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PHYSIOLOGICAL RESPONSES OF RABBIT DOES TO Synertox® SUPPLEMENTATION UNDER DIFFERENT HOUSING CONDITIONS DURING SUMMER IN EGYPT

G. Ashour, [1] A. A. Sedki[2], Samah M. Abdel-Rahman[2] and K. H. El-Kholy[3]

[1] *Department of Animal Production, Faculty of Agriculture, Cairo University, Giza, Egypt.*

[2] *Animal Production Research Institute, Agricultural Research Center, Dokki, Giza, Egypt.*

[3] *Department of Poultry Production, Faculty of Agriculture, Damietta University, Damietta, Egypt.*

A total number of 24 mature New Zealand White (NZW) rabbits, was used in this work to determine some physiological reactions of rabbit does as affected by housing system (indoors versus outdoors housing) during Egyptian summer season conditions. Also, to ameliorate the adverse effects of stressful summer conditions by using highly concentrated nutritional supplement (Synertox® component). The animals were equally and randomly divided into two groups each of 12 does. In each group, 6 does received water plus Synertox and the other 6 does did not receive Synertox (control).

Results showed that, *the average values of rectal (RT) temperature was significantly lower in outdoors housing as compared to indoors one, and in the group received Synertox. The lowest and highest values of respiration rate (RR) were obtained in outdoors and indoors housing, respectively, for both control and treated groups. Synertox treatment caused significant (P≤0.01) decrease in RR in both housing models. The values of hematocrit, hemoglobin, red and white blood cells count, total proteins, albumin, aspartate and alanine aminotransferases, creatinine, urea-nitrogen and triiodothyronine, thyroxine hormone concentrations were significantly (P≤0.05) higher in does kept in outdoors housing than those kept in the indoors model. Treatment with Synertox caused significantly (P≤0.05) increase in most of these values under indoors housing condition.*

Conclusively, *it can be concluded that, in spite of indoors housing "double iron sheets roof" accommodate and ideal house for raising rabbits but the good ventilation and absence of walls and its* *intense short-wave radiation give best advantageous in the outdoors model*, during summer season, in Egypt.

Key words: Rabbits, housing, Synertox®, summer, thermal responses, hematology, metabolites, hormones, enzymes.

Rabbits are hoped to play an important role in solving meat production deficiency particularly in developing countries, because they have several advantages (small body size, high growth rate, high efficiency in converting feed into meat, short gestation period, high prolificacy, relatively low cost of production and high nutritional quality of its meat which includes low fat, sodium and cholesterol levels , (Marai *et al*., 1994) that support the increase of its use for human consumption (Dacinia-Crina *et al*., 2013).This requires the increase of the production of livestock to meet the protein demand from the population. For these reasons, the development of intensive rabbit rearing in Egypt is to be considered welcomed(Ali and Abdel-Wareth, 2014).

In Egypt, according to the hot conditions during a period of about nine months a year, the natural mating is not even performed with the result of reducing the productivity per doe to make uneconomical rabbit production (Fouad, 2005). One of the main problems with rabbits is their sensitivity to high temperatures since they have few functional sweat glands limiting their ability in eliminating excess body heat, which affects the animal in different ways, such as reducing the feed intake and increasing disease susceptibility(Ashour and Abdel-Rahman, 2016).Therefore, Webster (1991) stated that to reduce the heat stress damage it is better to improve the microclimate conditions.

Consequently, the economic loss due to hot conditions could be abolished by different technical approaches, proper feeding, housing treatments and good management. In this respect, Ashour (2001) stated that housing system should be cheap, manufactured by local material, simple handicraft, efficient in thermoregulation, adaptable to different situation and accepted by the breeders and sustainable.

Changes in outside climatic conditions; air temperature, solar radiation, wind speed etc…, will affect the building heat gains and losses and controllable gains or losses. To maintain heat balance, all these gains and losses need to be quantified for design purposes. The materials and construction of the building will mainly affect the building and radiation heat losses and the solar heat gain (Owen, 1994).

Lebas *et al*. (1997) demonstrated that in countries where the climate is hot but fairly constant (mean minimum and maximum between 20 and 30 ^{o}C) closed buildings are not really necessary. If the cages are of wood or concrete (solid walls) it may be enough to roof each hutch. A roof should keep off heat from direct sunlight. The hutches can also be placed under trees big enough to shade them all day long. They added that outdoor wire-mesh cages can be grouped under a common roof.

Alleviation of heat-stress can be carried out with growth promoters, minerals, amino acids or vitamins supplementation (El-Kholy *et al.*, 2003 and Badr, 2015) and housing design (Ashour *et al*., 2004). One of these supplementations is Synertox; which is a commercial product, contains an excellent cocktail of yeast (easily dissolved in water), essential amino acids, enzymes, organic acids and their salts(Amer *et al.*,2011).

Most of the studies used Synertox as detoxification agent in poultry feeds and reported the ability of it to compensate and supply the suffered chicks from aflatoxin with essential nutrients (Amer *et al*., 2011 and Shareef and Omar, 2012).

The current study was planned to assess the thermo-respiratory, hematological, metabolic, enzymatic and hormonal responses of rabbits does to different housing conditions under stressful conditions of summer season in Egypt. Also, to evaluate the potential and beneficial effect of Synertox addition in alleviating the adverse impacts of summer heat stress.

MATERIALS AND METHODS

This study was carried out in the rabbitry belonging to Animal Physiology Research Lab., Animal Production Department, Faculty of Agriculture, Cairo University, Giza, Egypt. The fieldwork was executed during the hottest three months of summer (July, August and September). The physiological reactions of does were determined as affected by using a highly concentrated nutritional supplement (Synertox component) as bio-ad solved in the drinking water. Rabbits were housed in two different planned housing models with the following characteristics:

1. Indoors housing:

The indoors house is roofed by two layers of 0.4 cm thick corrugated iron sheet fixed at 40 cm apart as air space (Fig. 1). The floor is covered by 10.0 cm concrete. The walls were made of 12 cm thick common brick and 2 cm plaster, inside and outside of the walls. The height of the house is 3.0 m

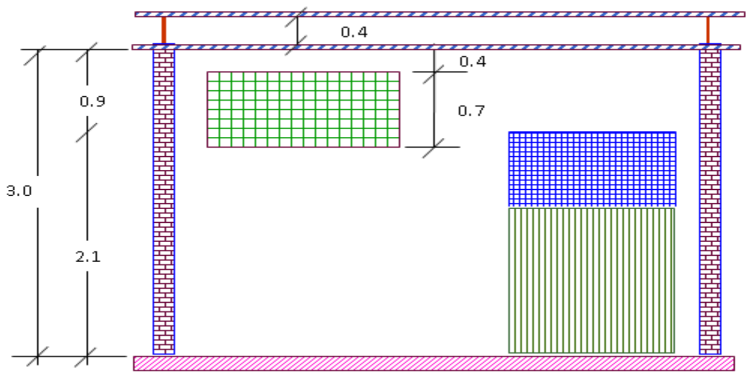

Fig. 1. Double roof housing model (m).

and the floor (4.1m length × 3.5 m width) is left as natural earthen ground. There were two windows, one big glass window (0.7 m high × 2.1 m width) at the north side and another glass window (0.6 m high × 1.10 m width) at the west side. These windows were located at 1.9 m above the ground level. The windows were open in the summer period. There is one door made of 0.6 cm steel sheet (2.1m high ×1.1 m width).

2. *Outdoors housing:*

Galvanized wire batteries were grouped under a wood-insulating roof and trees to protect the rabbits against direct sunlight. The height of the roof is 3.0 m.

Experimental animals and management:

A total number of 24 mature New Zealand White (NZW) rabbits does were used in this work. These does were all adult at the beginning of the study. The primiparous does weighed 2350-2830 g and aged 5-6 months. Animals were housed in individual cages of commercial type provided with feeders, automatic nipple drinkers and nest-boxes. The animals were fed *ad libitum* a commercial pelleted diet according to NRC (1977) recommendations, contains 18.5 % crude protein, 14.5 % crude fiber and 2.5 % fat. Calculated digestible energy of the diet was 2730 kcal/kg digestible energy. All animals were kept under the same managerial and hygienic conditions. The animals were equally and randomly divided into two groups of each (12 does). Each one was housed randomly in indoors housing model (IHM) and outdoors ones (OHM). In each group, 6 does received water plus 0.5 ml/litter Synertox supplement, wherease the other 6 does were served as control group, without any supplement. The ingredients of Synertox as stated by the manufacturer are shown in Table 1 (Agrarian Marketing Corporation (Middlebury, IN, USA).

Table 1. The ingredients of Synertox.

Ingredients (per 1000 ml)		**Ingredients**	**(g/L)**
Citric acid	80	Sodium citrate	40.0
Phosphoric acid	65	Potassium citrate	40.0
Malic acid	4	Papain	40.0
Tartaric acid	5	Sodium potassium tartrate	40.0
Disodium EDTA	15	Calcium pantothenate	3.0
Propylene glycol	100	Thiamine mononitrate	3.0
Aspartic acid	24	Riboflavin	3.0
Lactic acid	80	Pyridoxine hydrochloride	3.0
Calcium lactate	25		
Dried *Bacillus subtilis* fermentation extract	250		
Distilled water (180) up to 1 L			

Measurements and technical procedures:

Maximum (Max), minimum (Mini), ambient temperature(AT,°C) and relative humidity (RH, %) of outdoors and indoors conditions were recorded at 08.00-09.00h. Temperature – humidity index (THI, units) as accurate and particle measure for evaluating the intensity and severity of heat stress (HS) under the environmental conditions was calculated according to the following equation as proposed by Marai *et al*. (2001).

$$THI = db^{o}C - [(0.31 - 0.31\ RH)\ (db^{o}C - 14.4)]$$

Where: $db^{o}C$ = Dry bulb temperature in Celsius, RH= Relative humidity (%)

Internal and external temperatures of indoors' walls and roof were recorded twice a week by using Infrared thermometer at 08.00-09.00h. Body (BT), skin (ST) and fur (FT) temperatures (°C) were recorded by using digital Thermometer. Respiration rate (RR) was determined by counting the frequency of flank movements per minute.

Blood samples, about 3 ml, were collected weekly at 08.00-09.00h from the marginal ear vein in heparinized test tubes. A blood picture was determined immediately and plasma was separated by centrifugation and kept frozen at –20 ^{o}C until blood analysis and hormonal assay. Hematocrit value (Ht, %), hemoglobin concentration (Hb, g/dl), red blood cells count (RBCs,

$10^6/mm^3$),white blood cells count (WBCs, $10^3/mm^3$) were determined immediately in the fresh blood. Total protein (TP, g/dl), albumin (Alb, g/dl), aspartate aminotransferase (AST, U/l), alanine aminotransferase (ALT, U/l) and blood plasma urea nitrogen (BUN, mg/dl) were determined by the colorimetric methods with commercial kits obtained from Bio-Merieux Laboratory Reagents and Products (France). Serum creatinine (Crea., mg/dl) was determined by the colorimetric method with commercial kits obtained from Bochringer (Germany). Blood plasma triiodothyronine (T_3, ng/ml) and thyroxine (T_4, ng/ml) were determined by radioimmunoassay technique with commercial kits produced by the Diagnostic Products Corporation (DPC),Co. Los Angeles, USA. All the determinations were performed according to the methods outlined by the manufactures. In addition, the globulin concentration (Glb, g/dl), albumin-globulin ratio (A/G) and T4/T3 were calculated.

Statistical analysis:

Data of the present experiment was statistically analyzed by ANOVA test according to SPSS (2013) computer program using the following fixed model:-

$$Y_{ijk}=\mu+H_i + S_j + (HS)_{ij}+ e_{ijk}$$

Where*:* Y_{ijk} = observation of the ij^{th} rabbit; μ = Overall mean, common element to all observations; H_i = Fixed effect of the housing models (i = 1 “indoors" and 2 “outdoors”); S_j = Fixed effect of the treatment (j = 1 "control" and 2 "treated"); HS_{ij}= Interaction effect between i^{th} housing and j^{th} treatment; and e_{ijk} = Random error component assumed to be normally distributed.

The maximum, minimum, and environmental air temperatures and humidity affected by housing were assessed by the following model :

$$Y_i = \mu + H_i + e_i$$

Where: Y_i = observation of the i^{th} house; μ=overall mean, common element to all observations; H_i = the fixed effect of the housing models (i = 1 “indoor" and 2 “outdoor”); and e_i = random error component assumed to be normally distributed. Also, inside and outside surface temperatures (^oC) of roofs, walls and floors in the outdoors and indoors housing models were assessed by the previous model.

Means were compared using Duncan multiple range test procedure of the same statistical software (Duncan, 1955). All data are presented as least squares means ± standard error. For all data analyses, each animal was considered as an experimental unit.

RESULTS AND DISCUSSION

1. *Thermal conditions in the housing models*

Tables (2 and 3) show the thermal conditions for indoors and outdoors system. As shown in Table (2), the two housing systems significantly differed in maximum temperature and ambient the temperature that recorded at 9.00 am by 4.6 and 7.9%, respectively. Also, both systems significantly differed in values of THI, which indicated that absence of heat stress (HS) in indoors group (25.3) and moderate heat stress in outdoors system (27.02) according to Marai *et al*. (2001) who stated that when theTHI values obtained were: <27.8= absence of HS, 27.8 - < 28.9= moderate HS, 28.9- <30.0 = severe HS and 30.0 and more = very severe HS.

Verga *et al*. (2007) and Ashour and Abdel-Rahman (2016) stated that, the ideal temperature for rabbit does to live safely is ranged between 16-21^{o}C and they can tolerate low temperature more than higher one.

Table 2. Means ± S.E. of environmental air temperatures (^{o}C) and relative humidity (%) in indoors (IHM) and outdoors housing models (OHM).

House	Maximum	Minimum	Temp. 09.00h	RH (%)	THI (units)
IHM	34.42^{a}±1.43	25.92±0.67	26.33^{a}±0.73	72.42^{b}±2.12	25.31^{a}±0.69
OHM	36.00^{b}±0.88	25.50±0.78	28.42^{b}±0.79	67.58^{a}±1.81	27.02^{b}±0.75

$^{a, b}$ Means in the same column with different superscripts are significantly different (P<0.05).

On the contrary, the indoors system (IHM) was significantly higher than the outdoors model (OHM) in outside roof temperature (74.6 vs. 50.60^{o}C in indoors and outdoors, respectively) and inside roof temperature (Table 3).

The effect of housing model seems to be reflected on the roofs temperature. But in indoors model, the greater difference between the outer and the inner surfaces of the roof was not mean it's better, because of significant lower of outside and inside outdoors's roof temperature.

With regard to outdoors housing, there are more factors seem to be reflected on the significant decrease of floor temperature (Table 3): 1) absence of walls and its intense short-wave radiation, 2) trees shade, 3) wood

Table 3. Means ± S.E. of inside and outside surface temperatures (^oC) of roofs, walls and floors in the indoors and outdoors housing models.

House	Roofs			Walls*			Floor
	Outside	Inside	(I-O)	Outside	Inside	(I-O)	
IHM	74.6^a±0.3	32.7^a±0.2	41.91	33.2±0.2	30.2±0.2	2.96	29.7^a±0.2
OHM	50.6^b±0.4	29.6^b±0.3	21.00	-	-	-	27.6^b±0.3

a, b Means in the same column with different superscripts are significantly different (P<0.05). * Mean value of the four walls temperatures.

roof which has low thermal conductivity (0.10) (CIBS, 1980), 4) continuously air movement around housing and 5) humidity reflected from ground surround housing.

The previous differences in the indoors temperature is due to physical properties of the roofs and their efficacy towards solar radiation. In the case of the double iron sheets, the presence of air layer between the two layers minimizes heat transfer as a result of the low conduction (K value) of air (0.055). Similar results were obtained by Ashour and Shafie (2002) and El-Kholy (2003) on the same model. Regard to outdoors housing, Smith (1981) showed that the layer of air beneath trees and moving through shrubs receives the water vapour of transpiration, which has a substantial cooling effect, so that if such shading trees and shrubs are present, shade temperatures are less than on open turf.

2. *Effect of housing models and treatment with Synertox:*

2-1. Thermal responses

Table (4) shows that housing system did not significantly affect the skin temperature (ST) and fur temperature (FT). But, rectal temperature (RT) and respiration rate (RR) were significantly affected by the housing system.

The data cleared that RT was lower in OHM than in the IHM. The same trend was observed in RR which was lower in OHM by 4.5% than that recorded in IHM. It was well established that, RR is a good indicator of HS severity in rabbits as proved by many workers (Ashour, 2001, Ashour and Shafie, 2002 and Ashour and Abdel-Rahman, 2016).

Table 4. Means ± S.E. of thermo-respiratory responses in NZW rabbit does affected by housing models and Synertox treatment.

Factors	**RT (°C)**	**ST (°C)**	**FT (°C)**	**RR (Resp./min)**
Housing:	**	NS	NS	**
Indoors (A)	39.30±0.03	38.49±0.14	34.31±0.21	137.13±1.38
Outdoors (B)	39.09±0.02	38.35±0.15	33.85±0.19	132.91±1.01
Treatment:	**	NS	NS	**
Control (a)	39.28±0.03	38.47±0.15	34.33±0.22	140.18±1.15
Treated (b)	39.10±0.02	38.37±0.14	33.83±0.18	129.86±1.07
Interactions:	**	NS	NS	**
A × a	39.43^{c}±0.04	38.54±0.22	34.69±0.31	144.62^{c}±1.53
B × a	39.16^{b}±0.04	38.43±0.19	33.94±0.28	129.64^{a}±1.74
A × b	39.12^{ab}±0.03	38.40±0.21	33.98±0.29	135.73^{b}±1.47
B × b	39.05^{a}±0.02	38.30±0.21	33.73±0.24	130.09^{a}±1.28

$^{, b, c}$ Means in the same column with different superscripts are significantly different (P<0.05). NS= Not Significant; * = P<0.05, ** = P<0.01.

Generally, both RT and RR in NZW does were considered normal according to Marai *et al*. (1994). They stated that body temperature of NZW rabbits is 39.5°C, and respiration rate per minute is 168. This means that, rabbit does are still able to deal with environmental temperature, but they lose this ability when RT increased which is an indicator to the failure of physiological mechanisms in the body to deal with heat load caused by the surrounding ambient temperature (Habeeb *et al*., 1998).

So, from the present data, the OHM is more suitable and comfortable for rabbits during summer season. This could be attributed to the variations in the temperature of roof inner surface in each model, as reflection to climatic temperature alongside the intensity of solar radiation as shown previously in Table (3)

Adding Synertox to rabbit does water did not affect ST and FT, meanwhile significantly affects both RT and RR. It is obviously that RR was lower in treated group with Synertox (129.86) than that in indoors one (140.18), and this could be due to the rich components in Synertox such as calcium pantothenate (pantothenic acid). Pantothenic acid (vitamin B5) as coenzyme A is closely involved in adrenal cortex function and has come to be known as the “antistress” vitamin. It supports the adrenal glands to increase secretion of cortisone and other adrenal hormones to help counteract stress and enhance metabolism. It is generally important to healthy skin and nerves. Through, its adrenal support, vitamin B5 may reduce potentially toxic effects of antibiotics and radiation (McDowell, 2000).This result is in agreement with the findings of Kamel (2012) and Badr (2015) by using different nutritional conditions.

The interaction between adding Synertox and housing system (indoors and outdoors) showed that Synertox addition decreased RR in the group of indoor+Synertox than the control (without Synertox addition) in the same system by 6.15%. However, RR in the group of Synertox +outdoors was 130.09 and in control group (housed in outdoors without Synertox supplementation) was 129.64 RR resp./min. Values of RT (Table, 4) decreased with Synertox treatment in both housing system (indoors and outdoors). This means that addition of Synertox is recommended for rabbits housed in indoors system because its possible role in enhancement their thermo-respiratory responses and became closer to the group housed in outdoor but without Synertox treatment.

2-2. Hematological responses:

Generally, all the hematological parameters (Ht, Hb, RBC´s and WBC´s) were higher in the OHM compared to the IHM and this confirms with the previous results that OHM is more suitable for rabbits during summer season.

Also, it was found that, housing system did not significantly affect hematological parameters (Table, 5) except Hb concentration and WBC´s count. Also, Synertox addition significantly affects Hb concentration which was higher in treated group by 5.2% than the control group. In the same trend WBC´s count was significantly differed between treated and control group (5.97 and 5.51, respectively). Other parameters (Ht and RBC´s) were almost equal between the two groups.

With respect to the interaction between housing systems and Synertox treatment showed that, rabbits that housed in IHM had lower Hb concentration (12.14 g/dl in A ^{x} a) than the group housed in the same system and received Synertox in drinking water (13.67 g/dl in A ^{x} b). On the other hand, Hb concentration was increased insignificantly in outdoors group supplemented by Synertox (increased from 13.37 to 13.77 g/dl).

Table 5. Means ± S.E. of hematocrit value (Ht, %), hemoglobin concentration (Hb, g/dl), red blood cells count (RBCs, $10^6/mm^3$) and white blood cells count (WBCs, $10^3/mm^3$) in NZW does rabbit as affected by housing models and treatments.

Factors	Ht (%)	Hb (g/dl)	RBC´s ($10^6/mm^3$)	WBC´s ($10^3/mm^3$)
Housing:	NS	**	NS	*
Indoors (A)	35.21±0.17	12.75±0.16	04.47±0.09	05.60±0.08
Outdoors (B)	35.61±0.16	13.72±0.14	04.56±0.08	05.88±0.09
Treatment:	NS	**	NS	**
Control (a)	35.34±0.17	12.90±0.17	04.47±0.08	05.51±0.09
Treated (b)	35.47±0.16	13.57±0.15	04.57±0.09	05.97±0.09
Interactions:	NS	**	NS	**
A × a	35.09±0.23	12.14^{a}±0.21	04.41±0.12	05.34^{a}±0.12
B × a	35.33±0.23	13.37^{b}±0.21	04.54±0.13	05.86^{bc}±0.10
A × b	35.59±0.23	13.67^{b}±0.21	04.54±0.12	05.68^{b}±0.13
B × b	35.62±0.23	13.77^{b}±0.21	04.59±0.12	06.08^{c}±0.12

$^{a, b, c}$ Means in the same column with different superscripts are significantly different (P<0.05). NS= Not significant; * = P<0.05, ** = P<0.01.

Also, a significant elevation in WBC´s count in all interaction values was noticed, meanwhile RBC´s count in all groups was almost equal.

The effect of Synertox on some hematological parameters may attribute to the components of Synertox such as pantothenic acid which is a constituent of coenzyme A. One of the most important functions of coenzyme A is to act as a carrier mechanism for carboxylic acids reactions. The most important of these reactions is the combination of coenzyme A with acetate to form “active acetate”. In the form of active acetate, acetic acid can also combine with choline to form acetylcholine, the chemical transmitter at the nerve synapse and can be used for detoxification of drugs including sulfonamides. Also, succinic acid resulting from decarboxylation of ketoglutaric acid in the citric acid cycle can be converted to the “active” form by linkage with coenzyme A. This active succinate and glycine are together involved in the first step of heme biosynthesis (McDowell, 2000). This fact can explain increasing the hemoglobin value and hematocrit % in treated groups. Also, pantothenic acid also stimulate synthesis of antibodies which increase resistance of animals (McDowell, 2000). This can explain the increase in WBCs and RBC´s. Also, McDowell (2000) showed that Pyridoxine hydrochloride (B6) participate incorporation of iron in hemoglobin synthesis. On the other hand, Fortun-Lamothe and Drouet-Viard (2002) showed that B group vitamins can affect the resistance capacity (the immune system) in the rabbits.

The presented data were higher than reported by Askr and Ismail (2012) who found that, Hb, Ht, RBC´s and WBC´s in heat stressed rabbits were 6.61 g/dl, 33.18 %, 4.2110^6/mm^3 and 6.14 10^3/mm^3.

2-3. Blood Metabolites

The data in Table (6) cleared that housing systems were significantly affect TP, Alb, Glob and A/G ratio. This give the advantages to OHM which recorded the highest values in the mentioned parameters. On the other side, treated rabbits with Synertox had insignificant increase in all blood plasma proteins which were (in both groups, control and treated) close to each other.

Owing to the effect of the interaction between the two factors (Housing system and Synertox) which cleared that, adding Synertox to rabbits housed in IHM caused a significant increase in TP, Alb, Glob and A/G ratio. This may due to the rich components in Synertox such as calcium pantothenate (Pantothenic acid), thiamine mononitrate (B1) and papain. Pantothenic acid (vitamin B5) stimulates synthesis of antibodies, which increase resistance of animals to pathogens. It appears that when pantothenic acid is deficient, the incorporation of amino acids into blood albumin fraction is inhibited which would explain why there is a reduction in the titer of antibodies (McDowell, 2000). Also, thiamine mononitrate functions as the coenzyme thiamine pyrophosphate (TPP), which is important in the metabolic process. TPP is used in the citric cycle (Krebs cycle) of the decarboxylation of alpha-ketoacids from pyruvate to acetyl CoA. These alpha-ketoacids produce energy for cell use by converting carbohydrates, fats, and amino acids into metabolic energy (McDowell, 2000). These theories simply explain our results where, the treated groups recorded a significant increase in TP and Glb. Also, Wood *et al*. (1987) showed the role of T4 in increased concentrations of plasma total proteins and albumin as a response of T4 to the increase in the regulators of GH-mRNA and GH synthesis which had a major role in the movement of amino acids and peptides transport and subsequently blood and body proteins anabolism. On the other hand, the protein synthesis associated with the immune response (Fortun-Lamothe and Drouet-Viard, 2002). So, treatment with Synertox may result in increasing immune system. Kolb (1997) showed that vitamins B are involved in the functions of the immune system cells: production of antibodies

Table 6. Means ± S.E. of total protein (TP, g/dl), albumin (Alb, g/dl), globulin (Glob, g/dl) and albumin/globulin ratio (A/G) in NZW rabbit does as affected by housing models and Synertox treatments.

Factors	TP (g/dl)	Alb (g/dl)	Glob (g/dl)	A/G
Housing:	**	**	**	**
Indoors (A)	5.43±0.05	2.82±0.04	2.60±0.04	1.10±0.02
Outdoors (B)	6.04±0.04	3.00±0.03	3.04±0.02	0.99±0.01
Treatment:	NS	NS	NS	NS
Control (a)	5.65±0.07	2.89±0.04	2.76±0.04	1.06±0.02
Treated (b)	5.82±0.06	2.94±0.03	2.87±0.05	1.04±0.02
Interactions:	**	**	**	**
A × a	5.28^{a}±0.07	2.77^{a}±0.06	2.51^{a}±0.04	1.11^{b}±0.03
B × a	5.58^{b}±0.07	2.88^{ab}±0.05	2.68^{b}±0.06	1.09^{b}±0.03
A × b	6.02^{c}±0.05	3.01^{b}±0.05	3.01^{c}±0.02	1.00^{a}±0.02
B × b	6.06^{c}±0.06	3.00^{b}±0.03	3.06^{c}±0.04	0.98^{a}±0.02

a, b, c Means in the same column with different superscripts are significantly different (P<0.05). NS= Not significant; * = P<0.05, ** = P<0.01.

"immunoglobulins" (B1, B2, B5 and B6) and proliferation of immune cells (B6). Also, Abou El-Wafa *et al.* (2002) showed that thiamine (B1), riboflavin (B2) and pyridoxine (B6) are well known as an immunity enhancer. Finally, the improvements in blood metabolites can be affected and reflected positively on immune system (Ashour *et al*., 2004).

Also, Synertox addition in OHM caused a significant elevation in the blood metabolites, for instance, TP was higher in treated group with Synertox (6.06g/dl) than that in the control group (5.28 g/dl).

2.4. Liver and kidney functions

From Table (7) it was found that OHM was significantly higher in activity of AST, ALT and BUN concentration except Crea. Concentration, but these values are all within the normal physiological range as reported by Ismail *et al*. (2003) and Ashour *et al*. (2004). Also, previously Hewitt et al. (1989) illustrated that normal value of BUN and Crea. in rabbits are 8.1 – 8.5 mg/dl and 0.14 – 1.66 mg/dl, respectively. Addition of Synertox also

Table 7. Means ± S.E. of aspartate aminotransferase (AST, U/l), alanine aminotransferase (ALT, U/l), createnine (Crea, mg/dl) and urea-nitrogen (BUN, mg/dl) concentrations in blood plasma of NZW rabbit does as affected by housing models and Synertox treatment.

Factors	AST	ALT	Crea	BUN
Housing:	*	**	NS	**
Indoors (A)	28.33±0.43	20.03±0.30	1.00±0.04	16.33±0.37
Outdoors (B)	30.33±0.71	21.57±0.36	1.03±0.04	17.74±0.32
Treatment:	*	*	**	**
Control (a)	28.50±0.56	20.28±0.30	0.89±0.04	15.97±0.35
Treated (b)	30.16±0.62	21.32±0.38	1.14±0.03	18.10±0.30
Interactions:	*	**	**	**
A × a	27.50[a]±0.59	19.50[a]±0.33	0.87[a]±0.06	15.34[a]±0.58
B × a	29.16[ab]±0.58	20.56[ab]±0.49	1.14[b]±0.05	17.32[b]±0.39
A × b	29.50[ab]±0.93	21.05[bc]±0.45	0.91[a]±0.05	16.60[b]±0.38
B × b	31.15[b]±1.07	22.08[c]±0.54	1.15[b]±0.05	18.88[c]±0.26

[a, b, c] Means in the same column with different superscripts are significantly different (P<0.05). NS= Not significant; * = P<0.05, ** = P<0.01.

significantly affected liver functions (AST was 30.16 U/l in treated group vs. 28.50 in control group) and kidney functions (Crea. Concentrations were 1.14 and 0,89 mg/dl in treated and control groups, respectively.

Additionally, when the group that kept in IHM received Synertox in drinking water, recorded higher values in activity of liver enzymes (AST and ALT) and Crea. and BUN. For instance, AST was 29.50 in B × bvs. 27.50 U/l in A × a. The same was recorded in Crea. Which was significantly higher in group of A × b than that in A × a by 4.6%. Same trend was recorded for the group housed in outdoor and received Synertox in drinking water.Generally, increased levels of AST, ALT, Crea. and BUN in treated groups with Synertox (housed in out and indoor models) were within normal physiological range as mentioned previously and this indicating that, Synertox did not negatively affects liver and kidney functions and assure the safety of using Synertox as enriched compound in ameliorating heat stress in rabbits.In this respect, El-Sawy *et al*. (2014) showed that natural feed additive was responsible for the normal increase in AST, ALT, Crea. and BUN concentrations. Also, this increase in AST and ALT can be attributed to the inclusions of Synertox to a lot of factors (enzyme, citric and lactic acids) which can affect liver activity. This result is in agreement with the findings of Ismail (2003). Also, increasing plasma total proteins and their fractions (Alb and Glb) within the normal range may reflect an increase in the hepatic function (El-Harairy *et al*., 2003).

This phenomenon was observed in treated groups compared to control groups. The higher activity of liver function in treated groups compared to the control groups can be attributed to the inclusion of Synertox to many factors, which can affect liver activity (enzyme, citric and lactic acids). These results are in agreement with the findings of Ismail *et al*. (2002).

Many studies proved that heat stressed rabbits increased their BUN (mg/dl) by using different nutritional means to alleviate heat stress, 18.3 vs. 19.4 to 33.3 (Abo El-Ezz *et al*., 1996) and 34.9 vs. 35.1 to 37.8 (Abdel-Samee *et al*., 2003a). Additionally, other studies indicated that BUN (mg/dl) was higher in winter than in summer, 16.1 to 18.8 vs. 13.6 to 16.7 (Ayyat and Marai, 1996) and 58.2 vs. 34.9, respectively (Abdel-Samee *et al*., 2003b). These studies indicated that alleviation of heat stress by using different techniques as in the present study, Synertox treatment; improve rabbit's health, vitality performance and metabolic activity.

2.5. Thyroid hormones

The concentrations of metabolic hormones in Table (8) cleared that the T4 was significantly lower in IHM (43.13ng/ml) than that recorded in OHM (46.72 ng/ml), meanwhile T3 concentration was almost equal in both housing system.

The decrease of T_4 and T_4/T_3 ratio in IHM than that in OHM revealed that the building materials affected markedly the thyroid release of T_4. This could be explained by Ashour *et al*. (2005) who stated that, hot conditions hamper the activity of the thyroid gland causing reduction in both T_4 and T_3 levels to decrease the metabolic heat production.

Adding Synertox to drinking water did not significantly affects hormones concentration, but resulted in a slight elevation in T4 concentration in OHM than that in IHM (Table, 8). However, T3 concentration and ratio of T4/T3 in both housing systems were close to each other.

When Synertox added to the groups housed in two different housing, T4 significantly elevated from 42.29 to 46.44 ng/ml in IHM and increased from 43.96 to 47.02 ng/ml in OHM. The increase in T_4 concentration in treated group may be due to the rich components in Synertox such potassium citrate and probiotics. Hallmark (2003) showed that potassium citrate enhance thyroid function. Ahmed (2001) demonstrated that probiotics improve secretion of T_3 and T_4 and thyroid index (T_4/T_3) by activation of T_3

Table 8. Means ± S.E. of thyroxine (T_4, ng/ml) and triiodothyronine (T_3, ng/ml) concentrations in blood plasma of NZW rabbit does as affected by housing models and Synertox treatment.

Factors	T_4	T_3	T_4 / T_3
Housing:	**	NS	NS
Indoors (A)	43.13±0.58	1.51±0.03	29.70±0.57
Outdoors (B)	46.72±0.37	1.52±0.03	31.19±0.67
Treatment:	NS	NS	NS
Control (a)	44.36±0.65	1.51±0.03	30.47±0.66
Treated (b)	45.49±0.41	1.52±0.03	30.41±0.61
Interactions:	**	NS	NS
A × a	42.29^{a}±1.04	1.50±0.05	30.02±0.88
B × a	43.96^{a}±0.48	1.52±0.04	29.37±0.74
A × b	46.44^{b}±0.54	1.53±0.04	30.92±0.98
B × b	47.02^{b}±0.51	1.52±0.04	31.47±0.94

[a, b, c] Means in the same column with different superscripts are significantly different ($P<0.05$). NS= Not significant; * = $P<0.05$, ** = $P<0.01$.

transformation of T_4. Granner (2003) mentioned that thyroid hormones are transported by thyroid binding globulin. So, the increased in globulin concentration in treated rabbits could be contributed to the increased of thyroid secretion. Additionally, Ashour *et al*. (2005) suggested that the decrease in thyroid hormones as a result of heat stress might be due to decreasing basal metabolic rate and muscle activity to decrease heat production. Meanwhile, T3 and the ratio T4/T3 did not significantly affected by Synertox treatment in both housing systems and their values were almost equal between all the interactions as presented in Table 8.

So, the present results cleared that the OHM is more suitable for rabbits during summer season in Egypt, because it is provide the appropriate environment and help them to be adapted to the thermal conditions. This was confirmed through the lower RT and RR in comparison with the group housed in IHM. Also, the increased in some blood parameters (Ht, Hb, TP, Alb, Glob and T4), which was within the normal physiological range, gave the advantages model than the IHM.

Also, the data showed the positive use of Synertox addition in drinking water especially in IHM which significantly lowered RR and RT in rabbits compared to control group, with no negative effects on liver and kidney functions.

This reflects the safety of using it, and its role in helping rabbits to be comfortable and made their physiological responses during summer season in close to the rabbits housed in outdoor system.

Conclusively, it can be concluded that, in spite of indoors housing “double iron sheets roof” accommodate and ideal house for raising rabbits but the good ventilation and absence of walls and its intense short-wave radiation give best advantageous in the outdoors model, during summer season, in Egypt.

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الإستجابة الفسيولوجية لإناث الأرانب النيوزيلاندي لإضافة السينرتوكس تحت نظم الإيواء المختلفة خلال فصل الصيف بمصر

جمال عاشور حسن [1]- عبد المنعم صدقي [2]- سماح محمد عبد الرحمن 2- خالد حسان الخولي [3]
١ - قسم الإنتاج الحيواني -كلية زراعة - جامعة القاهرة- جيزة - مصر
٢ - معهد بحوث الإنتاج الحيواني – مركز البحوث الزراعية- جيزة - مصر
3- قسم الإنتاج الداجني – كلية الزراعة – جامعة دمياط – دمياط- مصر.

أجريت هذه الدراسة لتقييم الإستجابة الفسيولوجية لإناث الأرانب النيوزيلاندي تحت نظم الإسكان المختلفة (النظام المغلق والنظام المفتوح) خلال موسم الصيف وكذلك محاولة تخفيف العبء الحراري الواقع عليها من خلال إضافة مركب عالي القيمة الغذائية (مركب السينرتوكس)، وتم إستخدام 32 من أرانب النيوزيلاندي (24 أنثي + 8 ذكور) والتي قسمت عشوائياَ الي مجموعتين إشتملت كل مجموعة علي 12 أنثي + 4 ذكور وداخل كل مجموعة قسمت الي مجموعتين كل مجموعة بها 6 إناث تم معاملتها بالسينرتوكس والمجموعة الأخري لم يتم معاملتها بالمركب.

أظهرت النتائج إنخفاض درجة حرارة الجسم في مجموعة نظام الإسكان المفتوح وكذلك في المجموعة المعاملة بمركب السينرتوكس في مياه الشرب، كذلك تم تسجيل أقل معدل للتنفس في النظام المفنوح والمجموعة التي تناولت السينرتوكس بينما اعلي قيمة لمعدل التنفس سجلت في الإسكان المغلق.

كذلك وجد أن تركيزات كلاَ من البروتينات الكلية، الألبيومين، انزيمات الكبد الناقلة لمجموعة الأمين، اليوريا والكرياتنين وهرمون الثيروكسين كانت اعلي في مجموعة نظام الإسكان المفتوح وكذلك مع المجموعة المعاملة.

التوصية: يمكن ان نستنتج أن نظام الإسكان المفتوح أفضل للارانب وكذلك أثبتت التجربة قدرة مركب السينرتوكس علي تخفيف العبء الحراري و تحسين الخصائص الفسيولوجية لأرانب النيوزيلاندي تحت الظروف المصرية خلال فصل الصيف فى مصر.