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EFFECTS OF DIETARY SUPPLEMENTATION WITH ZINC AND BETAINE ON GROWTH PERFORMANCE AND SOME PHYSIOLOGICAL RESPONSES FOR GROWING RABBITS UNDER HOT CONDITIONS

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Sixty weaned males APRI line rabbit about 35 days with average initial weight 530±10.3 gm were randomly distributed into six experimental groups (10 per each) from June to August (hot season). Group 1 fed the basal diet as control (C). While, groups 2 (R1, basal diet+100mg zinc/kg diet), 3 (R2, basal diet+160 mg betaine/kg diet), 4 (R3, basal diet+320 mg betaine/kg diet), 5 (R4, basal diet+100mg zinc+160 mg betaine/kg diet) and 6 (R5, basal diet+100mg zinc+320 mg betaine/kg diet). Initial body weight, final body weight (FBW), feed intake (FI), body weight gain (BWG), feed conversion ratio (FCR), total protein (TP), albumin (ALB), globulin (GL), red blood cells (RBCs), white blood cells (WBCs), packed cell volume (PCV%), total antioxidant capacity (TAC), malonaldehyde (MAD), thiroxine (T_4), triiodotherionine (T_3), carcass characteristics and economic study were determined.

Results showed *significant ($P \leq 0.05$) increases in FBW, BWG and significant ($P \leq 0.05$) improving in FCR in all treated groups compared with the control one. Dressing and testes percentages were significant ($P \leq 0.05$) increasing compared with the control. Also, RBC_s, WBCs, PCV% and lymphocytes were increased in treated groups while neutrophils and eosynophils were decreased compared with the control one. Zinc showed significantly ($P \leq 0.05$) increasing lymphocytes and monocytes compared with control. While betaine recorded a decreasing in neutrophils compared with zinc and control groups. There were decreasing in TP, ALB, GL and TAC in control group comparable with all treated groups. Also, control group significantly ($P \leq 0.05$) increased in cholesterol and MAD. The economic efficiency values and relative economic efficiency were significantly improved in all treated groups compared with control group.*

Conclusively: *using fed supplemented with 100 mg zinc/kg feed for growing APRI rabbit could be recommended for realizing best results of growth performance, carcass characteristics and relative economic efficiency% during summer season.*
Key words: Rabbits, zinc, betaine, blood, heat stress, anti oxidant

Rabbits are very sensitive to rise environmental temperature, where the dense fur and lack of sweat glands make heat loss very difficult above the zone of thermal neutrality (18-22ºC, 60-70% RH%) (Verga *et al.,* 2007). Thermal stress affects the animal in different ways, such as depression in feed intake, feed efficiency, utilization, disturbances in water metabolism, protein, energy and minerals balances, enzymatic reactions, hormonal secretions and blood metabolites (Marai *et al.,* 2002).

Zinc is an essential component of many enzymes and it has catalytic antioxidant, cofactor of 300 enzymes and immunity role (McCall *et al.,* 2000). Zinc is also involved in several cell functions including signal transduction, transcription and replication (Cousins *et al.,* 2006), metabolic activities and productive performance like growth (Underwood and Suttle, 1999). Ayyat and Marai (2000) reported that supplementing zinc to rabbit diets significantly increase live weight gains, but had no effect on feed intake, feed conversion ratio or dressing yield of the rabbits.

Betaine is a common term for dimethylglycine, substrate for Bet-homocysteine methyltrans ferase in the liver and kidney (Kettunen *et al*., 2001 b). When the three methyl groups were transferred to homocysteine to produce methionine, betaine become the amino acid glycine then it is metabolized as normal (Graham, 2002). Betaine donatesits labile methyl group which can be used intrans methylation reactions for synthesis of substances like carnitine and creatine (Kidd *et al.,* 1997). Subsequently, the dietary supplementation of betaine may reduce the requirement for other methyl group donors such as methionine and choline (Siljander-Rasiinc *et al.,* 2003) and Eklund *et al.,* (2005), and decrease mortality rate in rabbits (Morsy *et al.,* 2012).

Therefore, the objective of this study was evaluating the effects of dietary betaine and zinc on productivity, physiological parameters and antioxidant status of APRI line rabbits under high ambient temperature.

MATERIALS AND METHODS

Animal and diets:

This experiment was carried out at Rabbits Research Station, El-Sabahia, Animal Production Research Institute, Agriculture Research Center, Egypt at June and extended to August.

Sixty weaning males of APRI rabbit about 35 days with average initial weight (530±10.3) gm were randomly distributed to six experimental groups (10 per each) during June to August (hot season). The basal diet composition was formulated to cover all essential nutrient requirements for growing rabbits according to NRC (1977). Feed were allowed to a standard pelleted diet all times containing 17% crude protein, 2.56% crude fat, 13% crude fiber and containing 2500 Kcal/kg-ration DE. Fresh water was offered all times. Animals were kept under similar management and hygienic conditions and were healthy and clinically free of external and internal parasites. The lighting program provided was 18 hrs of light per day.

Experimental design:

Group 1: Fed basal diet as control group (C).
Group 2: Fed basal diet +100 mg zinc*/ kg diet (R1).
Group 3: Fed basal diet + 160 mg betaine**/ kg diet (R2).
Group 4: Fed basal diet + 320 mg betaine/ kg diet (R3).
Group 5: Fed basal diet + 100 mg zinc +160 mg betaine / kg diet (R4).
Group 6: Fed basal diet + 100 mg zinc + 320 mg betaine / kg diet (R5).

Diet additives: ***=** Zinc sulphate and **= Betaine was provided as Betafin®-BP (betaine anhydrous/pharmaceutical grade, Finn feeds Finland Ltd.).

Ambient temperature and relative humidity were recorded at 10 am and temperature humidity index (THI) was calculated according to Marai *et al.*, (2001) as following formula:

$$THI = db°C – [(0.31 - 0.31\times RH\ \%)*(db°C - 14.4)],$$

Where: db°C is dry bulb temperature in Celsius and RH is the relative humidity as a percentage. The values obtained are then classified as absence of heat stress (<27.8), moderate heat stress (27.8-28.8), severe heat stress (28.9-29.9) and very severe heat stress (≥30.0).

Data collection:

Initial and final live body weight (IBW and FBW), feed intake (FI), body weight gain (BWG) and feed conversion ratio (FCR) was recorded. At the end of the experimental period carcass characteristics were evaluated for three rabbits from each treatment. Economic efficiency determine according to Elspeiy *et al*., (2015).

Blood sampling and chemical analysis:

Blood samples were collected for determination of total protein, albumin, cholesterol, total antioxidant capacity and malonyaldehyde. White blood cells differential were done. Total antioxidant capacity (TAC) and malonyaldehyde (MAD) were determined according to (Koracevic *et al.*, (2001). Thyroxin (T_4) and triiodothyronine (T_3) were determinated by radioimmunoassay (RIA) technique. Corticosterone and cortisol concentrations were evaluated by RIA, using the CORT kit (ICN Biomedical Inc., Costa).

Statistical analysis:

All data were subjected to analysis of variance according to the statistical analysis system (SAS, 2002). The differences among groups means were Duncan's multiple rang test (Duncan, 1955).

RESULTS AND DISCUSSION

***Climatic conditions*:**

The THI values clearly indicated that rabbits were exposed to severe heat stress according to estimated THI units 29.14 (Table 1). It was suggested that the optimal temperature humidity index for the rabbit husbandry is 27.8 (Marai *et al.*, 2002).

Table 1. Averages of ambient temperature (AT °C), relative humidity (RH %) and temperature humidity index (THI units) during the experimental period

Month	AT °C	RH %	THI Units
June	29.8	69.7	28.35
July	30.4	75.2	29.17
August	31.6	68.2	29.9
Average	**30.6**	**71.0**	**29.14**

1- Growth performance:

Results in Table 2 showed significant ($P \leq 0.05$) increases in FBW, BWG and significant ($P \leq 0.05$) improve in FCR in all treated groups compared with control one. Group R4 recorded the heavier FBW and BWG followed by R1, R2, R3 and R5 respectively at the end of experiment. Also, treated groups had the best FCR while, control group recorded decline all observation. Results are in agreement with Selim Nessrin *et al.*, (2012) and

Table 2. Growth performance (Mean± S.E) of APRI line rabbits as affected by feeding basal diet supplemented with zinc and betaine

Items	Experimental groups					
	C	**R1**	**R2**	**R3**	**R4**	**R5**
IBW, g	533.8 [a] ±9.6	536.7 [a] ±2.3	532.8 [a] ±6.2	534.2 [a] ±4.5	538.3 [a] ±8.3	524.5 [a] ±5.9
FBW, g	1830.0 [e] ±17.3	2110.7 [b] ±31.4	2080.0 [cb] ±31.8	1992.0 [d] ±26.9	2199.4 [a] ±34.0	2013.5 [c] ±34.8
BWG, g	1296. 3[e] ±17.7	1573.9 [b] ±31.0	1547.2 [cb] ±30.6	1457.8 [d] ±25.3	1661.1 [a] ±34.8	1479.0[cd] ±32.5
FI , g	4720.5 [a] ±29.8	4644.1 [a] ±33.0	4726.8 [a] ±1.7	4389.6 [b] ±37.6	4620.8 [a] ±35.9	4478.9 [b] ±2.5
FCR, %	3.65 [a]± 0.05	2.96 [b] ±0.05	3.07 [b] ±0.05	3.03 [b] ±0.06	2.80 [c] ±0.06	3.05 [b] ±0.06

Means bearing different litter (a, b, c, d) superscripts in the same row differ significantly ($P \leq 0.05$).
C = Control, R1 = Basal diet±100 mg zinc, R2 = Basal diet±160 mg betaine, R3 = Basal diet±320 mg, R4 = Basal diet±100 mg zinc+160 mg betaine, R5 = Basal diet±100 mg zinc+320 mg betaine/kg diet, IBW= Intial body weight, FBW= Final body weights, BWG= Body weights gain, FI= Feed intake, FCR= Feed conversion ratio.

Chrastinov *et al.,* (2016) who reported that supplementation of zinc to rabbit diet lead to improving in BWG, FCR and FI.

The degree of fermentation in the digestive tract of monogastric animals affected by dietary betaine supplementation, that increase the contractile activity of the duodenal smooth muscle cells leads to increase is associated with enhanced pancreatic secretion and digest mixing (Puchala *et al.,* 1998). However, the influence of betaine on intestinal muscle cell activity seems to be dose-dependent with higher levels reducing muscle-cell activity, thus possibly decreasing the absorption capacity of the duodenum (Puchala *et al.,* 1998). The positive effect of adding betaine may due to support intestinal growth and function, betaine may has an accumulation results in an increased water-binding capacity of the intestinal cells and promotes changes in the structure of the gut epithelium and enhanced gut strength.

2- Carcass characteristics:

Supplementation with zinc and betaine continuously after weaning till 84 days of age increased significantly ($P \leq 0.05$) dressing and testes percentages in respect to the control group (Table 3). While, R2, R3 and R4 were recorded high significant ($P \leq 0.05$) improved in dressing percentage.

Table 3. Carcass characteristics of APRI line rabbits as affected by feeding basal diet supplemented with zinc and betaine

Items	Experimental groups						SE
	C	R1	R2	R3	R4	R5	
Blood (%)	3.45	3.31	3.18	3.24	3.25	3.30	0.07
Skin (%)	16.45	17.6	17.25	17.12	17.21	17.32	0.22
Head (%)	6.00	5.89	5.78	5.88	5.91	5.94	0.20
Lungs (%)	0.739^{a}	0.634^{b}	0.629^{b}	0.625^{b}	0.605^{c}	0.601^{c}	0.05
Pancreas (%)	0.275^{a}	0.208^{b}	0.198^{c}	0.201^{b}	0.212^{b}	0.199^{c}	0.06
Spleen (%)	0.061	0.048	0.052	0.08	0.050	0.054	0.00
Testes (%)	0.193^{c}	0.285^{b}	0.291^{ab}	0.298^{ab}	0.310^{a}	0.318^{a}	0.05
Giblets (%)	4.12	3.83	3.80	3.82	3.91	3.86	0.08
Heart (%)	0.336^{a}	0.301^{c}	0.318^{b}	0.316^{b}	0.308^{bc}	0.305^{bc}	0.01
Liver (%)	3.15^{a}	2.93^{b}	2.87^{b}	2.90^{b}	2.98^{b}	2.93^{b}	0.02
Kidney (%)	0.636	0.601	0.613	0.602	0.626	0.623	0.02
Carcass (%)	49.90^{c}	54.55^{b}	54.90^{a}	54.95^{a}	54.88^{a}	54.57^{b}	0.92
Dressing (%)	54.02^{b}	58.38^{ab}	58.70^{a}	58.78^{a}	58.79^{a}	58.43^{ab}	1.03

Means bearing different litter (a, b, c, d) superscripts in the same row differ significantly (P≤0.05).
C = Control, R1 = Basal diet±100 mg zinc, R2 = Basal diet±160 mg betaine, R3 = Basal diet±320 mg, R4 = Basal diet±100 mg zinc+160 mg betaine, R5 = Basal diet±100 mg zinc+320 mg betaine/kg diet, IBW= Intial body weight, FBW= Final body weights, BWG= Body weights gain, FI= Feed intake, FCR= Feed conversion ratio.
Dressing (%) = Carcass (%) + Giblets% (HEART+Liver+Kidney)

The liver percentage increased (P≤0.05) due to the heat stress in control group (C). Supplemented zinc and betaine reduced (P≤0.05) the pancreas, heart, liver and lungs percentages compared with control group.

Results are agreed with Younas *et al., (*2015) who showed that zinc improved the hemoglobin in rabbits. El Hendy *et al.*, (2001) who recorded that zinc deficiency has depressing effect on body growth, organ weights and hematological traits. Wang *et al.*, (2004) who mentioned that betaine is highly effective in improving carcass quality. Also, Esteve-Garcia and Mack, (2000) reported that betaine does not replace methionine in its function as essential amino acid in protein metabolism, but may improve carcass yield.

Finely, betaine could enhance synthesis of carnitine by improving methylation metabolism and could stimulate beta-oxidation of long chain fatty acids in the inner mitochondria membrane of muscle cells (Wang, 2000).

3- Blood hematology:

Results in Table 4 showed a significant ($P\leq0.05$) increases in RBC_s, $WBCs_,$ PCV% and lymphocytes in treated groups and significant ($P\leq0.05$) decreases in neutrophils and eosynophils compared with control group. While, zinc showed significantly ($P\leq0.05$) increasing lymphocytes and monocytes compared with control while, betaine recorded a decreases in neutrophils compared with zinc and control groups.

Table 4. Some blood hematological parameter (Mean ±S.E) of APRI line rabbits as affected by feeding basal diet supplemented with zinc and betaine

Items	Experimental groups					
	C	R1	R2	R3	R4	R5
RBC_s ($10^6/mm^3$)	5.08^{b} ±0.19	5.93^{a} ±0.17	5.80^{a} ±0.15	5.80^{a} ±0.04	5.87^{a} ±0.08	5.83^{a} ±0.02
WBCs ($10^3/mm^3$)	9.63^{c} ±0.56	9.67^{c} ±0.23	9.93^{c} ±0.40	10.80^{b} ±0.17	11.40^{ab} ±0.23	11.80^{a} ±0.10
PCV (%)	35.33^{b} ±0.56	36.00^{b} ±0.73	37.01^{ab} ±0.37	38.15^{a} ±0.37	38.01^{a} ±0.37	38.33^{a} ±0.76
Neutrophils (%)	46.00^{a} ±0.37	43.84^{b} ±0.93	39.73^{c} ±0.15	39.70^{c} ±0.30	38.63^{c} ±0.44	38.33^{c} ±0.62
Lymphocyte (%)	42.37^{d} ±0.40	45.63^{c} ±0.96	48.67^{b} ±0.21	48.77^{b} ±0.21	50.33^{a} ±0.76	50.67^{a} ±0.42
Monocyte (%)	5.47^{b} ±0.04	5.87^{a} ± 0.08	5.67^{ab} ±0.12	5.73^{a} ±0.04	4.80^{c} ±0.22	4.93^{c} ±0.05
Eosynophils (%)	1.80^{a} ±0.04	1.43^{d} ±0.08	1.63^{b} ±0.04	1.57^{cb} ±0.08	1.90^{a} ±0.07	1.37^{d} ±0.02
Basophils (%)	4.36^{a} ±0.13	4.23^{a} ±0.06	4.30^{a} ±0.04	4.23^{a} ±0.09	4.34^{a} ±0.15	4.70^{a} ±0.15

Means bearing different litter (a, b, c, d) superscripts in the same row differ significantly ($P\leq0.05$).

C = Control, R1 = Basal diet±100 mg zinc, R2 = Basal diet±160 mg betaine, R3 = Basal diet±320 mg, R4 = Basal diet±100 mg zinc+160 mg betaine, R5 = Basal diet±100 mg zinc+320 mg betaine/kg diet, IBW= Initial body weight, FBW= Final body weights, BWG= Body weights gain, FI= Feed intake, FCR= Feed conversion ratio.

RBCs = Red blood cells, WBCs =White blood cells, PCV= Packed cell volume.

Results are in agreement with Okab and El-Banna, (2008) who showed that when the heat stress increased the reduction in RBCs, WBC_s Count and PCV presenting the overall means of these parameters tended to decline during summer season. Ashour, (2001) found that hematological parameters were highest in winter retained during spring and were lowest in summer; this drop is responsive trail to reduce oxygen intake, thus reduction metabolic heat production under this hot condition.

Younas *et al*., (2015) showed that zinc significantly improved the T-lymphocytes and hemoglobin in rabbits. El Hendy *et al.*, (2001) recorded that the effects of different zinc levels on hematological parameters were significantly affected by zinc insufficiency included hemoglobin, PCV, RBCs and WBCs count and zinc deficiency has depressing effect on body growth, organ weights and heamatological traits.

4- Blood biochemical and oxidation:

Concerning blood analysis of growing male rabbits at 84 days, Table 5 showed a significant ($P \leq 0.05$) decreased in TP, ALB, GL and TAC in control group comparable with all treated groups under. Also, control group significantly increased in cholesterol and MAD.

Harmony with our results, Zainab and Al-Mousawi, (2013) reported that zinc significantly ($P \leq 0.05$) reduced the serum total cholesterol concentration, while there were significant changes ($P \leq 0.05$) on serum levels of total protein, albumin, globulin and albumin/globulin ratio. Duzguner and Kaya, (2007) concluded that daily zinc supplementation could reduce the harmful effects of oxidative (by reduce MAD) stress in diabetics patient. Ayyat *et al*., (2002) mentioned that the decline in serum protein with rising temperature seems to be due to a dilution of plasma proteins caused by the increase intake of water, and/or could be due to increases in protein utilization and amino acid transamination in the heat–stressed rabbits.

Exposure of rabbits to heat stress evokes a series of remarkable changes in their biological functions which ends with impairment of production (Marai and Rashwan, 2004). Lu *et al*., (2008) found that the antioxidant capacity of betaine enabled to scavenge free radicals and protect cells from loss in rats.

5- *Blood hormones:*

Results presented in Table 6 revealed that all studied hormones were significantly ($P \leq 0.05$) decreased due to dietary zinc and betaine supplementation with the exception of triiodothyronine (T_3) when compared with control group.

Table 5. Some blood constituents (Mean± S.E) of APRI line rabbits as affected by feeding basal diet supplemented with zinc and betaine

Items	Experimental groups					
	C	**R1**	**R2**	**R3**	**R4**	**R5**
TP (g/dl)	5.37 ^{c} ±0.08	5.93 ^{b} ±0.06	6.00 ^{b} ±0.10	6.26 ^{a} ±0.06	6.17 ^{a} ±0.09	6.27 ^{a} ±0.07
ALB (g/dl)	3.23 ^{c} ±0.06	3.27 ^{c} ±0.02	3.37 ^{ab} ±0.06	3.43 ^{a} ±0.02	3.37 ^{ab} ±0.06	3.30 ^{bc} ±0.06
GL (g/dl)	2.2 ^{d} ±0.04	2.67 ^{c} ±0.06	2.63 ^{c} ±0.11	2.83 ^{ab} ±0.06	2.80 ^{b} ±0.06	2.93 ^{a} ±0.06
Cholesterol mg/dl	55.9 ^{a} ±0.66	50.4 ^{d} ±0.31	53.3 ^{b} ±0.33	51.9 ^{c} ±0.46	49.5 ^{d} ±0.29	45.4 ^{e} ±0.31
TAC (mM/L)	11.51 ^{d} ±0.24	25.47 ^{c} ±0.67	24.83 ^{c} ±0.55	27.93 ^{b} ±0.31	29.97 ^{a} ±0.44	31.00 ^{a} ±1.03
MAD (nmol/ml)	67.0 ^{a} ±0.50	51.80 ^{b} ±1.04	51.37 ^{b} ±0.75	50.97 ^{b} ±1.19	48.53 ^{c} ±0.45	48.17 ^{c} ±0.44

Means bearing different litter (a, b, c, d) superscripts in the same row differ significantly ($P \leq 0.05$).

C = Control, R1 = Basal diet±100 mg zinc, R2 = Basal diet±160 mg betaine, R3 = Basal diet±320 mg, R4 = Basal diet±100 mg zinc+160 mg betaine, R5 = Basal diet±100 mg zinc+320 mg betaine/kg diet, IBW= Initial body weight, FBW= Final body weights, BWG= Body weights gain, FI= Feed intake, FCR= Feed conversion ratio.

TP = Total protein, GL =Globulin, ALB= Albumin, TAC =Total antioxidant capacity, MAD= Malonaldehyde.

Both the thyroid and adrenal gland are important for animals to regulate heat stress. Triiodothyronine and T_4 are the main substances secreted by the thyroid. Triiodothyronine is mainly transformed from T_4. Although lower quantities of T_3 are produced compared to T_4, its activity is stronger than T_4. Triiodothyronine and T_4 levels in serum decline when animals are subject to heat stress. Lowered thyroid hormone levels reduce heat production, which helps the body to adapt to warmer environments (Horowitz, 2002).

Heat exposure significantly elevated the level of adrenocorticotrophic hormone (ACTH) and Cortical (Li-wang *et al*., 2015). Agreement with our results, Lin *et al*., *(*2004) mentioned that increase in corticosterone during acute heat stress enhances gluconeogenesis. Yan-Qiang and Jing-Fan, (2001) suggested that zinc might influence the metabolism of hypothalamic-hypophysial-adrenocortical axis due to serum ACTH concentration leads to activity were significantly decreased. Baumgard and Rhoads, (2013) demonstrated a marked increase in corticosteroids in response to heat stress.

Table 6. Some blood hormones (Mean±S.E) of APRI line rabbits as affected by feeding basal diet supplemented with zinc and betaine

Items	Experimental groups					
	C	R1	R2	R3	R4	R5
T_4 (ng/ml)	22.43 ^{a} ±0.24	21.63 ^{b} ±0.30	21.73 ^{b} ±0.31	21.53 ^{b} ±0.14	20.83 ^{c} ±0.18	20.03 ^{d} ±0.04
T_3 (ng/ml)	4.27 ^{b} ±0.13	5.23 ^{a} ±0.15	5.47 ^{a} ±0.08	5.36 ^{a} ±0.36	5.47 ^{b} ±0.14	5.60 ^{a} ±0.01
Cortico (ng/ml)	4.97 ^{a} ±0.04	3.93 ^{b} ±0.06	3.80 ^{c} ±0.04	3.40 ^{d} ±0.07	3.80 ^{c} ±0.04	3.50 ^{d} ±0.04
Cortisol (µg/dl)	11.9 ^{a} ±0.24	7.27 ^{b} ±0.45	5.73 ^{c} ±0.81	5.90 ^{c} ±0.78	5.13 ^{c} ±0.92	4.97 ^{d} ±1.01

Means bearing different litter (a, b, c, d) superscripts in the same row differ significantly (P≤0.05).

C = control, R1 = Basal diet±100 mg zinc, R2 = Basal diet±160 mg betaine, R3 = Basal diet±320 mg, R4 = Basal diet±100 mg zinc+160 mg betaine, R5 = Basal diet±100 mg zinc+320 mg betaine/kg diet,

T_4 = Thyroxin, T_3 = Triiodothyronine, Cortico= Corticosteron.

Cortical and corticosterone are thus often used as biomarkers for stress and depressive disorders. Although corticosterone is considered the main glucocorticoid involved in regulation of stress responses in rodents, also, often choose to detect cortisol for stress indicators. Brandao-Neto *et al*., (1990) detected an acute inhibitory effect of zinc on cortisol secretion during 240 min. Azukizawa *et al.*, (1976) mentioned that glucocorticoids inhibited the conversion of T_4 to T_3, some of the T_3 decrement may have resulted from the suppression of TSH which is known to induce the thyroidal secretion of T_3 in preference to T_4.

Tollba *et al.*, (2007) and Zou *et al.*, (1998) reported that T_3 hormone concentration in serum was increased without significant effect due to dietary betaine supplementation under summer conditions.

6- Economic efficiency:

The prices of feed, costs of management and rabbit's meat during 2016 as listed in Table 7. The economic efficiency values of C, R1, R2, R3, R4 and R5 were 1.23, 2.15, 2.08, 2.07, 1.79 and 1.56, respectively and relative economic efficiency 123, 215, 208, 207, 179 and 156% for C, R1, R2, R3, R4, R5, respectively. Zinc and betaine supplementation of growing rabbits resulted in clear improvement of net revenue and relative economic efficiency as compared to the control group. The best value of economic

Table 7. Economic efficiency of APRI line rabbits as affected by feeding basal diet supplemented with zinc and betaine

C = Control, R1 = Basal diet±100 mg zinc, R2 = Basal diet±160 mg betaine, R3 = Basal

Items	Experimental groups					
	C	R1	R2	R3	R4	R5
Body weight at marketing (kg)	1830	2110	2080	1992	2199	2013
Price of weaning litter (L.E)	20	20	20	20	20	20
Total fed intake at marketing (kg)	4.33	3.80	3.91	3.60	4.620	4.48
Total cost fed intake (L.E.)	18.19	15.96	16.42	15.12	19.4	18.82
Total cost of managements (L.E.)/ litter	2.0	2.0	2.0	2.0	2.0	2.0
Total cost (L.E.)	40.19	37.96	38.42	37.12	41.40	40.82
Price of body weight at marketing L.E.)	64.05	73.85	72.80	69.72	76.97	70.46
Net revenue (L.E.)	23.86	35.89	34.38	32.60	35.57	29.64
Economic efficiency	0.59	0.95	0.89	0.88	0.86	0.0.73
Relative economical efficiency (%)	100	161	151	149	146	124

diet±320 mg, R4 = Basal diet±100 mg zinc+160 mg betaine, R5 = Basal diet±100 mg zinc+320 mg betaine/kg diet

Total cost of feed = (Total feed intake × Kg feed cost)

Total cost of managements (L.E.)/litter =cost of housing +cost of medication +cost of care

Total cost = (Total feed intake × Kg feed cost) + Price of weaning litter +Total of managements

The Net revenue = Price body weight -Total cost price

Economical efficiency =Net revenue / Total cost

Relative Economical efficiency (%) = (Net revenue/ Total cost) x 100

efficiency (EE) was recorded for rabbits fed diet supplemented with zinc (R1) in summer season than the other treated groups, while control showed minimal group. In our present study supplementation of zinc to the basal diet of growing rabbits was highly significant in relative economic efficiency than betaine under heat stress. In the other hand, El-Husseiny *et* *al.,* (2007) explained that the highest economic efficiency when diet contained the highest levels of betaine.

Ingredients and selling of male growing rabbits in the local market at the time of experiment (2016). Price of one kg pellets diet was 4.20 L.E. and kg of marketing live weight 35 L.E.

Conclusively, from these results it could be concluded that using fed supplemented with 100 mg zinc/kg feed for growing APRI rabbit could be recommended for realizing best results of growth performance, carcass characteristics and relative economic efficiency% during summer season.

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تأثير إضافة الزنك والبيتايين على الأداء الإنتاجى والفسيولوجى للأرانب النامية تحت ظروف الصيف

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إستخدم فى هذة التجربة عدد ٦٠ ذكر أرنب عمر ٣٥ يوم بمتوسط وزن ٥٣٠ جم من خط APRI، حيث تم توزيعهم عشوائيا على ٦ مجاميع (١٠ بكل معامله) حيث تغذت المجموعة الأولى على العليقة الأساسيه فقط كمجموعة ضابطة (C) بينما تغذت باقى المجاميع على العليقة الأساسية مضافا إليها ١٠٠مجم زنك أو ١٦٠مجم بيتايين أو ٣٢٠مجم بيتايين أو ١٠٠مجم زنك+١٦٠مجم بيتايين أو ١٠٠مجم زنك+٣٢٠مجم بيتايين/كجم علف للمجاميع R1, R2, R3, R4 and R5 بالترتيب. تم تقدير وزن الجسم وكمية العلف المأكول وبروتينات الدم كما تم تقدير عدد كرات الدم الحمراء والبيضاء والهيماتوكريت وإنزيمات الأكسدة وهرمونات الغدة الدرقية كما تم عمل دراسة إقتصادية فى نهاية التجربة.

وقد أوضحت النتائج مايلى:

- حدث زيادة معنوية عند مستوى (٥%) نتيجة إضافة الزنك أو البيتايين فى كل من وزن الجسم النهائى (FBW) ومعدل الزيادة فى الوزن (BWG) مع تحسن معنوى فى معدل الأستفادة من الغذاء (FCR) مقارنة بالكنترول.
- إضافة الزنك أو البيتايين أدى لزيادة معنوية عند مستوى (٥%) فى وزن الذبيحة والخصيتين مقارنة بالكنترول.
- زادت معنويا عند مستوى (٥%) كل من كرات الدم الحمراء والبيضاء والهيماتوكريت والليمفوسيت فى المجاميع المعاملة بالزنك أو البيتايين بينما إنخفضت خلايا النيوتروفيل والإيزينوفيل مقارنة بالكنترول.
- أدى إضافة الزنك لزيادة معنوية عند مستوى (٥%) فى خلايا الليمفوسيت والمونوسيت مقارنة بالكنترول.
- أدى إضافة البيتايين لإنخفاض فى خلايا النيوتروفيل مقارنة بالزنك أو الكنترول.

- حدث إنخفاض فى بروتينات الدم الكلية والألبيومين والجلوبيولين وإنزيم TAC فى مجموعة الكنترول مقارنة بالمجاميع المعاملة. كما سجلت مجموعة الكنترول زيادة معنوية فى مستوى الكوليسترول وال MAD.
- حدث تحسن معنوى فى كل المجاميع المعاملة بالزنك أو البيتايين فى معدلات الكفاءة الإقتصادية والكفاءة الإقتصادية النسبية مقارنة بالكنترول.

التوصية : إضافة ١٠٠مجم زنك/ كجم علف لعليقة أرانب الأبرى النامية أدى لتحسين كل من صفات النمو والذبيحة وكذلك العائد الإقتصادى خلال موسم الصيف.