of vaporization (Selim *et al.,* 2004). The present study's results agreed with Marai *et al.* (1999) who found that the treatment with drinking water improved final live body weight and feed conversion. Similar results were reported by Bassuny *et al.* (2004), Selim *et al.* (2004), Shehata (2005) and Yassein *et al.* (2008).

Mortality Rate

Results in Table 3 revealed that treatment of heat-stressed rabbits with 40 or 80 mg copper sulfate/L drinking water insignificantly decreased mortality rate as a compared with control or 120 mg copper sulfate/L water. The beneficial effect of copper sulfate may be due to its productive effects against enteritis. Since enteritis is known to be a major problem in commercial rabbit production. These results agreed with the finding of Abo El-Ezz *et al.* (1996) who observed a decrease in mortality rate % occurred in rabbits given drinking water supplemented with copper sulfate at levels 20, 60 and 180 mg/L water as compared with control. Patton *et al.* (1982) and Bassuny (1991) stated that adding copper sulfate reduced mortality. Grobner *et al.* (1986) stated that mortality was not significantly differed by dietary copper or oxytetracycline.

With regard to ascorbic acid and drinking cooled water treatments, adding ascorbic acid to drinking water or drinking cooled water reduced mortality rate in heat-stressed growing rabbits compared with control. Death of rabbits wasn't observed in the 250 or 750 mg ascorbic acid/L water. These results suggest ascorbic acid has a tendency to reduce mortality. It is thought that ascorbic acid reduces mortality rate through its effect on plasma corticosterone. The most striking effect of corticosterone is a serve involution of lymphatic tissue (Brake, 1989). A significant immunosurpression would be expected where such extensive corticosterone effects occurred. Ascorbic acid is known to reduce the concentration in plasma (Doulas *et al.*, 1987). According to North (1981) the birds with low plasma corticosterone showed higher resistance to many vital infections. Our results agree with Skrivanova *et al.* (1999) who showed that the mortality rate of Hyla 2000 weaned rabbits were kept at 25°C and received ascorbic acid in water at 30 mg per kg of body weight, twice a week, was (21.4% vs. 5.4%) comparing with the control group. While, Skrivanova and Marounek (1997) reported that mortality of Hyla 2000 rabbits supplied with ascorbic acid at 30 mg/kg body weight, twice a week, was lower ($P<0.025$) than those of control group. On the same trend, Ibrahim and Moubarak (2002) who observed that adding vitamin C to drinking water reduced mortality rate in Fayoumi growing chicken and high level of vitamin C (500 mg/L) resulted in the lowest rate of mortality. Similar results were obtained by Wilson (1989); Abd-Ellah (1995) and Abou-Zeid *et al.* (2000).

Economic Efficiency

Data presented in Table 3 cleared that all treatment groups improved economic efficiency during the whole experimental period It is clear that, the highest value was achieved with cooled water then that of 40 ppm of $CuSO_4$ and that of 500 ppm of ascorbic acid (132.9, 122.8 and 117.0%, respectively), while the lowest economic efficiency value was recorded by unsupplemented group (control). These results were in accordance with those of Marai *et al.* (1999) who reported that the treatment with cooled water increased final margin by 29.6%. Also, Ayyat (1995) observed that addition of 100 or 200 mg copper in rabbit diets increased final, margin with 27.0 and 51.7%, respectively than the control diet.

Digestibility Coefficients and Feeding Values

Results tabulated in Table 4 showed that, digestibility coefficients of dry matter (DM), organic matter (OM), ether extract (EE), nitrogen free extract (NFE) and crude fiber (CF) and feeding values as TDN and DE were not affected significantly by either different levels of copper sulfate and ascorbic acid or cooled drinking water but with a marked trend to decrease. It could be noticed that digestibility of crude protein (CP) was increased insignificantly by treatment of heat-stressed rabbits with 40 or 80 mg copper sulfate/L water or cooled drinking water.

On the other hand, it was decreased insignificantly by different levels of ascorbic acid and 120 mg copper sulfate/L water. In agreement with these the finding of Attia (2003) who found that digestibility coefficients of nutrients and nutritive values as TDN and DE were not affected significantly by copper levels. Abd El-Azeem and Abd El-Reheem (2006) reported that the digestibility coefficients of DM and OM insignificantly increased were noticed for treated groups with supplementing dietary levels of copper when compared to the control group. Contradicting results were obtained by Ayyat *et al.* (1995) who found that, nutrients digestibility were improved by addition of 100 or 200 mg copper in rabbit diets. Zanaty (2005) reported that digestibility coefficients of DM and CF were significantly increased ($P<0.05$) by the addition of copper.

Table 4. Digestibility Coefficients and feeding values ($\bar{X}\pm$ SE) of NZW growing rabbits as affected by addition of copper sulfate ($CuSO_4$), ascorbic acid (AA) in drinking water or drinking cooled water

Items	Digestibility coefficients %						Feeding values (as fed)	
	Dry matter (DM)	Organic matter (OM)	Crude protein (CP)	Ether extract (EE)	Nitrogen free extract (NFE)	Crude fiber (CF)	TDN (%)	DE (Kcal/ Kg diet)
Sig.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Unsupplemented (Control)	66.62±0.48	68.71±0.07	75.74±1.37	80.22±3.65	54.70±0.42	40.88±4.23	62.23±1.00	2415.2±7.1
Copper sulfate mg/L water								
40	60.17±3.87	61.69±3.77	77.15±2.20	66.51±6.91	42.23±5.98	21.93±6.03	56.31±3.14	2287.9±127.6
80	64.50±6.54	66.56±5.94	79.82±6.27	61.29±4.60	50.54±7.99	31.48±3.88	59.90±5.27	2442.9±214.0
120	58.73±3.16	60.77±3.06	73.48±2.76	73.60±1.50	41.71±4.96	39.16±4.20	56.14±2.46	2029.4±188.7
Ascorbic acid mg/L water								
250	61.21±3.55	62.85±3.23	73.26±2.59	72.60±3.77	45.54±4.52	34.32±4.98	57.77±2.97	2329.5±117.4
500	59.29±4.90	61.60±4.37	71.15±2.73	65.72±6.50	44.66±6.67	29.12±3.27	56.17±4.11	2271.8±159.0
750	57.53±1.25	58.23±0.92	67.76±1.58	64.71±6.04	40.03±1.81	22.26±1.91	53.31±0.51	2153.5±25.2
Cooled water	60.73±5.72	63.28±5.45	78.51±1.23	53.99±20.26	45.65±8.36	22.88±7.93	56.60±5.96	2319.7±211.2

Means in the same column within each classification bearing different letters are significantly different.
N.S. = not significant and ** ($P \leq 0.01$).

Regarding to the effect of ascorbic acid, our results agreed with Sallam *et al.* (2005) who found that treatment with ascorbic acid in drinking water of growing rabbits caused insignificant effect in digestibility coefficients of DM, OM, CP, CF, EE, NFE and feeding values as TDN and DE. Also, Skrivanova and Marounek (1997) reported that the digestibility of nutrients of Hyla 2000 rabbits supplied with ascorbic acid at 30 mg/kg body weight, twice a week, was not significantly affected. While partially contrasted with these results, Selim *et al.* (2004) reported that the treatment with vitamin C (300 mg/kg diet) did not significantly affect digestibility coefficient of CP, while, it was significantly affected OM, EE and CF digestibility coefficients. Regarding to the effect of cooled water, our results agreed with Selim *et al.* (2004) who reported that the treatment with cooled water (16-20°C) did not significantly affect CP digestibility coefficient. On the other hand, Marai *et al.* (2001) stated that supplying the animals with cooled drinking water (10-15°C; between 10:00 AM and 5:00 PM) gave the highest digestibility coefficients for DM and CP.

Carcass Traits

Data in Table 5 revealed that dressing and hot carcass percentage were significantly ($P<0.01$) decreased with addition of 80 mg copper sulfate/L water and were significantly ($P<0.01$) increased with addition of 120 mg copper sulfate/L water to heat-stressed growing rabbits comparatively with unsupplemented and other levels of copper sulfate supplemented. Also, the relative weight of heart and total edible giblets were significantly ($P<0.05$ or $P<0.01$) decreased by treated heat-stressed rabbits with 40 and 80 mg copper sulfate/L water. These results are in agreement with those obtained by Abd El-Azeem and Abd El-Reheem (2006) and Zanaty (2005) who reported that copper supplementation improved dressing percentage and hot carcass weight (%). Yassein *et al.* (2011) observed that adding copper sulfate in drinking water increased dressing and carcass (%). Contradicting results were obtained by Ayyat *et al.* (1995) and Bassuny (1991) who found no effect of copper sulfate supplementation on carcass yield.

With regard to ascorbic acid supplementation, the results in Table 5 revealed that blood weight %, liver weight, kidney weight, and spleen weight percentages were not significantly affected by ascorbic acid supplementation compared with the control group. However, hot carcass weight percentage was significantly ($P<0.01$) increased by supplementing heat-stressed rabbits with 250 mg ascorbic acid/L water against

Table 5. Carcass characteristics ($\bar{X}$ ± SE) of NZW growing rabbits as affected by addition of copper sulfate ($CuSO_4$), ascorbic acid (AA) in drinking water or drinking cooled water during the experimental periods

Items	Body weight (g)	Hot carcass weight (%)	Blood weight (%)	Dressed weight (%)	Edible giblets (%)				Spleen (%)
					Liver	Kidney	Heart	Total edible	
Sig.	**	**	N.S.	**	N.S	N.S.	**	*	N.S.
Unsupplemented (Control)	$1756.7^{cd}\pm49.53$	$54.44^{b}\pm1.32$	1.90±0.12	$59.21^{bc}\pm1.47$	3.72±0.12	0.733±0.03	$0.310^{a}\pm0.01$	$4.77^{ab}\pm0.16$	0.053±0.003
Copper sulfate mg/L water									
40	$1938.3^{ab}\pm70.97$	$52.78^{bc}\pm1.04$	1.98±0.02	$56.98^{cde}\pm1.31$	3.25±0.31	0.670±0.02	$0.267^{ab}\pm0.01$	$4.19^{c}\pm0.31$	0.047±0.007
80	$1921.7^{ab}\pm10.93$	$51.78^{c}\pm0.31$	1.82±0.15	$55.98^{de}\pm0.43$	3.28±0.19	0.570±0.07	$0.240^{bc}\pm0.01$	$4.09^{c}\pm0.14$	0.057±0.003
120	$1633.3^{cd}\pm10.14$	$58.46^{a}\pm0.31$	2.24±0.09	$63.33^{a}\pm0.45$	3.92±0.15	0.673±0.10	$0.270^{ab}\pm0.01$	$4.86^{a}\pm0.08$	0.053±0.009
Ascorbic acid mg/L water									
250	$1713.3^{d}\pm58.40$	$57.18^{a}\pm1.21$	1.85±0.03	$61.41^{ab}\pm1.20$	3.40±0.20	0.620±0.04	$0.210^{c}\pm0.03$	4.22b$^{c}\pm0.19$	0.037±0.003
500	$1910.0^{ab}\pm40.41$	$54.56^{b}\pm0.47$	1.92±0.08	$58.44^{cd}\pm0.34$	3.10±0.16	0.643±0.08	$0.233^{bc}\pm0.02$	$3.98^{c}\pm0.10$	0.043±0.009
750	$1828.3^{bc}\pm15.90$	$54.41^{b}\pm0.21$	2.01±0.10	$58.93^{bc}\pm0.10$	3.31±0.19	0.683±0.03	$0.250^{bc}\pm0.02$	4.25b$^{c}\pm0.24$	0.050±0.006
Cooled water	$2000.0^{a}\pm18.93$	$51.42^{c}\pm0.77$	1.84±0.09	$55.48^{e}\pm0.76$	3.11±0.07	0.697±0.01	$0.253^{bc}\pm0.09$	$4.06^{c}\pm0.07$	0.053±0.003

Means in the same column within each classification bearing different letters are significantly different.
N.S. = not significant, * ($P \leq 0.05$) and ** ($P \leq 0.01$).

the unsupplemented group (control). Adding 500 mg ascorbic acid/L water decreased significantly (P<0.05) total giblets percentage when compared with unsupplemented (control). Heart percentage was significantly (P<0.01) decreased by supplementing drinking water of growing rabbits with vitamin C at the studied levels comparatively with control. Al-Shanty (2003) and Abd El-Hamid and El-Adway (1999) reported that carcass percentage, dressing hot carcass weight, kidney and spleen percentages were not significantly affected by the treatment by ascorbic acid of heat-stressed rabbits. Also, other studied carried out by Selim *et al.* (2004 and 2008) who reported no effect of vitamin C on carcass traits.

Regarding the treatment with drinking cooled water, results tabulated in Table 5 showed that cooled water decreased significantly (P<0.01 or P<0.05) each of hot carcass weight %, dressed weight %, heart weight % and total edible giblets weight % and insignificantly decreased each of blood weight %, liver weight % and kidney weight %. Contrary with these results, Marai *et al.* (1999) found that treatment of heat-stressed rabbits by drinking cooled water increased weights of carcass, fore part and intermediate parts. Also, Selim *et al.* (2004) reported that the treatment with cooled water (16-20°C) did not significantly affect total edible parts (%).

Conclusion

It could be use each of copper sulfate, ascorbic acid and cooled water (10-15° C) as water supplements for NZW male rabbits to reduce the negative effects under Egyptian summer conditions, especially the levels of 40 mg/L of $CuSo_4$, 500 mg/L of ascorbic acid and cooled water which was the most efficient physical technique for alleviation the heat stressed NZW male rabbits until marketing age in this study.

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اسـتجابة الأرانب النامية للمعاملة بكبـريتـات النحـاس أو فيتـامين جـ أو المـاء المبرد تحت ظروف الصيف المصرية

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استخدم فى هذه التجربة ٩٦ من ذكور الأرانب النيوزيلاندي الأبيض عمر ٥ أسابيع متساوية تقريبا فى وزن الجسم (650.3 ± 3.7 g) الابتدائي وزعت عشوائيا إلى ٨ مجموعات (٤ مكررات ولكل مكرره ٣ أرانب) ، وقد أجريت التجربة فى مزرعة أرانب خاصة بالزقازيق - محافظة الشرقية - مصر، وقد تم إسكان كل مكررة فى قفص مجلفن بأبعاد ٤٠×٣٠×٢٥ سم واستمرت التجربة لمدة ٨ أسابيع خلال الفترة من يوليو إلى سبتمبر ٢٠١١، وقد أعطيت المجموعة الأولى ماء الصنبور بدون أى إضافات (مجموعة الكنترول) فى حين أعطيت المجموعات الثانية والثالثة والرابعة كبريتات النحاس بمستويات ٤٠ و ٨٠ و١٢٠ ملجم/ لتر ماء على الترتيب ، كما أعطيت المجموعات الخامسة والسادسة والسابعة فيتامين جـ بمستويات ٢٥٠ و ٥٠٠ و ٧٥٠ ملجم/ لتر ماء على الترتيب ، بينما عوملت المجوعة الثامنة بشرب الماء المبرد (١٠-١٥° م) فى تصميم تام العشوائية. وقد تم دراسة تأثير هذه المعاملات على بعض صفات النمو (وزن الجسم النهائي، وزن الجسم المكتسب، معدل استهلاك الغذاء، معدل استهلاك المياه، معامل التحويل الغذائي، معدل النفوق) خلال الفترة الكلية للدراسة (٥-١٣ أسبوع)، وكذلك تأثيرها على معاملات الهضم لكل من البروتين والدهون والألياف والكربوهيدرات الذائبة الكلية والمادة الجافة والمادة العضوية، وتأثيرها على الكفاءة الاقتصادية وبعض صفات الذبيحة. وقد أظهرت النتائج أن استخدام كل من مستوى ٤٠ و ٨٠ ملجم كبريتات نحاس/ لتر ماء أدى إلى زيادة معنوية (P<0.01) فى صفة وزن الجسم النهائي ووزن الجسم المكتسب ومعدل استهلاك المياه وكذلك زيادة فى الكفاءة الاقتصادية وانخفاض معنوى (P<0.01) و(P<0.05) فى وزن القلب % ووزن الأجزاء المأكولة % منسوبه لوزن الجسم على الترتيب. كما حقق مستوى ٤٠ ملجم كبريتات نحاس/ لتر تحسن معنوى (P<0.01) فى معامل التحويل الغذائي بينما لم يحقق المستويين الآخرين أى تحسن معنوى مقارنه بمجموعه الكنترول، فى حين لم يحقق مستوى ١٢٠ ملجم كبريتات نحاس/ لتر ماء أى زيادة معنوية فى صفة وزن الجسم النهائي ووزن الجسم المكتسب ومعدل استهلاك المياه ومعامل التحويل الغذائي وحقق زيادة ضئيلة فى الكفاءة الاقتصادية ، كما حقق نفس المستوى زيادة معنوية (P<0.0.1) فى نسبة التصافى % ووزن الذبيحة % منسوبة إلى وزن الجسم فى حين حقق مستوى ٨٠ ملجم كبريتات نحاس/ لتر ماء انخفاض معنوى (P<0.01) فى هاتين الصفتين. كذلك أوضحت النتائج عدم وجود تأثير معنوى فى معدل استهلاك الغذاء ومعدل التفوق وجميع معاملات الهضم لجميع مستويات كبريتات النحاس المستخدمة. كما أظهرت النتائج أن استخدام فيتامين جـ بمستوي ٥٠٠ ملجم/ لتر ماء أدى إلى تحسن معنوى (P<0.01) فى صفات وزن الجسم النهائي ووزن الجسم المكتسب ومعامل التحويل الغذائي ووزن الأجزاء المأكولة % منسوبه الى وزن الجسم فى حين لم يحقق كلا المستويين الآخرين لفيتامين جـ أى تأثير معنوى فى تلك الصفات مقارنة بمجموعه الكنترول. وقد حققت جميع مستويات فيتامين جـ المستخدمة زيادة ملحوظة فى الكفاءة الاقتصادية وزيادة معنوية (P<0.01) فى معدل استهلاك المياه وانخفاض معنوى (P<0.01) فى وزن القلب % منسوب لوزن الجسم ، بينما لم تحقق أى تأثر معنوى فى معدل استهلاك الغذاء ومعدل النفوق ووزن الدم % والكبد % والكلي % والطحال % منسوبة لوزن الجسم ونسبة التصافى % وجميع معاملات الهضم المدروسة مقارنة بمجموعة الكنترول. كذلك أدى استخدام الماء المبرد (١٠-١٥°م) إلى زيادة معنوية (P<0.01) فى صفات وزن الجسم النهائي ووزن الجسم المكتسب وتحسن معنوى (P<0.01) فى معامل التحويل الغذائي وأعلى زيادة فى الكفاءة الاقتصادية فى حين أدى إلى انخفاض معنوى (P<0.01) فى وزن الذبيحة % ووزن القلب % ووزن الأجزاء المأكولة % منسوبة إلى وزن الجسم ونسبة التصافى % وانخفاض غير معنوى فى معدل استهلاك المياه ووزن الدم % والكبد % والكلى % والطحال % منسوبة إلى وزن الجسم، فى حين لم تتأثر صفات معدل استهلاك العلف ومعدل النفوق وجميع معاملات الهضم المدروسة معنويا باستخدام الماء المبرد (١٠-١٥°م). يمكن تلخيص نتائج هذه التجربة بأن استخدام كبريتات النحاس أو فيتامين جـ أو الماء المبرد (١٠-١٥°م) أدى إلى تقليل الأثر الضار للإجهاد الحرارى على الأرانب النامية وتحسين معدل نموها تحت ظروف الصيف فى مصر خاصة مستويات ٤٠ ملجم/ لتر ماء من كبريتات النحاس و ٥٠٠ ملجم/ لتر ماء من فيتامين جـ أو المعاملة بالماء المبرد (١٠-١٥°م) والتى تعتبر أفضل المعاملات المستخدمة.

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