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

M. A. El-Sawy; M.E. El-Speiy and T.A. Sadaka

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 (T₄), triiodotherionine (T₃), carcass characteristics and economic study were determined.

Results showed significant (P≤0.05) increases in FBW, BWG and significant (P≤0.05) improving in FCR in all treated groups compared with the control one. Dressing and testes percentages were significant (P≤0.05) increasing compared with the control. Also, RBCs, WBCs, PCV% and lymphocytes were increased in treated groups while neutrophils and eosynophils were decreased compared with the control one. Zinc showed significantly (P≤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≤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 feed 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, antioxidant

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 (18-22°C, 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 methyltransferase 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 donates its labile methyl group which can be used in trans 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:

\[ \text{THI} = \text{db}^\circ\text{C} - [(0.31 - 0.31 \times \text{RH} \%) \times (\text{db}^\circ\text{C} - 14.4)] \]

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 malonaldehyde. White blood cells differential were done. Total antioxidant capacity (TAC) and malonaldehyde (MAD) were determined according to (Koracevic et al., 2001). Thyroxin (T₄) and triiodothyronine (T₃) were determined 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 range 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

<table>
<thead>
<tr>
<th>Month</th>
<th>AT °C</th>
<th>RH %</th>
<th>THI Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>29.8</td>
<td>69.7</td>
<td>28.35</td>
</tr>
<tr>
<td>July</td>
<td>30.4</td>
<td>75.2</td>
<td>29.17</td>
</tr>
<tr>
<td>August</td>
<td>31.6</td>
<td>68.2</td>
<td>29.9</td>
</tr>
<tr>
<td>Average</td>
<td>30.6</td>
<td>71.0</td>
<td>29.14</td>
</tr>
</tbody>
</table>

1- Growth performance:

Results in Table 2 showed significant (P≤0.05) increases in FBW, BWG and significant (P≤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

<table>
<thead>
<tr>
<th>Items</th>
<th>Experimental groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>IBW, g</td>
<td>533.8±9.6</td>
</tr>
<tr>
<td>FBW, g</td>
<td>1830.0±17.3</td>
</tr>
<tr>
<td>BWG, g</td>
<td>1296.3±17.7</td>
</tr>
<tr>
<td>FI, g</td>
<td>4720.5±29.8</td>
</tr>
<tr>
<td>FCR, %</td>
<td>3.65±0.05</td>
</tr>
</tbody>
</table>

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= Initial 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<0.05) dressing and testes percentages in respect to the control group (Table 3). While, R2, R3 and R4 were recorded high significant (P<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

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

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 zinc, 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.

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 <i>et al.</i>, (2015) who showed that zinc improved the hemoglobin in rabbits. El Hendy <i>et al.</i>, (2001) who recorded that zinc deficiency has depressing effect on body growth, organ weights and hematological traits. Wang <i>et al.</i>, (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≤0.05) increases in RBCs, WBCs, PCV% and lymphocytes in treated groups and significant (P≤0.05) decreases in neutrophils and eosynohils compared with control group. While, zinc showed significantly (P≤0.05) 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

<table>
<thead>
<tr>
<th>Items</th>
<th>C R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBCs (10^6/mm^3)</td>
<td>5.08 ±0.19</td>
<td>5.93 ±0.17</td>
<td>5.80 ±0.15</td>
<td>5.80 ±0.04</td>
<td>5.87 ±0.08</td>
</tr>
<tr>
<td>WBCs (10^3/mm^3)</td>
<td>9.63 ±0.56</td>
<td>9.67 ±0.23</td>
<td>9.93 ±0.40</td>
<td>10.80 ±0.17</td>
<td>11.40 ±0.23</td>
</tr>
<tr>
<td>PCV (%)</td>
<td>35.33 ±0.56</td>
<td>36.00 ±0.73</td>
<td>37.01 ±0.37</td>
<td>38.15 ±0.37</td>
<td>38.01 ±0.37</td>
</tr>
<tr>
<td>Neutrophils (%)</td>
<td>46.00 ±0.37</td>
<td>43.84 ±0.93</td>
<td>39.73 ±0.15</td>
<td>39.70 ±0.30</td>
<td>38.63 ±0.44</td>
</tr>
<tr>
<td>Lymphocyte (%)</td>
<td>42.37 ±0.40</td>
<td>45.63 ±0.96</td>
<td>48.67 ±0.21</td>
<td>48.77 ±0.21</td>
<td>50.33 ±0.76</td>
</tr>
<tr>
<td>Monocyte (%)</td>
<td>5.47 ±0.04</td>
<td>5.87 ±0.08</td>
<td>5.67 ±0.12</td>
<td>5.73 ±0.04</td>
<td>4.80 ±0.22</td>
</tr>
<tr>
<td>Eosynophils (%)</td>
<td>1.80 ±0.04</td>
<td>1.43 ±0.08</td>
<td>1.63 ±0.04</td>
<td>1.57 ±0.08</td>
<td>1.90 ±0.07</td>
</tr>
<tr>
<td>Basophils (%)</td>
<td>4.36 ±0.13</td>
<td>4.23 ±0.06</td>
<td>4.30 ±0.04</td>
<td>4.23 ±0.09</td>
<td>4.34 ±0.15</td>
</tr>
</tbody>
</table>

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 = Initial body weight, FBW = Final body weights, BWG = Body weights gain, FI = Feed intake, FCR = Feed conversion ratio.
Results are in agreement with Okab and El-Banna, (2008) who showed that when the heat stress increased the reduction in RBCs, WBCs, 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 hematological traits.

4- Blood biochemical and oxidation:

Concerning blood analysis of growing male rabbits at 84 days, Table 5 showed a significant (P≤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≤0.05) reduced the serum total cholesterol concentration, while there were significant changes (P≤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≤0.05) decreased due to dietary zinc and betaine
supplementation with the exception of triiodothyronine (T₃) 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

<table>
<thead>
<tr>
<th>Items</th>
<th>C</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP (g/dl)</td>
<td>5.37±0.08</td>
<td>5.93±0.06</td>
<td>6.00±0.06</td>
<td>6.26±0.06</td>
<td>6.17±0.09</td>
<td>6.27±0.07</td>
</tr>
<tr>
<td>ALB (g/dl)</td>
<td>3.27±0.06</td>
<td>3.27±0.06</td>
<td>3.37±0.06</td>
<td>3.43±0.06</td>
<td>3.37±0.06</td>
<td>3.30±0.06</td>
</tr>
<tr>
<td>GL (g/dl)</td>
<td>2.2±0.04</td>
<td>2.67±0.06</td>
<td>2.63±0.06</td>
<td>2.83±0.06</td>
<td>2.80±0.06</td>
<td>2.93±0.06</td>
</tr>
<tr>
<td>Cholesterol mg/dl</td>
<td>55.9±0.66</td>
<td>50.4±0.31</td>
<td>53.3±0.33</td>
<td>51.9±0.46</td>
<td>49.5±0.29</td>
<td>45.4±0.31</td>
</tr>
<tr>
<td>TAC (mM/L)</td>
<td>11.5±0.24</td>
<td>25.4±0.67</td>
<td>24.8±0.55</td>
<td>27.9±0.31</td>
<td>29.9±0.44</td>
<td>31.0±1.03</td>
</tr>
<tr>
<td>MAD (nmol/ml)</td>
<td>67.0±0.50</td>
<td>51.8±1.04</td>
<td>51.3±0.75</td>
<td>50.9±1.19</td>
<td>48.5±0.45</td>
<td>48.1±0.44</td>
</tr>
</tbody>
</table>

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= Initial body weight, FBW= Final body weights, BWG= Body weights gain, FI= Feed intake, FCR= Feed conversion ratio.

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

Both the thyroid and adrenal gland are important for animals to regulate heat stress. Triiodothyronine and T₄ are the main substances secreted by the thyroid. Triiodothyronine is mainly transformed from T₄. Although lower quantities of T₃ are produced compared to T₄, its activity is stronger than T₄. Triiodothyronine and T₄ 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 adrenocorticotropic 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

<table>
<thead>
<tr>
<th>Items</th>
<th>C</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4 (ng/ml)</td>
<td>22.43 ±0.24</td>
<td>21.63 ±0.30</td>
<td>21.73 ±0.31</td>
<td>21.53 ±0.14</td>
<td>20.83 ±0.18</td>
<td>20.03 ±0.04</td>
</tr>
<tr>
<td>T3 (ng/ml)</td>
<td>4.27 ±0.13</td>
<td>5.23 ±0.15</td>
<td>5.47 ±0.08</td>
<td>5.36 ±0.36</td>
<td>5.47 ±0.14</td>
<td>5.60 ±0.01</td>
</tr>
<tr>
<td>Cortico (ng/ml)</td>
<td>4.97 ±0.04</td>
<td>3.93 ±0.06</td>
<td>3.80 ±0.04</td>
<td>3.40 ±0.07</td>
<td>3.80 ±0.04</td>
<td>3.50 ±0.04</td>
</tr>
<tr>
<td>Cortisol (µg/dl)</td>
<td>11.9 ±0.24</td>
<td>7.27 ±0.45</td>
<td>5.73 ±0.81</td>
<td>5.90 ±0.78</td>
<td>5.13 ±0.92</td>
<td>5.03 ±0.91</td>
</tr>
</tbody>
</table>

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.

T4 = Thyroxin, T3 = Triiodothyronine, Cortico= Corticosterone.

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 T4 to T3, some of the T3 decrement may have resulted from the suppression of TSH which is known to induce the thyroidal secretion of T3 in preference to T4.

Tollba et al., (2007) and Zou et al., (1998) reported that T3 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 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

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

<table>
<thead>
<tr>
<th>Items</th>
<th>Experimental groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Body weight at marketing (kg)</td>
<td>1830</td>
</tr>
<tr>
<td>Price of weaning litter (L.E)</td>
<td>20</td>
</tr>
<tr>
<td>Total fed intake at marketing (kg)</td>
<td>4.33</td>
</tr>
<tr>
<td>Total cost fed intake (L.E.)</td>
<td>18.19</td>
</tr>
<tr>
<td>Total cost of managements (L.E./litter)</td>
<td>2.0</td>
</tr>
<tr>
<td>Price of body weight at marketing (L.E.)</td>
<td>64.05</td>
</tr>
<tr>
<td>Net revenue (L.E.)</td>
<td>23.86</td>
</tr>
<tr>
<td>Economic efficiency</td>
<td>0.59</td>
</tr>
<tr>
<td>Relative economical efficiency (%)</td>
<td>100</td>
</tr>
</tbody>
</table>

C = Control, R1 = Basal diet±100 mg zinc, R2 = Basal diet±160 mg betaine, R3 = Basal diet±320 mg zinc, 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
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.

REFERENCES


Ayyat, M. S. and I. F. Marai (2000). Growth performance and carcass traits as affected by breed and dietary supplementation with different zinc levels under Egyptian condition. 7th World rabbit Congress. July 4-7, Spain, 83-88.


Chrastinov, L.; K. Čobanov; M. Chrenkov; M. Poláčikov; Z. Formelov; A. Laukov; L. Ondruška; M. Pogány Simonov; V. Strompfov; Z. Mlyněkov; A. Kalafat and L. Grešákov (2016). Effect of dietary zinc supplementation on nutrients digestibility and fermentation


Mohamed Abd AlAziz Al-Sawawi - Mohamed El-Sayed Abo Elnaye - Tarek Amine Sadek

Institute of Animal Production - Center for Agricultural Research - Ministry of Agriculture - Egypt.

Using in this experiment 60 male rabbits of 35 days of age with an average weight of 530 grams. APRI was calculated and used in the first group as the base measure. They were then divided into 6 groups (R1, R2, R3, R4 and R5) based on the following distribution:

- The first group (R1) received 100 mg of zinc or 200 mg of betaine.
- The second group (R2) received 160 mg of zinc or 320 mg of betaine.
- The third group (R3) received 200 mg of zinc or 400 mg of betaine.
- The fourth group (R4) received 300 mg of zinc or 600 mg of betaine.
- The fifth group (R5) received 400 mg of zinc or 800 mg of betaine.

The performance and feed efficiency were measured and calculated, as well as the final body weight, feed conversion ratio, and carcass meat yield. The results showed:

- There was a significant increase in weight gain (5%) in the groups that received zinc or betaine compared to the control group.
- Similarly, betaine was able to increase weight gain (5%) compared to the control group.
- There was a significant increase in carcass meat yield (5%) in the groups that received zinc or betaine compared to the control group.
- There was a significant increase in carcass meat yield (5%) in the groups that received zinc or betaine compared to the control group.
- The results showed a significant increase in hemoglobin levels (5%) in the groups that received zinc or betaine compared to the control group.
- The results showed a significant increase in hemoglobin levels (5%) in the groups that received zinc or betaine compared to the control group.
- The results showed a significant increase in hemoglobin levels (5%) in the groups that received zinc or betaine compared to the control group.
- The results showed a significant increase in hemoglobin levels (5%) in the groups that received zinc or betaine compared to the control group.
- The results showed a significant increase in hemoglobin levels (5%) in the groups that received zinc or betaine compared to the control group.

And was concluded:

- There was a significant increase in weight gain (5%) in the groups that received zinc or betaine compared to the control group.
- There was a significant increase in weight gain (5%) in the groups that received zinc or betaine compared to the control group.
- There was a significant increase in weight gain (5%) in the groups that received zinc or betaine compared to the control group.
- There was a significant increase in weight gain (5%) in the groups that received zinc or betaine compared to the control group.
- There was a significant increase in weight gain (5%) in the groups that received zinc or betaine compared to the control group.
- حدث انخفاض في بروتينات الدم الكلية والأليكومن والجلوبولين وإنزيم TAC في مجموعة الكنترول مقارنة بالمجامع المعالمة. كما سجلت مجموعة الكنترول زيادة معنوية في مستوى الكوليسترول والكوليسترول HDL. 

- حدث تحسن معنوي في كل المجامع المعالمة بالزنك أو البتاين في معدلات الكفاءة الاقتصادية والكفاءة الاقتصادية النسبية مقارنة بالكنترول. 

التوصية: إضافة 100 مجم زنك/ كجم علف لعنبة أرانب الأبر النامية أدى لتحسين كل من صفات النمو والذبيحة وكذلك العائد الاقتصادي خلال موسم الصيف.