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Effect of vitamin c or betaine supplementation on growing rabbit's performance under Aswan condition

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Abstract

The purpose of this study was to assess the effect of vitamin C (Vit.C) and betaine (BET.) supplementation in diets of growing rabbits on growth performance, nutrient digestibility, rectal temperature, and blood serum constituents. The experiment lasted a 6-month period under Aswan condition. Thirty New Zealand White growing rabbits were used at age 3 months, with an average weight of 1193.88±55.94 gm, and they were divided into three treatments (10 rabbits in each treatment). The first group was basal diet (control), the second group was basal diet plus (1000 mg vit. C/kg diet), and the third was basal diet plus (1000mg betaine/kg diet). The second group rabbits fed 1000 mg vit.C/kg achieved the numeric increase in nutrients digestibility for DM (75.78%), OM (80.68%) and NFE (68.38%) compared control (73.04%,79.60% and 68.36%) respectively. While in the third group rabbits fed 1000 mg betaine/kg diet achieved the numeric increase in nutrients digestibility for CP (75.97) and EE (57.55) compared control (74.34 and55.81) respectively. The Third group fed 1000 mg betaine/kg diet achieved the highest significant ($P<0.05$) final body weights (3353 g) compared with the control (3060 g). Also, rectal temperature was decreased (39.2 °C) compared with the control (39.39°C) while vitamin C supplementation recorded (39.22°C). Rabbits fed 1000mg betaine/kg diets recorded non-significant increase in serum total protein, albumin, urea, creatinine triglyceride, ALT and glucose concentration while serum globulin was significantly increased due to dietary betaine supplementation. supplemental dietary betaine enhanced growth performance and reduced rectal temperature in growing rabbits.

Keywords: Growing rabbits; Betaine; Vitamin C; Performance.

Introduction

Rabbit farming is an essential part of the livestock industry, providing a vital source of protein for human consumption. Improving rabbit growth is essential for efficient and sustainable production. Recent studies have focused on nutritional techniques that can improve rabbit growth, feed efficiency, and overall health. Among these treatments, vitamin C and betaine supplementation has shown good results.

Vitamin C (Vit C), ascorbic acid, is an important vitamin necessary for optimal metabolic functioning of the organism **[1].** In particular, Vit C might defend against oxidative stress damage by its free radical scavenging action **[2].** Betaine (BET), also known as N, N, N-trimethyl glycine, is a rich supply of methyl groups that can replace methionine and choline. Betaine is produced from choline utilizing choline oxidase and can supply methyl groups to homocysteine, resulting in methionine. Betaine has osmo-protective properties that benefit the kidney, nervous, cardiovascular, and immune systems. It is used in farm animal feeds to reduce carcass fat, conserve choline, and improve cell osmoregulation **[3].**

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In hot periods, rabbits have difficulty eliminating body heat because of their non-functional sweat glands **[4].** There is a lack of information on the effect of dietary betaine on performance, carcass characteristics and immunity in rabbits under heat stress conditions. In Egypt, the climate is characterized by a long hot period (from May to October) and short mild one (from December to March). The objective of this study was to investigate the effect of dietary supplementation of Vitamin C and Betaine as a natural antioxidant on growth performance and digestibility rectal temperature, blood serum constituents of growing rabbits under high ambient temperature.to alleviate the negative effects of heat stress conditions.

This Study aimed to investigate the effect of supplements vitamin c and betaine on growing rabbits under Aswan governorate conditions.

Materials and methods

Experimental animals and Diets:

This study was conducted at Rabbit farm in Aswan Governorate. Thirty growing male New Zealand White rabbits, 3 months old, with an average weight 1193.88±55.94 g. divided randomly into three similar groups of 10 rabbits each. The experimental groups were randomly assigned to one of the three experimental Treatments. The experimental rabbits were individually weighed at the beginning of the experiment period.

Rabbits and Housing:

All rabbits were individually house-caged (galvanized wire). The dimensions of the cage were 40×30×25 cm. All rabbits were continually provided with fresh water, and were maintained under the same managerial, hygienic and environmental conditions all over the experimental period (6 months). The rabbits were acclimatized for a period of one week before the beginning of the trial. Fresh water was automatically available all the time of study by stainless steel nipples fixed in each cage.

Animal Feed Formulation and feeding

The basal diet was formulated to cover the recommended nutrient requirements of growing rabbits according to **[5].** The daily ration was divided into equal meals at 16.00 with the provision of drinking water all the time.

The first group (T1) was the control group with no additives (basal diet), the second group (T2) was given a basal diet supplemented with 1000 mg/kg vitamin C, and the third group (T3) was given a basal diet supplemented with 1000 mg/kg betaine.

(Table 1) showed The Chemical composition analysis of the experimental rations was carried out according to **[6]** at the laboratory of Animal production, Animal Production Department, Faculty of Agriculture and Natural Resources, Aswan University. According to **[4]** there is severe heat stress when THI is higher than 28.9. The THI was calculated according to **[7]:**

$$THI = db^{\circ}C[(0{:}31 – 0{:}031RH) \times (db^{\circ}C – 14{:}4)]$$

where, dbºC is dry bulb temperature in Celsius degrees, and RH is the relative humidity as a percentage. All the experimental animals were healthy and clinically free from internal and external parasites and were kept under the same management and hygienic conditions. All experiments were performed in accordance with institutional guidelines concerning animal use.

Table 1. Chemical composition (dry matter basis) of basal diet fed to growing rabbits.

Item	CFM
DM %	92,02
OM,	80,08
CP %	17,27
CF %	11,38
EE %	2,78
NFE % (Nitrogen Free Extract)	48,65
Ash %	11,94

Digestibility trails

At the last week of the experimental period, 4 rabbits from each group randomly choosing for the digestibility trial. Rabbits were housed in individual metabolism cages diet for a period of 7 days (preliminary period) for adaptation then dry Faeces were collected every 24 hours for 7 consecutive days (collection period). Faeces were collected daily every 24 hrs in plastic bags and weighed before offering next diet. The total daily faeces of each animal was taken as and sprayed with solution of 10% formaldehyde and 10% H_2SO^4 and dried in the oven at 65°C for 12 hrs.

Representative samples of feed offered and feces of each rabbit were chemically analyzed for determinations of DM, crude protein (CP), ether extract (EE), crude fiber (CF) and ash which were carried out according to **[6]** methods. Nitrogen free extract (NFE) was determined by difference. Nutritive values in terms of TDN % and DCP % were calculated according to classic formula **[8].**

Apparent digestibility coefficient (ADC) was calculated as follows:

ADC= [(total nutrients intake – total nutrients in feces)/total nutrients intake] × 100.

Nutritive values in terms of total digestible nutrients (TDN %) and the digestible crude protein (DCP %) were calculated according to classic formula **[8]** as follows:

TDN (%) = DCP (%) + DCF (%) +DNFE (%) + (DEE (%) × 2.25)

Where: DCP =Digestible crude protein, DCF=Digestible crude fiber, DNFE=Digestible nitrogen free extract, DEE=Digestible ether extract.

Measurements:-

1- All rabbits were individually weighed at the beginning of the experiment then weekly.
2- Feed intakes were determined by weighing the remained amounts of feed a before putting the new ones daily.
3- Rectal Temperature using Digital Thermometer weekly.
4- At the last week of trial, rabbits from each group were randomly choosing 4 for the digestibility trial.
5- Feces of each rabbit was daily collected, weighed before offering the next meal for 7 days.
6- The temperature and relative humidity of the surrounding atmosphere of the rabbits were taken daily at three different times of the day: 8 am, 12 pm and 3 pm.
7- Blood samples were taken from 3 random rabbits from each group via the ear vein.

Blood sampling:

At the end of the feeding trial (six months) feeding. Blood samples were taken of 9 rabbits in the experiment. The samples were directly collected into a vacuum tube and centrifuged at 3000 rpm for 15 min. Serum was separated then transferase into polypropylene tube and stored at -20º C until analysis for total proteins (g/dl) and albumin (g/dl) according to **[9]** and **[10]**, respectively. Globulin (g/dl) was calculated by the difference between total protein and corresponding value of albumin. Glucose was determined as recommended by **[11].** Urea (mg/dl) was determined by the method of **[12].** Creatinine (mg/dl) was measured as reported by **[13].** Uric acid was determined according to the method described by **[14].** Alanine amino transaminase (ALT) and aspartate transaminase (AST) were determined according to the method described by **[15].** Cholesterol (mg/dl) was determined according to the method described by **[16].**

Statistical analysis

The obtained data were analyzed using the general linear model procedure of **[17]**, using the following model:

$$Yij = \mu + Ti + Eij$$

Where:

Yij = Observed value of a given dependent variable.

μ = Overall adjusted mean.

Ti = The effect of treatments.

Eij = The experimental random error.

Significant differences between means were separated by Duncan's multiple range tests **[18]**.

Results and discussion

Digestibility coefficients

Results in Table (2) showed the digestibility coefficients of nutrients as affected by different dietary treatments. Digestibility coefficient value of dry matter was 72.04% for control ration and increased to 75.78% with adding vitamin C, while decreased to 72.72% with adding betaine. Statistical analysis showed that control ration had no significant ($p>0.05$) differences compared with all supplemented rations. Organic matter digestibility almost followed the same trend of DM digestibility. Digestibility of OM was 79.60% for control ration and increased to 80.68% with adding vitamin c, while decreased to 79.93% with adding betaine.

Regarding crude protein, it was higher in betaine and vitamin c (75.97% and 75.01%) compared than the control diet (74.34%). The digestibility coefficient values of CF were 65.82% for control ration and decreased to 64.79% with adding vitamin c, to 62.73% with adding betaine. As for the ether extract, it was higher in betaine, reaching 57.55%, then in the control diet (55.81%), and decreased in vitamin c to 55.41%. The digestibility of the nitrogen-free extract (NFE) was almost the same with no significant differences between all treatments.

Table 2. Effect of vitamin c and betaine on digestion coefficients of growing rabbit.

Item	Experimental rations			SEM	*p* Value
	T1	T2	T3		
Nutrient digestibility %					
Dry matter (DM)	72.04	75.78	72.72	0.85	0.1629
Organic matter (OM)	79.60	80.68	79.93	1.10	0.9381
Crude protein (CP)	74.34	75.01	75.97	0.98	0.8338
Crude fiber (CF)	65.82	64.79	62.73	0.72	0.2177
Ether extract (EE)	55.81	55.41	57.55	0.68	0.446
Nitrogen free extrac(NFE)	68.36	68.38	67.00	3.07	0.9834

The negative effect of heat stress on nutrient found that digestibility and nutritive values possibly because of that heat stress may affect cecal flora structure which lead to increase the harmful bacteria **[19]**. Earlier, **[20]** pointed out that rise in temperature will significantly inhibit the immune function. Our results are in agreement with **[21]** they reported that supplementing growing rabbits during heat stress with vitamin C improve of the digestibility of DM, OM, CP and NFE nutritive values compared to the control group.

Our results are in agreement with many researches **[22, 23, and 24]** they found that the Betaine improve of the digestibility of DM, OM, CP and EE in nutrients digestibility and TDN and SV.

Feed consumption:

Nevertheless, not significant differences were recorded in DMI, TDN, SV and CPI between all experimental groups along the experimental period.

The present results are in good agreement with **[25 and 26]** who showed that studies have demonstrated that vitamin C can improve feed consumption, body weight gain, and feed conversion ratio in rabbits. In addition, Studies have demonstrated that betaine can improve growth performance, feed conversion ratio, and nutrient digestibility in rabbits [**24, 27 and 28**]. Betaine supplementation at 1-1.5 g/kg diet has been found to be particularly effective in enhancing average daily gain and feed efficiency **[23 and 28]**

Table (3). Effect of vitamin c and betaine on feed consumption in rabbits.

Item	Experimental rations			SEM	*p* Value
	T1	T2	T3		
Dry matter intake (g)	114.74	116.12	116.42	0.94	0.7102
TDN intake, g	76.56	82.17	79.34		
SV intake, g	37.56	40.27	47.32		
CP intake, g	19.82	20.05	20.11		

Live body weight:

Result reported in table (4) showed that the rabbits fed diet supplemented with 1g of betaine/1kg diet (T3) were significantly ($P < 0.05$) higher FBW by 2.94, 9.58% Compared with control and vitamin c, respectively.

In general, supplementation of betaine to growing rabbit diets increased final body weight compared to control group. But the difference was significant between T1, T2 and T3.

The data represented in table (4) showed that rabbits fed betaine had increased significantly (P <0.05) live body weight compared to other groups. In creating in body weight could be attributed to improved their CP digestibility.

These results agreement with **[29]** they reported that the vitamin C supplementation in dose 200 mg/kg feed resulted in higher final body weights and lower production costs compared to control groups under tropical humid conditions.

Studies have reported increased live body weight and daily weight gain in rabbits fed betaine-supplemented diets **[30]**.

Body weight gain:

Results represent in table (4) showed that body weight gain of rabbits fed diet supplemented with 1g of betaine / kg diet were significantly (P < 0.05) increased at the end of experimental period by 8.68 and 2.39% compared to control and vitamin c respectively. Daily weight gains of rabbits treated with 1g of betaine / kg diet significantly (p < 0.05) increased by 8.68 and 4.28% compared to control and vitamin c, respectively.

These increases in BWG and DGW could be attributed to improving their crude protein digestibility, which led to improving nutrient and protein utilization and resulting in higher protein anabolism and intestine absorptive capacity.

Generally, body weight gain achieved by rabbits between 15-16 gm(h/d) which are similar to the results of **[22 and 31]** reported arrange of 17.32 - 27.39 gm (h/d) for NZW rabbits.

This results agreement with **[32]** found that the growing rabbits received vitamin C (200 ppm) achieved the highest live weight gain and best feed conversion ratio.

The optimal dosage appears to be around 1.5 g/kg diet betaine, which significantly improves average daily gain and feed efficiency **[23]**.

Effect of supplementing of vitamin c and betaine on Growth Performance on rabbits:

Mean Values and their standard errors for live body weight (LBW), daily body weight gain (DBWG), daily feed consumption (DFC) and feed conversion ratio (FCR) are presented in table (2 and 3).

Table (4) showed that Results of initial live body weight, final body weight, and body weight gain as affected by the different dietary treatments. Changes in live body weight during the experimental period. It could be noticed that rabbits fed rations supplemented with betaine had the highest final body weight followed by those fed ration vitamin c with significant differences among supplemented groups.

Total gain was the highest for rabbits fed betaine followed by vitamin c then control diet being 2065, 2016.67, and 1900g, respectively. Results in Table (2) showed that the average daily gain (ADG) of rabbits fed both vitamin c and betaine was significantly higher than the control diet being 15.88, 16.26, and 14.96g, respectively.

In addition, **[30]** found that betaine can improve growth performance, such as enhanced body weight gains and feed conversion.

[21] reported that the Vitamin C supplementation at dose 0.5-1 g/kg diet enhanced growth performance, nutrient digestibility, and antioxidant status in rabbits under both summer and winter conditions in Egypt**.**

This result agreement with **[33]** who found that dietary vitamin C supplementation in rabbits at values 1.0 g/kg diet increases final BW, BWG and FCR, however DFI was not modified.

It is reported that 200 mg vitamin C supplementation significantly increased rabbits' live body weight, total weight growth, and decreased average total feed intake when compared to the control group **[25]**.

This result agreement with **[30]** they reported that dietary supplementation with vitamin C (500 mg/kg diet) significantly improved growth performance, antioxidant status, and reduced water intake in heat-stressed growing rabbits.

The present results are agreement with multiple studies **[23,27 and 30]** showed that have demonstrated that betaine improves growth performance, including increased body weight gain, daily body weight gain, and feed conversion ratio in growing rabbits.

Table (4). Effect of vitamin c and betaine on growth performance on rabbits.

Item	Experimental rations			SEM	*p* Value
	T1	T2	T3		
Initial wt. (g)	1160	1133.33	1288.33	55.94256	0.4849
Final wt. (g)	3060^{b}	3150^{ab}	3353.33^{a}	57.74953	0.0754
Total gain (g)	1900	2016.67	2065	59.61637	0.552
Daily gain (g)	14.96063	15.87927	16.25984	0.46942	0.552

Means are significantly different (P< 0.05). * T1= control group, T2 = rabbits fed 1g vitamin c / kg diet, T3= rabbits fed 1g betaine/kg diet.

Effect of supplementing different levels of vitamin c and betaine on blood serum parameters on rabbits:

Total protein

Data in Table (5) showed the effect of vitamin c and betaine supplementation on serum total protein concentration. Results clearly indicated that the rabbits fed vitamin c and betaine had higher (P<0.05) serum total protein concentration than the control. The results are consistent with **[34]** who showed that the ascorbic acid (40 mg/kg) increased total protein in plasma.

Albumin

The effect of vitamin c and betaine supplementation in rations on blood serum albumin concentration, are shown in Table (5). Results showed non-significant differences for serum albumin between treatments. These results are consistent with **[34]** who showed that the ascorbic acid (40 mg/kg) increased albumin in plasma.

Globulin

The results in Table (5) clearly indicated that the rabbits fed vit. C and Betaine had higher (P < 0.05) serum globulin concentration 3.79 and 3.73 g/dL in vitamin C and betaine, respectively, compared to the control (3.29 g/dL).

The present results are agreement with **[35]** who found that the in diabetic rabbits, vitamin C (50 mg/kg) significantly reduced serum glucose, cholesterol, and liver enzymes while increasing total protein and albumin levels. Similarly, ascorbic acid (40 mg/kg) decreased liver enzyme activities and increased globulin in plasma **[34]**.

Dietary betaine supplementation had a substantial influence on blood serum components in developing rabbits at high ambient temperatures, increasing total protein and globulin **[36]**. Total blood protein and globulin levels were greater (P<0.05) compared to the controls. The rise in blood total protein and globulin following betaine intake might be attributed to its propensity to donate methyl groups, which is pretty constant in protein metabolism **[3]**. These findings are consistent with **[37],** who hypothesized that betaine increased (P<0.07) the average plasma total protein in coccidiosis-infected chicks.

Table 5. Effect of vitamin C and betaine on blood serum parameters.

Item	Experimental rations			SEM	*P value*
	T1	T2	T3		
Total Protein g/dl	7.19	7.46	7.65	0.16	0.5683
Albumin g/dl	3.90	3.67	3.92	0.13	0.7313
Globulin g/dl	3.29^{b}	3.79^{a}	3.73^{a}	0.15	0.0347
Urea mg/dl	23.60	23.83	22.20	0.53	0.7945
Creatinine g/dl	0.80	0.80	0.79	0.18	0.7244
Triglycerides mg/dl	104.30	103.72	98.96	3.71	0.8524
Cholesterol mg/dl	111.54^{a}	109.06^{a}	96.25^{b}	3.51	0.016
AST U/l	107.67^{b}	118.83^{a}	102.17^{b}	3.19	0.0688
ALT U/l	36.52	35.29	37.16	0.64	0.5445
Glucose mg/dl	101.37	106.48	98.10	4.47	0.7934

Urea

The results in Table (5) showed that the serum urea concentrations were insignificant (P>0.05) affected by added vitamin C and betaine in the diet of rabbits. These results agree with **[38]** found that, while not directly connected to betaine, urea supplementation of up to 1.5% in diets had no negative impact on growth performance, hematological parameters, or serum biochemical indices.

The results are agreed with **[34]** found that a dosage of 40 mg/kg body weight of ascorbic acid significantly lowered plasma enzyme activity (AST, ALT, ALP, AcP) and concentrations of urea, creatinine, and lipids, while raising total protein, globulin, and albumin levels.

Creatinine

Data in Table (5) showed the effect of vitamin C and betaine supplementation in rations on blood serum creatinine. There was a non-significant difference in blood serum creatinine between the different groups. These results may indicate that the different supplementation had no adverse effect on kidney function.

The results are agreement with **[34]** found that a dosage of 40 mg/kg body weight of ascorbic acid concentrations of creatinine.

AST and ALT

The results in Table (5) showed the effect of vitamin C and betaine supplementation on blood serum ALT and AST concentrations. There were insignificant differences among the different groups. At ALT while there is difference on among the different groups in AST.

Vitamin C has an ideal (P>0.05) range condition for AST and ALT enzymes; it was 60.21 and 12.80 U/L, compared to 59.33 and 13.63 U/L in control rabbits, respectively **[26]**.

Cholesterol

The results in Table (5) showed the effect of vitamin C and betaine supplementation on serum cholesterol. It was significantly (P<0.05) lower with both vitamin c followed by betaine than control diet being 109.06, 96.25, and 111.54 mg/dl, respectively. These results agree with **[40]** who found that the betaine supplementation during gestation decreased blood cholesterol and triglyceride levels in gestating sows. And **[35]** who found that in diabetic rabbits, vitamin C administration (50 mg/kg body weight) reduced serum cholesterol.

Glucose

Data in Table (5) showed the effect of vitamin C and betaine supplementation in rations on blood serum glucose. There was a non-significant difference in blood serum glucose between the different groups. These results agree with **[35]** who found that in diabetic rabbits, vitamin C administration (50 mg/kg body weight) reduced serum glucose, triglycerides, and liver enzymes. **[41]** discovered that subcutaneous vitamin C injections reduced blood sugar levels in both normal and diabetic rabbits.

The results disagree with **[24]** who showed that betaine has been shown to reduce serum glucose levels and improve the apparent total tract digestibility of nutrients, particularly in low digestible energy diets.

Effect of supplementing different levels of vitamin c and betaine on Climatic conditions and physiological parameters on rabbits:

The shift from hot to cold months led to a gradual decrease in the ambient temperature as shown in Table (6). The maximum increase was recorded during the first period (August and September), while it began to decline in the second period (October and November), then reached the lowest decrease during the third period (December and January). The relative humidity increased to the maximum in the second period, as shown in Table (6), and decreased in both the first and third periods. As a result, the calculated temperature and humidity index was gradually increased from hot to cold months to record the highest value during the first period **Table (6)**.

The measured climatic data showed that rabbits in this study were exposed to severe heat stress during the first period because THI values >25.6 are considered as extreme severe heat stress **[7].** Furthermore, THI values <22.2 are normally considered as acceptable, i.e., absence of heat stress **[7]**. Therefore, climatic data recorded during the third period indicates that rabbits were exposed to acceptable environmental conditions during this period. In addition, during the second period, THI values 22.2 to <23.3 are moderate heat stress **[7].**

Data in table (7) showed that the rectal temperature of the rabbits, it decreased with betaine and vitamin C compared to the control, which was higher, reaching 39.20, 39.22, and 39.39, respectively, and the differences were significant. This is evidence that supplementing with vitamin C and betaine lessens the effects of heat stress. These results are consistent with those of **[42],** who demonstrated that adding betaine to broiler chicken feed reduces body temperature under heat stress conditions.

The RT in rabbits ranged between 35.60 and 39.80 ° C **[43]**. Meanwhile, RT ranges from 38.61 to 39.72 ° C **[44]**.

These results are in agreement with **[45]** who found that supplementing with vitamin C decreased body temperature in heat-stressed rabbits. In addition, **[46]** reported that vitamin C supplementation in drinking water (50 mg/head/day) reduced rectal temperature, respiratory rate, and water consumption while boosting feed intake compared to control groups. And also **[30]** found that the vitamin C, together with other antioxidants including vitamin E and betaine, improved growth performance, nutrients digestibility, and antioxidant status in heat-stressed rabbits.

These results agree with **[45]** that showed that betaine can reduce body temperature in heat-stressed rabbits**.**

Table 6. Ambient temperature (AT), relative humidity (RH) and temperature humidity index (THI) during the experimental period

Item	Time	Period 1	Period 2	Period 3	SEM	p value
AT	8:00 AM	25.48^{a}	17.16^{b}	18.55^{b}	0.90	<0.0001
	12:00 PM	37.25^{a}	33.14^{b}	26.11^{c}	1.03	<0.0001
	3:00 PM	33.32^{a}	33.16^{a}	30.58^{b}	0.69	<0.0001
	Mean	32.02^{a}	27.82^{ab}	25.08^{b}	0.87	<.0001
RH	8:00 AM	44.18	47.64	44.68	1.03	0.1966
	12:00 PM	36.27	31.00	27.36	1.15	0.3438
	3:00 PM	31.82^{a}	26.55^{c}	28.45^{b}	1.47	0.0034
	Mean	37.42^{a}	35.06^{b}	33.50^{c}	1.22	0.0034
THI	8:00 AM	23.34^{a}	16.63^{b}	17.60^{b}	0.72	<0.0001
	12:00 PM	30.03^{a}	30.14^{a}	27.77^{b}	0.57	<0.0001
	3:00 PM	31.73^{a}	27.21^{b}	24.51^{c}	0.93	<0.0001
	Mean	28.37^{a}	24.66^{b}	23.29^{b}	0.74	<0.0001

Table 7. Rectal temperatures of rabbits during the experimental period.

Item	Experimental rations			SEM	*p* Value
	T1	T2	T3		
Rectal temperatures	39.39583^{a}	39.22887^{b}	39.20653^{b}	0.035684	0.062

Conclusions:

It is clear from the results of the daily and final growth rates that the doses used of both vitamin C and betaine improved the performance of rabbits. Therefore, it is recommended to study the synergistic effect between vitamin C and betaine on growth rates and nutritional efficiency.

References

1. Carr, A.; Frei, B. Does Vitamin C Act as a Pro-Oxidant under Physiological Conditions? *FASEB J.* 1999, *13*, 1007–1024.
2. Lee, C. Explaining Just How Vitamin C Works against Cancer. *Lancet* 2002, *359*, 9301.
3. Kidd, M.; Ferket, P.; Garlich, J. Nutritional and Osmoregulatory Functions of Betaine. *World's Poult. Sci. J.* 1997, *53*, 125–139.
4. Marai, I.F.M.; Habeeb, A.A.M.; Gad, A.E. Rabbits' Productive, Reproductive and Physiological Performance Traits as Affected by Heat Stress: A Review. *Livest. Prod. Sci.* 2002, *78*, 71–90.
5. NRC. *Nutrient Requirements of Domestic Animals. Nutrient Requirements of Rabbits*, 2nd ed.; National Research Council, National Academy of Sciences: Washington, DC, USA, 1977.
6. AOAC. *Official Methods of Analysis*, 15th ed.; Association of Official Analytical Chemists: Arlington, VA, USA, 1995.
7. Marai, I.F.M.; Ayyat, M.S.; Abd El-Monem, U.M. Growth Performance and Reproductive Traits at First Parity of New Zealand White Female Rabbits as Affected by Heat Stress and Its Alleviation under Egyptian Conditions. *Trop. Anim. Health Prod.* 2001, *33*, 451–462.
8. Cunha, T.J.; Cheeke, P.R. *Rabbit Feeding and Nutrition*; Elsevier: Amsterdam, The Netherlands, 2012.
9. Weichselbaum, T.E. Quantitative Colorimetric Determination of Total Protein in Serum. *Am. J. Clin. Pathol.* 1946, *7*, 40.
10. Doumas, B.; Wabson, W.; Biggs, H. Albumin Standards and Measurement of Serum with Bromocresol Green. *Clin. Chim. Acta* 1971, *30*, 87.
11. Burtis, C.A.; Ashwood, E.R. *Tietz Textbook of Clinical Chemistry*, 3rd ed.; W.B. Saunders Co.: Philadelphia, PA, USA, 1999; pp. 29–150.
12. Henry, J.B.; Davidsohn, T.S. Stanbio Enzimatico Urea Nitrogeno (BUN) Procedimiento No.1050. In *Clinical Diagnosis and Measurement by Laboratory Methods*, 16th ed.; W.B. Saunders Co.: Philadelphia, PA, USA, 1974; p. 260.
13. Bartels, H. Modified Method of Bartels for Kinetic Measurements. *Clin. Chim. Acta* 1971, *32*, 81.
14. Barham, D.; Trinder, A. Determination of Plasma Uric Acid. *Analyst* 1972, *97*, 142.
15. Reitman, S.; Frankel, S. A Colorimetric Method for the Determination of Plasma Aspartate Aminotransferase. *Am. J. Clin. Pathol.* 1957, *28*, 56–63.
16. Boutwell, J.H.M. Total Lipid Reagent Set (Colorimetric Method); Tex. Diagnostics, Inc.: Chino, CA, USA, 1972.
17. SAS Institute Inc. *SAS/STAT User's Guide*, Version 9.4 ed.; SAS Institute Inc.: Cary, NC, USA, 2016.
18. Duncan, D.B. Multiple Range and Multiple F-Test. *Biometrics* 1955, *11*, 1–42.
19. Liu, B.; Zheng, D.; Zhou, S.; Chen, L.; Yang, J. VFDB 2022: A General Classification Scheme for Bacterial Virulence Factors. *Nucleic Acids Res.* 2022, *50*, D912–D917.
20. Thaxton, P.; Sadler, C.R.; Glick, B. Immune Response of Chickens Following Heat Exposure or Injections with ACTH. *Poult. Sci.* 1968, *47*, 264–266.
21. Sayed-Ahmed, I.E.; El-Monem, A.; Al-Sagheer, A.A.; Khalil, B.A. Effect of Ascorbic Acid Supplementation on Performance of Growing Rabbits under Egyptian Conditions. *Zagazig J. Agric. Res.* 2018, *45*, 363–373.
22. Abd El-Moneim, A.M. Using Restaurants' Foods Wastes (RFW) on the Growth and Semen Characteristics of Male Rabbits. M.Sc. Thesis, Faculty of Agriculture, Alexandria University, Alexandria, Egypt, 1990.
23. Chen, X.; Li, Z.; Pu, J.; Cai, J.; Zhao, H.; Jia, G.; Tian, G. Dietary Betaine Improves the Intestinal Health and Growth Performance of Heat-Stressed Growing Rabbits in Summer. *J. Anim. Sci.* 2023, *101*, skad363.

24. Li, Z.; Pu, J.; Zeng, T.; Cai, J.; Jia, G.; Zhao, H.; Tian, G. Effects of Betaine on Growth Performance and Intestinal Health of Rabbits Fed Different Digestible Energy Diets. *J. Anim. Sci.* 2024, *102*, skae029.
25. Al-Kanaan, G. A., Al-Bader, S. H., Al-Kanaan, A. J., & Al-Aqaby, H. S. (2021, November). Effects of different levels of vitamin C intake on some productive traits and blood parameters in rabbits. AIP Conference Proceedings, 2372(1). AIP Publishing.
26. Sherif, S. (2018). Response of growing rabbits to stoking density and dietary supplementation with ascorbic acid, and vitamin E under summer conditions. Egyptian Poultry Science Journal, 38(3), 831–846.
27. El-Azeem, A., Ahmed, E., Al-Sagheer, A. A., Daader, A. H., & Bassiony, S. M. (2019). Effect of dietary supplementation with betaine, thyme oil and their mixtures on productive performance of growing rabbits. Zagazig Journal of Agricultural Research, 46(3), 815–828.
28. Morsy, W. A., Hassan, R. A., & Abd El-Lateif, A. I. (2012). Effect of dietary ascorbic acid and betaine supplementation on productivity of rabbit does under high ambient temperature. Proceedings of the 10th World Rabbit Congress, 3–6.
29. Smitha, S., Kannan, A., & Sabin, G. (2014). Growth response of New Zealand White rabbits to dietary probiotic and vitamin C under tropical humid climate. Journal of Animal Research, 4(2), 273–281.
30. El-Moniem, A., Elham, A., Daader, A. H., Al-Sagheer, A. A., & Gabr, H. A. (2016). Effect of vitamin C, vitamin E or betaine addition on alleviation of heat stress impacts on growing rabbits. Zagazig Journal of Agricultural Research, 43(5), 1601–1613.
31. Attyia, E. A. A. (1996). Effect of treated low quality roughage on rabbits (Master's thesis, Faculty of Agriculture, Menoufiya University, Egypt).
32. Selim, N. A., Abdel-Khalek, A. M., Nada, S. A., & El-Medany, S. A. (2008). Response of growing rabbits to dietary antioxidant vitamins E and C. 1. Effect on performance. Proceedings of the 9th World Rabbit Congress, 10–13.
33. Hamza, S. S. (2019). Effect of ascorbic acid supplementation on performance of growing rabbits under Egyptian conditions. Middle East Journal Apply Science, 9, 91–99.
34. Salem, M. M., Saber, S. A., & Nabeeh, A. (2021). Therapeutic effects of ascorbic acid on hormonal and histological alteration produced in the reproductive system of albino rats intoxicated by herbicide atrazine. Egyptian Academic Journal of Biological Sciences, B. Zoology, 13(1), 1–16.
35. Al-Mousawi, Z. A. (2013). Effect of vitamin C and zinc on some biochemical parameter in alloxan induced diabetic rabbits. Basrah Journal of Veterinary Research, 12(1), 77–86.
36. Hassan, R. A., Ebeid, T. A., Abd El-Lateif, A. I., & Ismail, N. B. (2011). Effect of dietary betaine supplementation on growth, carcass and immunity of New Zealand White rabbits under high ambient temperature. Livestock Science, 135(2–3), 103–109.
37. Matthews, J. O., & Southern, L. L. (2000). The effect of dietary betaine in Eimeria acervulina-infected chicks. Poultry Science, 79, 60–65.
38. Mansour, M. M., & Ali, E. F. (2017). Glycinebetaine in saline conditions: An assessment of the current state of knowledge. Acta Physiologiae Plantarum, 39, 1–7.
39. Ramadan, M. E.-S., & Shalaby, O. A. (2024). Alleviating the adverse effects of salinity stress on the growth and yield of tomato plants by using foliar spraying with jasmonic acid and glycine betaine. Egyptian Journal of Desert Research, 74(1), 175–195.
40. Mishra, A., Verma, A. K., Das, A., Singh, P., & Sahoo, N. R. (2019). Effect of betaine supplementation on serum metabolite profile in gestating sows. Indian Journal of Animal Nutrition, 36(2), 202–203.
41. Bera, G. N., & Chowdhury, J. (1958). Effects of niacin and vitamin C on blood sugar. American Journal of Physiology, 192(3), 511–513.

42. Zulkifli, I., Mysahra, S. A., & Jin, L. Z. (2004). Dietary supplementation of betaine (Betafin®) and response to high temperature stress in male broiler chickens. Asian-Australasian Journal of Animal Sciences, 17, 244–249.
43. Jaén-Téllez, J. A., Bartolomé, E., Sánchez-Guerrero, M. J., Valera, M., & González-Redondo, P. (2021). Relationship between rectal temperature measured with a conventional thermometer and the temperature of several body regions measured by infrared thermography in fattening rabbits. World Rabbit Science, 29(4), 263–273.
44. Reddy, B., & Sivajothi, S. (2017). Vital and electrocardiographic parameters in domestic New Zealand White pet rabbits. International Journal of Livestock Research, 7(10), 86–91.
45. Daader, A. H., Al-Sagheer, A. A., Gabr, H. A., & Abd El Moniem, E. A. (2018). Alleviation of heat-stress-related physiological perturbations in growing rabbits using natural antioxidants. Spanish Journal of Agricultural Research, 16(3), 12.
46. Mousa-Balabel, T. M. (2004). Effect of heat stress on New Zealand White rabbits' behavior and performance. Minufiya Veterinary Journal, 3(1), 125–134.