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Heat stress and its amelioration with nutritional, buffering, hormonal and physical techniques for New Zealand White rabbits maintained under hot summer conditions of Egypt.

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SUMMARY. A total number of 73 growing female New Zealand White (NZW) rabbits with nearly equal average body weight, were used during winter (16.4 to 20.3°C and 74 to 66% R.H.) and summer (34.2 to 38.4°C and 64 to 41% R.H.) seasons to study the growth performance and haemobiochemical profiel as affected by summer heat stress conditions of Eygpt and their amelioration with various 5 days of \techniques. In winter (January and February months), ten animals at 60 18.5 g initial live body weight (LBW), were used. During summer \age with 1400 16.92 g \(July and August months), sixty three animals at the same age with 1398 LBW were used and divided into 9 groups of 7 each. One of these groups altogether with the winter group were used to study the effect of heat stress on rabbits. The other summer groups were treated with nutritional, buffering, hormonal and physical techniques for amelioration of heat stress of rabbits under hot summer conditions of Egypt.

The results showed that the non-supplemented summer group was significantly (P< 0.05) lower in LBW, daily body gain (DBG), dry matter intake (DMI), plasma concentrations of cholesterol, low density lipoprotein (LDL), high density lipoprotein (HDL), total lipids, total protein, globulin, thyroxine (T_4) and Na and was significantly (P< 0.05) higher in rectal temperature (RT), respiration rate (RR) and daily water intake (DWI) than in the winter group.

Addition of 5 or 7% palm oil or 1.25% KHCO3 to the basal diets and T_4 injection of 30 or 50 ug/kg LBW increased (P< 0.05) LBW, DBG and feed efficiency (FE) at 90 and 120 days of age. Cool drinking water (10oC) and shearing improved FE at 120 days of age, while DWI decreased (P< 0.05) at 120 days of age due to supplementation the diet with 5 or 7% palm oil and at 90 and 120 days of age with shearing, and incrased (P< 0.05) at all ages studied by 1.25% KHCO3 and cool drinking water treatments. RT and RR decreased (P< 0.05) only with cool drinking water and shearing treatments at all ages studied. With regard to haemobiochemical levels, most lipid fractions decreased (P< 0.05) with palm oil (5 or 7%), KHCO3 (1.25 or 2.5%), T_4 (30 or 50 mg/kg LBW) and cool drinking water (10°C) techniques. Plasm T_4 decreased (P< 0.05) with palm oil treatments and increased (P< 0.05) with T_4 injection. All plasma protein levels significantly increased with T_4 injection and total proteins and albumin decreased (P< 0.05) with cool drinking water, while globulin level increased (P< 0.05) only with shearing treatment.

Keywords: *rabbit, heat stress, growth, palm oil, KHCO3, thyroxine, cooling.*

Introduction

The NZW rabbits are nearly introduced to Egyptian agriculture. However, the studies on the effects of heat stress conditions and their amelioration on the growth performance in NZW rabbits are lacking.

The aim of the present work was to study the growth performance and haemobiochemical profile changes as

affected by summer heat stress conditions of Egypt and their amelioration with nutritional (palm oil, 5 or 7%), buffering agent ($KHCO_3$, 1.25 or 2.5%), hormonal (30 or 50 mg T_4 per kg LBW) and physical (cool drinking water or shearing) techniques.

Materials and Methods

A total number of 73 growing female NZW rabbits with nearly equal average body weights, were used during winter and summer conditions in the present study. In winter (January and February months), ten growing female NZW rabbits at 60± 5 days of age with 1400 ±18.5 g initial live body weight, were used. During summer (July and August months), sixty three female NZW rabbits at the \same age and approximated 1398± 16.92 g in their LBW were assigned to 9 groups of 7 animals each. One of the summer groups was considered as a control and was compared also with winter group to study the effect of heat stress on growth performance of rabbits, while the other 8 groups were treated as shown in Table 1.

The animals were provided daily by pelleted ration and water *ad libitum* at 10.00 h and the residuals of both were measured by weight back technique at 10.00 h in the next day. The chemical analysis according to AOAC (1980) and gross energy according to Alderman *et al.* (1975) of the diet used, are shown in Table 2. Each one kilogram of the pelleted ration contained 17.42 MJ/ kg dry matter calculated as described by Alderman *et al.* (1975) based on the chemical analysis of the pelleted ration. The amount of 5 g/ kg DM of a rabbit premix composed of minerals and vitamins was added to the balanced nutrient requirements.

The rabbits were housed in cages of commercial type (59 x 55 x 39 cm) provided with feeders and each 3 or 4 animals were housed in each cage. The animals were exposed to light 14-16 hours per day throughout the experimental period. all groups were kept under the same managerial and hygenic conditions. The experimental temperature and relative humidity (RH %) during day ranged between 16.4 and 20.3°C and 74 and 66 R.H. %, respectvely, during the experimental period in winter and between 34.2 and 38.4°C and 64 and 41% RH, respectively, during the experimental period in summer. LBW, DBG, DMI, RT and RR were recorded during the experimental periods of winter and summer groups at 60, 90 and 120 days of age. The animals were weighed at weekly intervals and FE was calculated as daily gram gains per daily Mega Joule gross energy intake.

At the end of the experimental period (at 120 days of age), heparinized

Table 1. Experimental groups and numbers, ages and weights (x ± S.E.) of NZW growing female rabbits used in the study.

Items	Winter group	Summer groups								
		Non-supplemented group	Palm oil		$KHCO_3$		T_4 / kg LBW		Cool water 10 °C	Shearing
			5%	7%	1.25%	2.5%	30 ug	50 ug		
Number of animals/ group	10	7	7	7	7	7	7	7	7	7
Age of animals (days)	60 ± 4	60 ± 5	60 ± 4	59 ± 6	60 ± 6	62 ± 4	60 ± 7	63 ± 3	61 ± 4	60 ± 4
Live body weight (g)	1400 ± 18.5	1406 ± 16.5	1380 ± 13.8	1404 ± 19.8	1375 ± 15.8	1400 ± 19.0	1406 ± 17.2	1395 ± 12.4	1412 ± 18.3	1405 ± 13.6

Table 2. Chemical analysis of the experimental pelleted ration on DM basis (g/ 100 g DM).

Chemical composition	DM	OM	CP	CF	EE	NFE	Ash
Pelleted ration	100	88.20	16.50	17.80	3.20	50.70	11.80

blood samples were collected from the ear vein of each animal. Thyroxine hormone labelled with radioactive 125I was used in kits of radioimmunoassay technique manufactured by ICN Biomedicals, Inc. Costa Mesa, California, for plasma thyroxine hormone determination. Total protein, albumin, total lipids, phospholipids, triglycerides, plasma Na and K concentrations were determined as described by Tietz *et al.* (1982). Globulin was calculated by subtracting albumin from total protein concentrations. Total cholesterol, HDL and LDL concentrations were determined by using bioMerieux kits.

The differences between mean values of winter and non-supplemented summer groups were tested by unpaired t test and the differences between non-supplemented summer group and each of experimental supplemented groups in summer were tested by analysis of variance according to Snedecor and Cochran (1982).

Results

1- Effect of summer conditions on feed and growth performances, rectal temperature, respiration rate and some haemobiochemical levels of NZW rabbits:

Data presented in Table 3 showed that LBW at 60 days of age was similar in winter and summer groups. However, it significantly ($P < 0.05$) declined in summer by 10.71 and 9.16% at 90 and 120 days of age, respectively. DBG and DMI were significantly ($P < 0.01$) lower in summer by 21.6 and 53.1% at day 60 and 19.4 and 34.9% at day 90 of age, respetively. At 120 days of age, DBG and DMI significantly declined by 9.3 ($P < 0.05$) and 50.6% ($P < 0.01$) with no significant increase in FE due to hot summer conditions. DWI was signifcantly ($P< 0.01$) higher due to hot summer conditions than in the control conditions in winter with 112, 84.2 and 69.3% at 60, 90 and 120 days of age, respectively.

Rectal temperature and respiration rate were significantly ($P < 0.05$) higher in rabbits maintained under hot summer than in those of winter groups at all ages studied (Table 4).

Concentrations of cholesterol, HDL, LDL, total lipids, globulin, total proteins, T_4 and plasma Na were significantly ($P < 0.05$) lower in summer than in winter group. However, each of triglycerides, phospholipids, plasma Na increased and albumin concentrations decreased insignificantly in rabbits, maintained under hot summer conditions (Table 4).

2. Growth performance, RT, RR and some haemobiochemical levels of heat stressed growing NZW rabbits as affected by palm oil, $KHCO_3$, thyroxine

Table 3. Effects of nutritional, buffering, hormonal and physical amelioration techniques on live body weight, daily gain, dry matter intake, feed efficiency and water intake of heat stressed New Zealand White rabbits.

Items	Winter	Summer								
		Non-suppl-emented group	Palm oil 5%	Palm oil 7%	$KHCO_3$ 1.25%	$KHCO_3$ 2.50%	Thyroxine 30 ug	Thyroxine 50 ug	Physical treatments cool water	Physical treatments shearing
Live body weight (g) at :										
60 days of age	1580±15.7*	1550±18.0^a	1557±22.0^a	1551±29.0^a	1543±28.5^a	1564±29.5^a	1558±21.2^a	1563±20.2^a	1566±19.6^a	1563±20.9^a
90 days of age	2157±20.3*	2020±17.5^a	2247±17.0^b	2217±16.5^b	2317±18.8^b	2050±18.9^a	2338±19.50^b	2379±19.7^b	2046±17.8^a	1983±21.8^a
120 days of age	2640±25.9*	2420±19.8^a	2881±18.9^b	2751±17.0^b	2947±19.8^b	2534±19.3^a	2857±16.5^b	2955±19.5^b	1265±17.5^b	2442±19.5^a
Daily body gain (g) at :										
60 days of age	25.8±1.2**	21.6±0.60^a	25.3±0.8^b	21.3±0.35^a	24.3±1.21^b	24.1±1.37^b	21.6±0.80^a	24.0±0.37^b	22.1±1.21^a	22.5±1.35^a
90 days of age	19.5±0.8**	15.7±1.20^a	23.0±1.3^b	22.2±0.80^b	25.8±1.3^b	16.2±0.93^a	26.0±0.87^b	27.2±1.11^b	16.0±1.42^a	14.0±1.33^a
120 days of age	16.1±2.1*	14.6±1.21^a	21.2±0.85^b	18.7±1.11^b	21.0±1.35^b	16.2±2.2^a	17.3±1.27^b	19.2±1.07^b	15.1±1.72^a	15.0±1.66^a
Dry matter intake (g) at :										
60 days of age	130+6.6**	84.9±5.31^a	92.8±3.25^a	83.0±4.305^a	88.2±6.28^a	89.7±4.23^a	83±6.28^a	87.5±3.75^a	80.1±6.8^a	82.3±4.59^a
90 days of age	139+4.2**	103±6.78^a	98.1±5.61^a	82.1±2.61^b	135±6.25^b	127.0±6.61^b	112.3±7.11^b	113±7.25^a	88.8±4.2^a	84.0±3.79^b
120 days of age	146+7.4**	96.9±8.27^a	97.4±6.62^a	83.5±2.4^b	114.6±3.2^b	107.0±6.12^a	98.8±4.10^a	102±5.27^a	84.5±6.2^a	82.0±8.57^a
Feed efficiency at:										
60 days of age	12.0+0.6	13.7±0.50^a	14.8±0.53^a	14.6±0.70^a	15.9±0.4^b	15.5±0.32^b	15.0±0.71^a	15.9±0.35^b	15.3±0.41^a	15.2±0.59^a
90 days of age	8.5+0.8	8.8±0.60a	12.4±0.71^b	13.7±0.65^b	11.1±0.45^b	7.4±0.45^a	13.4±0.53^b	14.0±0.75^b	8.8±0.41^a	9.7±0.71^a
120 days of age	7.8+0.9	8.7±0.55a	11.4±0.49^b	11.4±0.49^b	10.7±0.41^b	8.7±0.6^a	10.1±0.41^b	10.9±0.59^b	10.3±0.49^b	10.8±0.60^b
Daily water intake (ml) at:										
60 days of age	125.2+11.5**	265±12.35^a	238±15.25^a	226.9±15.25^a	320.3±13.25^b	277.9±17.2^a	287.3±16^a	302.1±18.75^a	332±12.3^b	225±10.25^b
90 days of age	152.1+4.8**	280±14.25^a	234±16.37^a	246±11.79^a	314.0±9.75^b	297.2±14.2^a	291.5±11.75^a	281.0±16.2^a	327.5±14.0^b	224±16.2^b
120 days of age	183.0+11.7**	310±8.7^a	236.3±14.2^b	251±10.25^b	348±15.30^b	318.0±16.20^a	317.8±9.81^a	321.0±16.3^a	341.8±10.3^b	209±9.8^b

Gross energy in the supplemented palm oil was added to the gross energy of concentrates

*Means within the same row between winter and summer-nonsupplemented group are significantly different ($P<0.05$)

** Means within the same row between winter and summer-nonsupplemented group are significantly different ($P<0.01$)

a, b Means within the same row between non-supplemented (control) and supplemented group (treatments) in hot summer conditions are significantly different ($P< 0.05$).

Table 4. Effects of nutritional, buffering, hormonal and physical amelioration techniques on rectal temperature, respiration rate and some blood metabolites of heat stressed New Zealand White rabbits.

Items	Winter	Summer								
		Non-suppl-emented group	Palm oil 5%	Palm oil 7%	$KHCO_3$ 1.25%	$KHCO_3$ 2.50%	Thyroxine 30 ug	Thyroxine 50 ug	Physical treatments Cool water	Physical treatments Shearing
Rectal temperature (C):										
60 days of age	38.6±0.03*	39.5±0.03^{a}	39.5±0.02^{a}	39.4±0.04^{a}	39.2±0.05^{a}	39.3±0.03a	39.6±0.05^{a}	39.5±0.02^{a}	38.8±0.05^{b}	39.0±0.02^{b}
90 days of age	38.5±0.05*	39.4±0.03^{a}	39.3±0.04^{a}	39.5±0.05^{a}	38.9±0.05^{a}	39.2±0.02a	39.4±0.04a	39.5±0.02a	38.5±0.05^{b}	38.7±0.03^{b}
120 days of age	38.5±0.06*	39.3±0.02^{a}	39.2±0.02^{a}	39.3±0.05^{a}	39.1±0.04^{a}	39.1±0.03a	39.3±0.03a	39.4±0.03a	38.4±0.04^{b}	38.4±0.04^{b}
Respiration rate (rpm) :										
60 days of age	115±6.2*	196±9.18^{a}	201±11.28^{a}	187±9.50^{a} a	171±11.2^{a}	188±9.7^{a}	172±5.5^{a}	187±7.2^{a}	125±7.7^{b}	138±7.7^{b}
90 days of age	121±8.7*	185±8.75^{a}	178±8.25^{a}	165±7.11^{a} a	148±15.6^{a}	191±8.2^{a}	168±9.7^{a}	150±5.7^{a}	143±3.7^{b}	150±3.2^{b}
120 days of age	105±7.7*	173±11.27^{a}	149±6.28^{a}	177±11.2^{a} a	165±7.2^{a}	153±6.2^{a}	169±6.6^{a}	162±3.9^{a}	123±8.6^{b}	141±5.9^{b}
Blood metabolites:										
Cholesterol (mg/ dl)	71.3±2.70*	55.6±2.31^{a}	43.1±3.4^{b}	45.9±2.65^{b}	42.8±3.02^{b}	38±2.61^{b}	41.5±4.25^{b}	37.5±3.18^{b}	47.3±4.25^{b}	61.3±5.38^{a}
HDL (mg/ dl	38.5±2.60*	34.0±1.21^{a}	26.2±3.72^{b}	28.5±3.33^{b}	26.4±1.76^{b}	19.2±0.08^{b}	25.1±1.76^{b}	22.4±0.92^{b}	31.0±3.7^{a}	32.2±2.77^{a}
LDL (mg/ dl)	24.1±1.80*	17.4±1.76^{a}	13.7±0.81^{b}	13.9±0.67^{b}	13.3±0.88^{b}	15.6±1.70^{b}	13.1±1.20^{b}	11.7±0.97^{b}	13.2±1.32^{b}	20.5±1.50^{b}
Triglycerides (mg/ dl)	19.5+0.9*	21.0±1.80^{a}	16.0±1.2^{b}	17.5±0.9^{b}	15.5±1.2^{b}	15.8±1.6^{b}	16.5±1.30^{b}	17.0±1.4^{b}	15.5±1.35^{b}	23.0±1.50^{a}
Phospholipids (mg/ dl)	81.4+3.7*	94.1±8.11^{a}	88.6±8.70^{a}	91.5±10.7^{a}	83.2±8.55^{a}	89.8±6.7^{a}	87.2±9.81^{a}	84.0±10.5^{a}	86.7±8.6^{a}	91.7±11.5^{a}
Total lipids (mg/dl)	141.8+8.7*	128.9±7.2^{a}	106.5±6.5^{b}	114.6±4.25^{b}	101.2±6.77^{b}	111.2±3.8^{b}	115.4±6.28^{b}	102±4.46^{b}	115±6.62^{b}	135±11.5^{a}
Albumin (g/ dl)	3.3+0.02*	3.1±0.03^{a}	3.3±0.11^{a}	3.4±0.06^{b}	2.6±0.45^{b}	2.8±0.08^{b}	3.6±0.17^{b}	4.3±0.32^{b}	2.6±0.26^{b}	3.3±0.33^{a}
globulin (g/dl)	4.0+0.04*	3.6±0.04^{a}	3.6±0.02^{a}	3.7±0.11^{a}	3.1±0.03^{b}	3.4±0.07^{b}	4.2±0.12^{b}	3.9±0.09^{b}	3.6±0.06^{a}	3.9±0.12^{b}
Total protein (g/dl)	7.3+0.30*	6.7±0.22^{a}	6.9±0.61^{a}	7.1±0.87^{a}	5.7±0.33^{b}	6.2±0.31^{a}	7.8±0.60b	8.2±0.65^{b}	6.2±0.37^{a}	7.2±0.35^{a}
Thyroxine (ug/dl)	4.8+0.07*	3.5±0.11^{a}	2.9±0.11^{b}	2.7±0.20^{b}	3.1±0.22^{b}	2.8±0.08^{b}	4.1±0.24^{b}	4.8±0.31^{b}	2.4±0.13^{a}	3.6±0.20^{a}
Soldium (meq/l)	174+8.90*	152±6.25^{a}	146±4.18^{a}	135±6.67^{a}	142±8.11^{a}	131±4.47^{b}	146±6.22^{a}	153±4.25^{a}	144±6.20^{a}	156±3.27^{a}
Potassium (meq/l)	5.3+0.04*	5.8±1.20^{a}	6.2±0.80^{a}	6.7±0.70^{a}	7.8±0.27^{b}	8.8±0.37^{b}	6.1±0.53^{a}	5.7±0.32^{a}	5.3±0.41^{a}	5.9±0.27^{a}

* Means within the same row between winter and summer-nonsupplemented group are significantly different ($P< 0.05$)

** Means within the same row between winter and summer non-supplemented group are significantly different ($P < 0.01$)

a, b Means within the same row between non-supplemented (control) and supplemented groups (treatments) in hot summer conditions are significantly different ($P< 0.05$).

hormone, cool drinking water and shearing treatments under hot summer conditions:

a. GROWTH PERFORMANCE:

Table 3 shows that treatment of heat stressed rabbits with palm oil increased ($P < 0.05$) each of LBW at 90 and 120 days of age with 5 or 7% level, DBG at 60 days of age with 5% level and at 90 or 120 days of age with the use of 5 or 7% level and FE either at 90 or 120 days of age with 5 or 7% level, and decreased ($P < 0.05$) each of DMI whether at 90 or 120 days of age with 7% level and DWI at 120 days of age due to supplementation of either 5 or 7% level.

Treatment of heat stressed rabbits with $KHCO_3$ increased ($P < 0.05$) each of DBG and FE at 60 days of age with 1.25% level, LBW, DBG and FE at 90 days of age with 1.25 or 2.5% level and at 120 days of age with 1.25% level.

Injection the heat stressed rabbits with thyroxine hormone increased significantly ($P < 0.05$) each of LBW, DBG and FE at 90 and 120 days of age with 30 ug T_4 / kg LBW, and LBW at 90 and 120 days of age and DBG and FE at all of ages studied with 50 ug T_4/ kg LBW.

Cool drinking water increased insignificantly LBW and significantly ($P < 0.05$) each of DMI at 90 and 120 days of age and FE at 120 days of age and DWI at all of ages studied.

Shearing of heat stressed rabbits decreased significantly ($P < 0.05$) each of DMI at 90 days of age and DWI at all ages studied and improved significantly ($P < 0.05$) FE at 120 days of age only.

b. RECTAL TEMPERATURE, RESPIRATION RATE AND HAEMOBIOCHEMICAL LEVELS:

Tabel 4 shows that under summer conditions, cool drinking water or shearing treatments decreased significantly ($P < 0.05$) RT and RR as compared with non-treated group. Supplementation heat stressed animals with palm oil decreased significantly ($P < 0.05$) each of cholesterol, HDL, LDL, triglycerides, total lipids and T_4 concentrations with either 5 or 7% level, while albumin concentration increased significantly ($P < 0.05$) by 7 % level.

Supplementation of heat stressed rabbits with $KHCO_3$ decreased significantly ($P<0.05$) each of total lipids and their fractions with either 1.25 or 2.50% level and plasma Na with 2.5% level, while plasma K increased significantly ($P < 0.05$) with 2.5% level.

Injection of T_4 to the heat stressed rabbits decreased significantly ($P<0.05$) each of total lipids and their fractions and increased significantly ($P<0.05$) each of total proteins, albumin, globulin and T_4 concentrations with 30 or 50 ug

T_4 /kg LBW.

Cool drinking water (10°C) declined significantly ($P < 0.05$) each of cholesterol, LDL, total lipids, albumin and total protein concentrations.

Shearing of the heat stressed rabbits increased significantly ($P<0.05$) globulin level only.

Discussion

1. Effect of hot summer conditions on feed and growth performances, rectal temperature, respiration rate and some haemobiochemical levels of NZW rabbits:

The significant decline in LBW in summer is mainly due to the decline in each of DMI and DBG (Table 3). The changes in metabolite levels and T_4 concentration (Table 4) are indicators of the disturbance in protein and lipids metabolism which also affected inversly DBG.

The high respiration rate at 60 days of age gradually decreased at 90 and 120 days of age. This may be largely due to gradual acclimation to prolonged heat conditions in summer. Elevation in respiration rate leads to an increase in body heat loss through respiratory water vaporization in order to minimize elevation in body temperature during heat exposure.

The significant decline in total lipids concentration is mainly related to the decrease in most lipid fractions levels, i.e. cholesterol, HDL and LDL (Table 4). The decrease in total protein level is paralleled with the significant decline in globulin level (Table 4). Similarly, the lack of T_4 concentration under hyperthermia conditions may confirm its involvement in the decline in blood protein biosynthesis (Table 4). On the other hand, haemodilution effect which mainly appeared as a result of the increase in DWI (Table 3) may contribute in the decline in most blood metabolites, plasma Na and T_4 levels. The decrease in T_4 level during hot summer conditions may be a result to the decrease in DMI (Johnson and Yeck, 1964; Habeeb *et al.*, 1993 and Table 4), that relates in part to the decrease in heat production which is correlated closely with changes of blood concentration of T_4, during hyperthermia conditions (Sano *et al.*, 1983).

2. Growth performance, RT, RR and some haemobiochemical levels of the heat stressed NZW rabbits as affected by nutritional (palm oil 5 or 7%), buffering agen ($KHCO_3$ 1.25 or 2.5%), hormonal (30 or 50 ug T_4 / kg LBW) and physical (cool drinking water or shearing) treatments:

a. PALM OIL TREATMENT:

The significant decrease in DMI with 20.29 and 13.80% at 90 and 120

days of age, respectively, with supplementation of palm oil at 7% and the significant improvement of FE with 5 or 7% palm oil may be results to the increase in gross energy intake which leads in turn to the increase in daily and body weight gain (Table 3). In addition, the increase of daily and body weight gains may be results to the increase of insulin level which increases with the increase of energy intake as reported by Waghorn *et al.* (1987). The decrease in DWI by palm oil tretment (Table 3) may be related to depression in DMI (Table 3) and digestibility of feed as reported by Devendra and Lewis (1974). The results which show the significant decline in plasma total lipids due to palm oil tretment (Table 4) were associated with those reported by PORIM (1987) and may be explained through the decrease in most of lipid fractions i.e. cholesterol, lipoproteins, triglycerides and phospholipids (Table 4). Particularly, depression in plasma cholesterol may be attributed to direct effects of some fatty acids of the palm oil i.e. oleic acid (37%) and linolic acid (9.3%) as a mono and poly-unsaturated fatty acids, respectively, on cholesterol biosynthesis as reported by PORIM (1987). The negative response of the thyroid gland to palm oil supplementation may be considered as physiological action towards the decrease in heat production, since T_4 level may partly decrease with the increase in energy density as reported by Sano *et al.* (1983).

b. POTASSIUM BICARBONATE TREATMENT:

The singificant increase in DBG and LBW by 1.25% $KHCO_3$ supplementation may be a response to increase in DMI and FE (Table 3), since 1.25% $KHCO_3$ stimulate the appitie and fibre digestibility (Erdman *et al.*, 1980) and improve FE (Maglad *et al.*, 1987), prevent depression in rumen pH (Snyder *et al.*, 1983) and elevate volatile fatty acids production (Erdman *et al.*, 1980). The significant increase in DWI with 1.25% $KHCO_3$ (Table 3) could be mostly considered as a function of the increase in turnover rate of liquid in the digestive tract as reported by Thosmon *et al.*, (1978). The significant decline in triglycerides (Tabel 4) was similar to that obtained by Escobosa and Coppock (1984) when treating dairy cattle with $NaHCO_3$. The reduction ($P < 0.05$) in most of the other blood metabolites, except plasma K levels as a response to 1.25% $KHCO_3$ Rumen and fecal responses of lactating supplement may be mainly a result to haemodilution effects, since the animals recorded high ($P < 0.05$) water intake (Table 4). The decline in plasma protein, albumin and globulin concentrations with addition of $KHCO_3$ (Table 4) may be attributed to the decline in ruminal ammonia (Synder, 1981) by HCO_3 buffer. The increase ($P< 0.05$) in plasma K level

may be mainly a result to the increase in k intake from $KHCO_3$ which may be accompanied with retention most K ions in the animal's body, since the daily K requirement is raised in heat stressed animals because of the increased K loss via urine and faeces as reported by Kamal (1975) and Kamal *et al.* (1984).

c. THYROXINE HORMONE INJECTION TREATMENT:

The increase in daily and body weight gain with T_4 injection (Table 3) may be due to the fact that T_4 stimulates protein synthesis and increases each of nitrogen retention, sensitivity of tissues to GH (Ingbar and WOEber, 1981), GH level and stimulates GH-mRNA synthesis (wood *et al.,* 1987). The decrease in lipid fractions in heat stressed T_4 injected rabbits (Tabel 4) was in agreement with the results of Engelken *et al.* (1980) who found in rats that plasma cholesterol concentration was progressively reduced with increasing thyroid hormone levels altogether with alterations of lipoproteins and triglycerides metabolism. On the other hand, Lutton *et al.* (1980) reported that L-thyroxine injection strongly enhances jejunal excretion of plasma cholesterol which leads to two fold increase of fecal cholesterol excretion, leading to a marked reduction in plasma cholesterol. The increase in plasma total proteins and albumin concentrations as a function of T_4 injection treatment may be considered as a response to the increase in the regulators of GH-mRNA and GH synthesis (Wood *et al.,* 1987) which had a major role in the movement of amino acids and peptides transport and subsequently blood and body proteins anabolism. The significant rise in plasma T_4 level by T_4 injection in the heat stressed rabbits (Table 4) may be a result to the presence and release of some T_4 molecules into blood stream.

d. COOL DRINKING WATER TREATMENT:

The significant depression in RT and RR due to cool drinking water means that it is an excellent cooling agent because of its high heat capacity and high latent heat vaporization (Anonymous, 1962). On the other side, cool drinking water may have been meditated by cooling the area of the hypothalamus expressed by depression in tympanic membrane temperatures (Milam *et al.,* 1986), which reflected a reduction in both RT and RR. The significant rise of DWI was accompanied by decrease in concentrates intake which was reflected in hte insignificant increase in each of FE and daily and final body weight gains (Table 3). The depression respectively, in DMI by 13.78 and 12.79% of 90 and 120 days of age with 10°C drinking cool water may be attributed to the interrelationships

among feed or energy intake and water consumption and heat production, since the high water consumption leads to the subsequent decline in feed or energy intake and small heat production as reported by Loftgreen *et al.* (1975).

Considering blood metabolites (Table 4), the changes in both total lipids and protein concentrations are paralleled with the levels of their fractions. In addition the decline in DMI due to cool drinking water may affect lipids and protein levels. The decline in plasma T_4 level as a response to drinking cool water (Table 4) may be a result to the depression in heat production, since heat production during heat exposure relates in part to the decrease of blood T_4 concentraiton as reported by Sano *et al.* (1983). Haemodilution effect due to the increase in water intake (Table 3) may also contribute in such decline in T_4 level.

e. SHEARING TREATMENT:

The significant depression in both RT and RR as a function of shearing of heat stressed rabbits may be explained through that shearing enables rabbits to store less heat in their hair from the surrounding environment and to dissipate more heat from the body surface.

Conclusively, since the final body weight is the end and economic product in rabbit meat production, it can be stated that at 90 days of age, rabbits maintained under hot summer conditions of Egypt and injected with 50 or 30 ug T_4 / kg LBW showed the highest increase in LBW (17.77 and 15.74%, respectively) follwed by 1.25% $KHCO_3$ (14.7%) and the lowest increase was produced by 5 or 7% palm oil (11.23 and 9.75%, respectively) treatments. At 120 days of age, the highest final LBW was obtained by injection 50 ug T_4 per kg LBW (22.10%), followed by 1.25% $KHCO_3$ (21.77%), 5% palm oil (19.04%), 30 ug T_4 / kg LBW (18.05%), 7% palm oil (13.67%) and cool drinking water (5.99%), respectively.

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