EFFECT OF SALTS ADDITIVE TO DIET OF RAMS EXPOSED TO SOLAR RADIATION DURING SUMMER ON THERMO-HEMATO-RESPIRATORY FUNCTIONS.

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SUMMARY

Fifteen Farafra mature rams were divided into five equal groups (3 rams per group) according to their age and initial body weight. The animals exposed to solar radiation 3 hours daily during the period from 15th July to 30th August. The 1st group was control, and the other four groups were treated with different salts including 1% sodium bicarbonate (T_1), 1% potassium carbonate (T_2), 0.5% sodium bicarbonate + 0.5% potassium carbonate (T_3) and 1% sodium bicarbonate + 1% potassium carbonate (T_4). Thermal responses parameters, blood parameters and respiratory activities were determined only at the end of the experimental period before (11-12 am) solar exposure and after (3-4 pm) 3 hours of solar exposure to investigate the cumulative effect of dietary salts for 45 days. The results indicated that treated animals recorded a significantly ($P<0.05$) lower rectal temperature, skin temperature and decreased ear temperature before and after solar exposure, respectively. Dietary salts supplementation decreased ($P<0.05$) blood hematocrit values before and after solar exposure. In addition, dietary salts supplementation led to significantly ($P<0.05$) increase of serum glucose and total protein before and after solar exposure in comparison with control animals. Also, treated animals showed significantly ($P<0.05$ or $P<0.01$) higher serum sodium, potassium, dietary electrolyte balance and slightly increased serum thyroid hormones concentration before and after solar exposure as was compared to the control group. At the same time, dietary salts decreased slightly serum chloride concentration. As well as, treated animal illustrated significantly ($P<0.05$ or $P<0.01$) lower respiration rate, respiratory quotient and carbon dioxide production, while gas volume, tidal volume and oxygen consumption increased significantly ($P<0.05$) before and after solar exposure. According to the results of the present study it can be concluded that dietary salts led to alleviate body temperature by decreasing rectal and skin temperature and also, affect beneficially the dietary electrolyte balance and gas exchange parameters.

Keywords: *Blood parameters, respiratory activities, dietary salts, solar exposure.*

INTRODUCTION

Egyptian sheep breeds suffered from heat stress, particularly the animals which live in hot regions like the deserts and Upper Egypt environments. The homeostasis of the animals disrupts as a result of high temperature and humidity by evoking thermal regulatory reactions. These reactions include redistributed blood supply and increased heat loss *via* increasing respiration rate and sweating. Accelerated respiration rate caused respiratory alkalosis and apparently compensated metabolic acidosis, change the demand for sodium (Na) and potassium (K) during heat stress (Sanchez *et al.*, 1994). Additionally, chloride contributes the body acid-base balance. Along with sodium, potassium and carbon dioxide, it is important in evaluating acid base relationship, state of hydration, adrenal and renal functions. Additionally, the adverse effect of heat stress on some thermal responses (rectal, skin and ear temperature) of animals during solar exposure was reported by several authors (Silanikove, 2000; Abd El Khalek, 2002 and Beatty *et al.*, 2007).

Also, the adverse effect of heat stress on respiratory activities (respiration rate and respiratory quotient) and on gas change (gas volume, tidal volume, oxygen consumption and carbon dioxide production) under solar exposure and heat stress were investigated in animals by several investigators (Ibrahim, 2000; and Tsigos and Chrouso, 2002). Many of these investigations have been done during heat stress conditions but not during solar exposure condition. Limited information is available regarding the effect of dietary electrolytes on physiological and thermal responses of sheep. Therefore, the aim of this study was to investigate the effect of using some salts (sodium or potassium or both) on thermal responses, blood parameters and respiratory activities of solar exposed sheep.

MATERIALS AND METHODS

This study was carried out in Minia Governorate, Mallawi Experimental Station, Animal Production Research Institute (APRI), Agriculture Research Center (ARC), Ministry of Agriculture during the period from 15th July to 30th August.

Experimental design:

A total of fifteen Farafra mature healthy rams (aged 2.0-3.0 years old with average body weight of 59.3 ± 1.30 kg of body weight) were used in this investigation. Rams were divided into five equal groups (3 rams per group) as control, 1% sodium bicarbonate (T_1), 1% potassium carbonate (T_2), 0.5% sodium bicarbonate + 0.5% potassium carbonate (T_3) and finally 1% sodium bicarbonate + 1% potassium carbonate (T_4) groups. Animals were fed according to NRC (1985). Salts additives represent as a percent of daily dry matter intake from concentrate mixture and wheat straw. The concentrate mixture was mixed with the salt additives. Feed samples were analyzed for major electrolytes (Na, K and Cl) before the beginning of the experiment. Animals were fed these mixtures for 45 days and during this period the animals exposed to direct solar radiation. On the day of solar exposure the rams did not received feed and drinking water. Thermal responses parameters, blood samples collections and respiratory activities measurements were performed before solar exposure (11-12 a.m) and after three hours of solar exposure (3-4 p.m) to determine the cumulative effect of dietary salts for 45 days on thermal responses, blood parameters and respiratory activities under solar exposure conditions.

Ambient temperature and relative humidity were recorded before and after solar exposure using the conventional methods.

Data collected:

Rectal temperature (RT, °C) was measured using a clinical thermometer before and after solar exposure. Skin temperature (ST, °C) and ear temperature (ET, °C) was measured using portable infrared thermometer produced by Radioshack company designed for temperature measurements. Temperature Humidity Index (THI) was calculated from the ambient temperature (AT) and relative humidity (RH) according to Hahn *et al.* (2003):

THI= [(TDB*1.8) +32]-[(0.55*(RH/100)*(TDB*1.8) +32]-58.

Where: TDB = Dry bulb temperature in °C, RH = Relative humidity in %.

Blood samples (10 ml) were collected from all rams before and after exposure to solar radiation via jugular vein. The blood samples were divided into two parts (heparinized and non-heparinized). Heparinized blood samples were used for measuring hematocrit (Ht). Hematocrit value (Ht) was measured in micro hematocrit capillary tubes using a hematocrit centrifuge at 3000 r.p.m. for 15 minutes according to Schalm, (1986).

Non heparinized blood samples were centrifuged at 3000 rpm for 15 minutes and serum was collected and stored at –20°C for metabolites and hormonal assay. Serum total protein and glucose concentration were measured by a colorimetric method using commercial kits produced by Stanbio Company according to Patton and Crouch (1977), Fawcett and Soctt (1960) and Henry (1984), respectively. Serum sodium and potassium were determined using commercial kits produced by Biodiagnostic Company according to Trinder (1951).While serum chloride was determined by a colorimetric method using commercial kits produced by Dialab Company according to Skeggs and Hochstrasser (1964).

Direct radioimmunoassay (RIA) technique was performed for determination of serum thyroid hormones. The Coat-A-Count T_3 kits produced by Diagnostic Products Corporation (U.S.A) were used for the determination of serum triiodothyronine according to Bates (1974). The Coat-A-Count kits produced by Diagnostic Products Corporation (U.S.A) were used for the determination of serum thyroxine according to Albertini (1982).

Respiratory activities and gas exchange were determined for solar exposed rams individually. Respiration rate was expressed as the number of breaths per minute and was measured by counting the flank movements in one minute. Respiratory minute volume of exhaled air/minute was measured by Dry Gas Meters (liters) and gas volume was corrected to Standard Dry Temperature and Pressure (STPD) according to Yousef and Dill (1969). The volume of oxygen consumption (VO_2), carbon dioxide production (VCO_2) and respiratory quotient (RQ %) were measured with the open-circuit technique. Oxygen consumption was calculated from the oxygen deficit in expired air obtained from oxygen analyzer (Servomex 570). The rate of carbon dioxide production was calculated from the VCO_2 deficit in expired air obtained from infrared Gas Analyzer (Model-AR-411). The expired air was passed through over dried calcium chloride to prevent water vapor from entering the gas analyzer cells. The true % of VO_2 and VCO_2 were calculated. The volumes of VO_2 consumption and VCO_2 production were determined. Respiratory Quotient (RQ) was calculated using the equation of Consolazio *et al.*, (1963) as follows:

Percentage of true VO_2 = 0.265 (100-%VO_2 in expired air + %VCO_2 in expired air)-%VO_2 in expired air.
Volume O_2 consumption = GV (STPD) x % true O_2/100
Percentage of true VCO_2 = % VCO_2 in expired air- % CO_2 in inspired air.
Volume CO_2 production = GV (STPD) x % true VCO_2/100.
RQ= vol. CO_2 production/vol. O_2 consumption.

Tidal volume was calculated by dividing the respiratory minute volume (GV) STPD by the respiration rate per minute. TV = GV 1/RR r.p.m.

Statistical analysis:

Statistical analyses were carried out using SPSS 11.0 for Windows (SPSS Inc., Chicago, IL). ANOVA was used to test the effect of treatment. L.S.D (least significant difference) was used to test the significance among treatments. The following model was used in ANOVA:

$Y_{ij} = \mu + T_i + E_{ij}$ Where,
Y_{ij} = Experiment observations.
μ = Overall mean.
T_i = The effect of dietary treatments.
E_{ij} = The experimental error.

RESULTS AND DISCUSSION

Meteorological data:

Table (1) showed the data of climatic condition. The results indicated that during the experimental period the mean values of the ambient temperature at 11-12 a.m before solar exposure and 3-4 p.m. after solar exposure were 34.74 ± 0.43 and 41.24 ± 0.25 °C, respectively. The mean values of relative humidity at the same time were 42.28 ± 1.24 and 21.25 ± 1.26%, respectively. Thus the temperature humidity indexes (THI) at 11-12 a.m. before solar exposure and at 3-4 p.m. after solar exposure were 86.03 ± 1.24 and 100.84 ± 0.95, respectively.

Dietary electrolyte balance (DEB):

Table (2) showed the values of dietary electrolyte balance calculated according to Mongin (1980) as millequivallents per kilogram of feed DM. The values were 154, 246, 276, 257 and 407 mEq/kg of DM for control, T1, T2, T3 and T4 groups respectively. The difference in DEB for different diets was due to the supplementation of sodium and potassium salts, which used in our investigation.

Table (1). Changes in meteorological data during exposure of rams to heat stress (M ± SE)

Weeks	Ambient temperature °C		Relative humidity %		Temperature humidity index	
	a.m (11-12)	p.m (3-4)	a.m (11-12)	p.m (3-4)	a.m (11-12)	p.m (3-4)
1st	33.86 ± 0.52	40.18 ± 0.18	42.5 ± 1.28	20.5 ± 1.15	84.3 ± 1.12	100.28 ± 0.63
2nd	34.08 ± 0.34	40.48 ± 0.19	41.5 ± 1.03	19 ± 0.94	85.6 ± 1.14	99.45 ± 1.12
3rd	35.00 ± 0.54	40.53 ± 0.35	42.5 ± 1.18	23.5 ± 1.17	86.4 ± 0.89	100.29 ± 1.19
4th	35.01 ± 0.30	41.82± 0.22	41.5 ± 1.12	22 ± 1.39	87.0 ± 1.34	101.5 ± 0.82
5th	35.23 ± 0.45	41.93± 0.20	42 ± 1.81	21 ± 1.26	86.4 ± 1.42	101.39 ± 0.49
6th	35.29 ± 0.42	42.49 ± 0.33	43.5 ± 1.09	21.5 ± 1.46	86.5 ± 1.49	101.89 ± 1.51
Overall mean	34.74 ± 0.43	41.24 ± 0.25	42.28 ± 1.24	21.25 ± 1.26	86.03±1.24	100.84 ± 0.95

Table (2):- Electrolytes mineral content of experimental diets.

groups	Electrolytes content			
	Na^+ (%)	K^+ (%)	Cl^-(%)	DEB (mEq/kg of feed DM)
Control	0.297	0.523	0.563	154
T_1	0.567	0.523	0.653	246
T_2	0.297	1.088	0.563	276
T_3	0.432	0.806	0.563	257
T_4	0.567	1.088	0.563	407

T_1: (1% Sodium bicarbonate), T_2: (1% Potassium carbonate), T_3: (0.5% Sodium bicarbonate + 0.5% Potassium carbonate),
T_4: (1% Sodium bicarbonate + 1% Potassium carbonate).
DEB: Dietary Electrolyte Balance calculated as milliequivalents of (Na + K – Cl) per kilogram of feed DM.

Thermal responses:

1. ***Rectal temperature (RT):***

The effect of addition dietary salts in diets of solar exposed rams on rectal temperature before and after solar exposure is shown in Table (3). The results indicated that dietary salts reduced significantly (P<0.05) rectal temperature before and after solar exposure. There were no significant differences in rectal temperature among groups fed dietary salts before and after solar exposure.

Exposure to high environmental temperature has been reported to increase body temperature of either Merino rams (Hales and Brown 1974). There was no data available about the effect of dietary electrolytes on solar exposed rams, but these results are in line with those obtained Coppock *et al.*, (1982). They supplemented dairy cattle with sodium bicarbonate salts and found that cows fed sodium bicarbonate had lower body temperature than the control group. On the other hand, **West *et al.*, (1992)** studied the effect of dietary different levels of DEB on the body temperatures of dairy cows during heat stress. They found that body temperatures were not significantly differed between treatments.

2. ***Skin temperature (ST):***

The effect of dietary salts in diets of solar exposed rams on skin temperature before and after solar exposure is presented in Table (3). The results indicated that dietary salts reduced significantly (P<0.05) skin temperature before and after solar exposure in comparison with control group. Shalaby and Johnson (1993) found that skin temperature significantly increased with increasing ambient temperature. In addition, Khalifa *et al.*, (2000) found in goats, that exposure to solar radiation increased significantly (P<0.01) ST by 1.0°C.

Table (3). Effect of dietary salts on thermal responses of Frafra rams before and after solar exposure.

Parameters	Time	Treatments					Sig.
		Control	T_1	T_2	T_3	T_4	
Rectal temperature (C^0)	B.S.E	39.56^{a} ± 0.03	39.30^{b} ± 0.05	39.37^{b} ± 0.05	39.30^{b} ± 0.05	39.27^{b} ± 0.06	*
	A.S.E	39.73^{a} ± 0.07	39.53^{b} ± 0.03	39.62^{b} ± 0.04	39.50^{b} ± 0.04	39.56^{b} ± 0.03	*
Skin temperature (C^0)	B.S.E	35.09^{a} ± 0.24	34.17^{b} ± 0.16	34.06^{b} ± 0.08	34.21^{b} ± 0.21	34.18^{b} ± 0.09	*
	A.S.E	37.67^{a} ± 0.05	36.80^{b} ± 0.21	36.61^{b} ± 0.23	36.81^{b} ± 0.25	36.82^{b} ± 0.21	*
Ear temperature (C^0)	B.S.E	34.65^{a} ± 0.09	34.30^{b} ± 0.08	34.11^{b} ± 0.09	34.35^{b} ± 0.19	34.31^{b} ± 0.21	*
	A.S.E	37.43 ± 0.24	37.33 ± 0.29	37.10 ± 0.76	37.23 ± 0.16	37.28 ± 0.17	NS

^{a,b} Similar letters in the same raw indicated that there was no significant difference between treatments.

*T_1: (1% Sodium bicarbonate), T_2: (1% Potassium carbonate), T_3: (0.5% Sodium bicarbonate + 0.5% Potassium carbonate), T_4: (1% Sodium bicarbonate + 1% Potassium carbonate). DEB: Dietary Electrolyte Balance., *: Significant ($p<0.05$), NS: Non - Significant. B.S.E: Before solar exposure, A.S.E: After solar exposure.*

It is well known that the initial response of the animal to heat stress is increasing vasodilatation, which increases skin blood flow and resulted in increasing skin temperature. This beneficial effect of dietary electrolytes in alleviating body temperature may affect the temperature sensitive neurons, which is located in the pre-optic area of the hypothalamus and skin to regulate vasodilatation and decrease skin temperature (Yousef, 1985).

3. Ear temperature (ET):

The results for the effect of dietary salts and solar radiation on ram's ear temperature before and after solar exposure are shown in Table (3). Generally, dietary salts decreased significantly ($P<0.05$) rams ear temperature before solar exposure, however there was a slight decrease in ear temperature of rams after solar exposure compared to control group.

No data was available about effect of dietary electrolytes on ear temperature; but Khalifa *et al.*, (2000) found in goats, that exposure to solar radiation increased significantly ($P<0.01$) ET by 3.0°C. They explained that the increase in ET under heat stress indicating the occurrence of vasodilatation to facilitate in heat loss.

Effect of dietary electrolytes on some blood parameters of rams during solar exposure:

1. Blood hematocrit value (Ht):

Means for the effect of dietary salts on blood Ht of rams before and after solar exposure are presented in Table (4). The results showed that dietary salts decreased significantly ($P<0.05$) rams blood Ht before and after solar exposure. In other study, Ht decreased with exposure to solar radiation or to high ambient temperature (Ashour and Shafie, 1993). These results may be due to hemodilution or overhydration under solar exposure, which resulted in increasing plasma and interstitial fluids or may be resulted from the increase of water intake under hot conditions resulted from salts addition and heat stress to overcome the increase in sweating rate. These results are partly agreed with Escobosa *et al.*,(1984). Who found that increasing level of dietary cation anion balance (DCAD) decreased insignificantly blood Ht. The highest value of blood Ht in the control group may indicated that salts groups increased plasma volume to overcome the effect of salts on tissues. Kume *et al.*, (1998) reported that blood Ht of heifers was increased by heat stress. However, the addition of electrolytes alleviated the effect of heat stress.

2. Serum components:

Means for the effect of dietary salts on blood serum glucose of rams before and after solar exposure are presented in Table (4). The results showed that dietary salts increased significantly ($P<0.05$) blood serum glucose of salts rams before and after solar exposure compared with control. Serum glucose values before solar exposure increased by 9.11, 9.02, 9.06 and 10.74% for T_1, T_2, T_3 and T_4, respectively as compared to the control group. After solar exposure, serum glucose values increased by 11.87, 14.83, 11.90 and 13.76% for T_1, T_2, T_3 and T_4, respectively in comparison with the control group. However, there were no significant differences among supplemented groups. These results may be indicated that groups which received electrolytes suffer lesser from heat stress than the control group. The present results were in accordance

Table (4). Effect of dietary salts on some blood parameters of rams before and after solar exposure.

Parameters	Time	Treatments					Sig.
		Control	T_1	T_2	T_3	T_4	
Hematocrit (%)	B.S.E	$33.66^{a} \pm 0.53$	$30.65^{b} \pm 0.41$	$31.06^{b} \pm 0.46$	$30.45^{b} \pm 0.49$	$30.10^{b} \pm 0.65$	*
	A.S.E	$33.32^{a} \pm 0.54$	$30.31^{b} \pm 0.42$	$30.01^{b} \pm 0.46$	$30.66^{b} \pm 0.49$	$31.20^{b} \pm 0.65$	*
Glucose (mg/dl)	B.S.E	$70.14^{b} \pm 0.33$	$76.53^{a} \pm 0.40$	$76.47^{a} \pm 0.62$	$76.50^{a} \pm 0.41$	$77.68^{a} \pm 0.96$	*
	A.S.E	$67.28^{b} \pm 0.33$	$75.24^{a} \pm 0.39$	$77.26^{a} \pm 0.62$	$75.29^{a} \pm 0.41$	$76.54^{a} \pm 0.96$	*
Total Protein (g/dl)	B.S.E	$6.24^{b} \pm 0.08$	$6.43^{a} \pm 0.19$	$6.47^{a} \pm 0.12$	$6.40^{a} \pm 0.14$	$6.84^{a} \pm 0.23$	*
	A.S.E	$6.35^{b} \pm 0.39$	$6.58^{a} \pm 0.24$	$6.68^{a} \pm 0.19$	$6.86^{a} \pm 0.33$	$6.74^{a} \pm 0.37$	*
Sodium (mEq/l)	B.S.E	$136.84^{c} \pm 0.96$	$147.07^{b} \pm 1.41$	$145.83^{b} \pm 0.91$	$145.33^{b} \pm 1.74$	$150.83^{a} \pm 0.95$	**
	A.S.E	$126.48^{c} \pm 1.18$	$139.75^{b} \pm 1.81$	$136.29^{b} \pm 0.54$	$134.48^{b} \pm 1.91$	$135.15^{a} \pm 0.91$	*
Potassium (mEq/l)	B.S.E	$5.74^{b} \pm 0.14$	$6.49^{a} \pm 0.06$	$6.60^{a} \pm 0.33$	$6.50^{a} \pm 0.08$	$6.91^{a} \pm 0.21$	*
	A.S.E	$5.35^{b} \pm 0.06$	$6.33^{a} \pm 0.15$	$6.37^{a} \pm 0.14$	$6.21^{a} \pm 0.58$	$6.67^{a} \pm 0.37$	*
Chloride (mEq/l)	B.S.E	99.50 ± 1.02	94.12 ± 1.19	92.49 ± 1.35	94.74 ± 0.31	93.21 ± 0.60	NS
	A.S.E	97.74 ± 2.15	92.36 ± 2.82	92.24 ± 1.57	92.39 ± 1.03	92.62 ± 1.65	NS
DEB (mEq/l)	B.S.E	$43.09^{b} \pm 1.70$	$59.44^{a} \pm 1.71$	$59.97^{a} \pm 2.26$	$55.08^{a} \pm 2.01$	$64.55^{a} \pm 1.02$	*
	A.S.E	$34.09^{b} \pm 1.21$	$53.71^{a} \pm 1.41$	$50.39^{a} \pm 0.61$	$49.29^{a} \pm 2.34$	$49.24^{a} \pm 2.39$	*
Thyroxin (μg/dl)	B.S.E	2.19 ± 0.01	2.24 ± 0.04	2.20 ± 0.05	2.23 ± 0.11	2.24 ± 0.07	*NS*
	A.S.E	2.15 ± 0.02	2.19 ± 0.07	2.13 ± 0.04	2.16 ± 0.18	2.15 ± 0.09	*NS*
Triiodothyronine (ng/dl)	B.S.E	128.88 ± 1.25	129.20 ± 1.55	129.66 ± 1.20	129.82 ± 1.09	130.73 ± 1.18	NS
	A.S.E	127.19 ± 2.03	128.28 ± 1.06	128.39 ± 1.13	127.98 ± 1.33	127.69 ± 1.02	NS

[a,b,c] Similar letters in the same raw indicated that there was no significant difference between treatments.

*T_1: (1% Sodium bicarbonate), T_2: (1% Potassium carbonate), T_3: (0.5% Sodium bicarbonate + 0.5% Potassium carbonate), T_4: (1% Sodium bicarbonate + 1% Potassium carbonate). DEB: Dietary Electrolyte Balance., *: Significant ($p<0.05$), **: Significant ($p<0.01$), NS: Non - Significant. B.S.E: Before solar exposure, A.S.E: After solar exposure.*

with Escobosa *et al.*, (1984), who studied the effect of dietary sodium bicarbonate in the diet of cows during summer on blood glucose. They reported that the increase of blood glucose may be due to higher feed intake in high sodium bicarbonate group. On the other hand, Vicini *et al.*, (1987) and Belibasakis (1990) in cows and Rizzi *et al.*, (2004) in rabbits found that changing dietary cation anion difference (DCAD) levels in the diet did not significantly affected blood glucose concentration.

Serum total protein of rams before and after solar exposure are presented in Table (4). The present results showed that dietary salts increased significantly ($P<0.05$) blood serum total protein of rams before and after solar exposure as compared to the control group. Serum total protein has a particular importance in maintaining blood volume. Cunningham (2002) reported that proteins are playing role in intracellular buffers within the body tissues to provide a reserve buffering capacity. This indicates that increasing serum total protein concentrations by dietary electrolytes had a beneficial effect on acid base balance. The increase in the values of serum total protein, which come from dietary electrolytes in the present study may be beneficial to maintain the osmotic pressure. Kamal (1982) reported that during heat stress an increase in plasma total protein occurred to match colloid osmotic pressure. At the same time, Khalifa (1982) suggested that the increase in plasma total protein of sheep during heat stress caused an increase in plasma colloid osmotic pressure, which may help the animal to conserve water. On the other hand Cheirecato et al., (2003); Rizzi et al., (2004) in rabbits and Belibasakis (1990) in dairy cattle reported that the addition of electrolytes in diets had no significant effect on blood concentrations of total protein.

Means for the effect of dietary salts on rams serum sodium before and after solar exposure are presented in Table (4). The results showed that addition of salt to diet of rams increased significantly ($P<0.01$) serum sodium before solar exposure and increased significantly ($P<0.05$) serum sodium after solar exposure. Serum sodium values before solar exposure increased by 7.47, 6.56, 6.20 and 10.22% for T_1, T_2, T_3 and T_4, respectively compared to the control group. After solar exposure, serum sodium content increased by 10.49, 7.75, 6.32 and 6.85% for groups T_1, T_2, T_3 and T_4, respectively in comparison with the control treatment. However, there were no significant differences among salt supplemented groups. The present results indicated that the addition of salts, which contain sodium in the diet will led to increase circulating blood Na concentrations and it may have a beneficial effect to cover the loss of Na through renal excretion during heat stress conditions. These results are in agreement with those reported by Haydon *et al.*, (1990) and West *et al.*, (1992). On the other hand, on bucks Rizzi *et al.*, (2004) found that dietary electrolytes did not significantly affect plasma Na. Similar results obtained by Belibasakis (1990); Delaquis and Block (1995) and Chan *et al.*, (2005). Also, Mohammed (2005) noticed that alteration in DCAD in the diet of cattle did not affect significantly the concentrations of serum sodium

The effects of dietary electrolytes on serum potassium of Farafra rams before and after solar exposure are presented in Table (4). The results showed that dietary salts increased significantly ($P<0.05$) serum potassium before solar exposure. Abd El-Khalek (1997) found that there were non-significant differences between summer and winter concerning plasma Na^+, K^+ and aldosterone. The present results indicated that the addition of potassium salts in diets led to elevated circulating K. The supplementation of potassium salts was beneficial to preventing the severe losing of this ion during sweating. The present results are in line with those of West *et al.*, (1992) who studied the effect of changing dietary cation anion difference (DCAD) on dairy cows serum K and reported that serum K was increased significantly with increasing DCAB.

The effects of dietary electrolytes on serum chloride of rams before and after solar exposure are presented in Table (4). The results showed that dietary salts slightly reduced serum chloride before and after solar exposure. It is proven that losing HCO_3 caused a relative increase in blood Cl. So the control animals were suffering from metabolic acidosis. Similar results were obtained by Roche *et al.*, (2003) and Mohammed (2005). On the other hand, Delaquis and Block (1995) found that reducing dietary cation anion difference DCAD had no effect on plasma Cl concentrations of dairy cows at any sampling time. Additionally, similar results were obtained by Rizzi *et al.*, (2004) on rabbits and Chan *et al.*, (2005) in cattle.

The effects of dietary salts on serum electrolyte balance (DEB) of rams before and after solar exposure are presented in Table (4). The results showed that dietary salts increased significantly ($P<0.05$) serum electrolyte balance before and after solar exposure. Serum DEB values before solar exposure increased by 37.94, 39.17, 27.82 and 49.80 % for T_1, T_2, T_3 and T_4, respectively compared to the control treatment. While, after solar exposure, serum EB values were increased by 57.55, 47.81, 44.58 % and 44.44% for groups T_1, T_2, T_3 and T_4, respectively in comparison with the control treatment. However, there were no significant differences among supplemented groups. The addition of sodium and potassium salts in the diets led to increasing DEB resulting in improving of blood buffering capacity during heat stress. These results are in agreement with those noticed by findings of Haydon *et al.*, (1990). They observed that blood SEB was increased linearly as dietary EB increased in swine under heat stress. A linear increase in serum EB as a result of dietary DEB increase was also supported by West *et al.*, (1992) in heat stressed cows. Also, Mohammed (2005) found similar results in dairy cattle.

Data of serum thyroid hormones concentration in rams before and after solar exposure are illustrated in Table (4).The results indicated that dietary salts had no marked effect on serum thyroid hormone levels in comparison with control treatment either before after solar exposure. The slight increase of thyroid hormones may be an indicator of increasing carbohydrate, protein and fat metabolism, which resulted from alleviating heat stress. These results are in a harmony with Vicini *et al.*, (1987), who studied the effect of 2% sodium bicarbonate in the diet of dairy cows on plasma thyroid hormones. They found not significant increase of thyroid hormones concentration in sodium bicarbonate group. Meanwhile, Cheirecato *et al.*, (2003) reported that plasma levels of thyroid hormones in rabbits were not significantly influenced by high dietary DEB level. Also, Rizzi *et al.*, (2004) found that dietary electrolyte balance did not substantially modify the thyroid hormone profile of the bucks.

Effect of dietary salts on respiratory activities and gas exchange:

Data for the effect of dietary salts on respiration rate of solar exposed rams are shown in Table (5). The results indicated that respiration rate was decreased significantly ($P<0.05$) by dietary salts before and after solar exposure. Before solar exposure, the values

Table (5). Effect of dietary salts on respiratory activities of rams before and after solar exposure.

Parameters	Time	*Treatments*					Sig.
		Control	T_1	T_2	T_3	T_4	
Respiration rate (breathes / minute)	B.S.E	$62.11^a \pm 1.12$	$53.66^b \pm 2.12$	$53.30^b \pm 2.60$	$54.12^b \pm 2.08$	$54.55^b \pm 1.76$	*
	A.S.E	$132.66^a \pm 1.20$	$117.05^b \pm 2.60$	$119.21^b \pm 1.90$	$114.21^b \pm 1.57$	$112.15^b \pm 3.25$	*
Gas volume (L/minute)	B.S.E	$5.79^b \pm 0.03$	$6.07^a \pm 0.04$	$6.04^a \pm 0.06$	$6.03^a \pm 0.07$	$6.01^a \pm 0.06$	*
	A.S.E	$6.33^b \pm 0.01$	$6.51^a \pm 0.02$	$6.45^a \pm 0.04$	$6.47^a \pm 0.05$	$6.46^a \pm 0.03$	*
Tidal volume (ml/breath)	B.S.E	$93.51^b \pm 2.21$	$113.89^a \pm 4.35$	$114.82^a \pm 6.29$	$112.11^a \pm 5.75$	$110.12^a \pm 3.51$	*
	A.S.E	$47.69^b \pm 0.33$	$55.71^a \pm 1.68$	$54.26^a \pm 1.25$	$57.20^a \pm 3.66$	$57.62^a \pm 2.83$	*
Volume Oxygen consumption (L/day/BW$^{0.75}$)	B.S.E	$6.69^b \pm 0.08$	$6.92^a \pm 0.10$	$6.91^a \pm 0.08$	$6.95^a \pm 0.06$	$6.93^a \pm 0.07$	*
	A.S.E	$6.94^b \pm 0.01$	$7.18^a \pm 0.02$	$7.19^a \pm 0.02$	$7.21^a \pm 0.03$	$7.18^a \pm 0.04$	*
Volume carbon dioxide production (L/day/BW$^{0.75}$)	B.S.E	$5.73^a \pm 0.01$	$5.63^b \pm 0.03$	$5.59^b \pm 0.01$	$5.55^b \pm 0.04$	$5.64^b \pm 0.02$	**
	A.S.E	$6.02^a \pm 0.03$	$5.78^b \pm 0.02$	$5.75^b \pm 0.03$	$5.71^b \pm 0.01$	$5.77^b \pm 0.01$	*
Respiratory quotient ratio	B.S.E	$0.86^a \pm 1.10$	$0.81^b \pm 1.02$	$0.82^b \pm 1.08$	$0.82^b \pm 0.51$	$0.81^b \pm 1.18$	*
	A.S.E	$0.87^a \pm 1.14$	$0.81^b \pm 1.24$	$0.80^b \pm 1.51$	$0.79^b \pm 1.24$	$0.80^b \pm 1.05$	**

***a,b,c** Similar letters in the same raw indicated that there was no significant difference between treatments.*

*T_1: (1% Sodium bicarbonate), T_2: (1% Potassium carbonate), T_3: (0.5% Sodium bicarbonate + 0.5% Potassium carbonate), T_4: (1% Sodium bicarbonate + 1% Potassium carbonate). SEB: Dietary Electrolyte Balance., *: Significant ($p<0.05$), **: Significant ($p<0.01$), NS: Non - Significant. B.S.E: Before solar exposure, A.S.E: After solar exposure.*

of respiration rate decreased by 13.60, 14.18, 12.86 and 12.17% for T_1, T_2, T_3 and T_4, respectively compared to the control group. After solar exposure, the values decreased by 11.76, 10.13, 13.90 and 15.46% for groups T_1, T_2, T_3 and T_4, respectively compared to the control treatment. The differences observed among the treated groups were not statistically significant. In sheep, many authors found that respiration rate increased significantly after exposure to solar radiation (Khalil 1990). Moreover, Khalifa (1982) added that the significant increase in minute ventilation during the first 2 hrs of exposure to solar radiation was accompanied by a significant increase in respiration rate. The present results are in parallel whit the obtained by West *et al.*, 1992 and Jackson *et al.*, 1992). On the other hand, Beatty *et al.*, (2007) reported that supplementing ration with electrolytes did not affect significantly on respiratory rate of beef steers during summer.

The results for the effect of dietary salts on gas volume (GV) of rams before and after solar exposure are tabulated in Table (5). Dietary salts increased significantly ($P<0.05$) gas volume before and after solar exposure. Generally, there were no significant differences among sun exposed groups. This increase in gas volume may be an indicator of increasing heat loss through respiratory evaporation. Abd El-Khalek, (2002) reported that respiratory evaporation as indicated by GV was significantly ($P<0.01$) higher under high ambient temperature in summer than under low ambient temperature in winter to keep body temperature within the normal range. Also, Ibrahim (2000) found that gas volume was higher during summer.

The effects of dietary salts on tidal volume (TV) are presented in Table (5). Dietary salts increased ($P<0.05$) tidal volume of rams before and after solar exposure. Khalifa (1982) found in Barki sheep, those exposure shorn ewes to solar radiation increased significantly GV by increasing both respiratory rate (RR) and tidal volume (TV). An opposite trend was found in unshorn ewes where exposure to solar radiation. Under more heat stress, GV of both shorn and unshorn ewes after exposure to solar radiation increased significantly. Gas volume increased due to significant increase in TV. Meanwhile, decreasing respiration rate indicated that salts improved respiratory efficiency and gas exchange during solar exposure conditions and alleviating the reduction in TV during heat stress.

The effects of dietary salts on volume Oxygen consumption (VO_2) of sun exposed rams are shown in Table (5). The results indicated that dietary salts increased significantly ($P<0.05$) VO_2 before and after solar exposure. There were no significant differences among treated groups. The increase in VO_2 may be due to increase in TV, which can be indicate that the treated animals were more heat tolerant. Similar results were obtained by Christensen *et al.*, (1990). Additionally, Brosh *et al.*, (1998) examined the effect of exposing cattle to solar radiation on VO_2 and noticed that VO_2 consumption of protected cattle was 15% higher than that of exposed cattle. The effect of dietary salts on volume carbon dioxide production VCO_2 of rams is presented in Table (5). Dietary salts decreased significantly VCO_2 before solar exposure and after solar exposure. There were no significant differences among treated groups. These results may indicated that the treated animals were less suffering from heat stress, and tended to increase carbon dioxide output due to hyperventilation, which occurred at high ambient temperature. Schneider *et al.*, (1984) found that panting during heat stress tends to alter alveolar ventilation, subsequently affecting partial pressure and concentration of carbon dioxide.

Data for the effect of dietary salts on respiratory quotient RQ are shown in Table (5). Dietary salts decreased significantly ($P<0.05$) RQ of rams before solar exposure and ($P<0.01$) RQ of rams after solar exposure. Before solar exposure, RQ values were decreased by about 5.81, 4.65, 4.65 and 5.81 % for T_1, T_2, T_3 and T_4, respectively in comparison with that of control. While, after solar radiation, RQ values were decreased by about 6.90, 8.05, 9.2 and 8.05% for T_1, T_2, T_3 and T_4, respectively. No significant differences were observed among treated groups. The observed increase in VO_2 and decrease in VCO_2 led to automatically decreasing RQ (VCO_2 / VO_2). The lower RQ of treated rams and ewes may be an indicator of heat stress alleviation. These results are in harmony with those of Schrama *et al.*, (1993), who reported that mean RQ of young calves was significantly increased by increasing ambient temperature. Also, Kris-Angkanaporn (2002) observed that RQ value in case of hyperventilation (panting) was more than 1 (1.5-1.7) because of excess CO_2 production. Additionally, Abd El-Khalek (2002) reported that the RQ was significantly lower in thermoneutral temperature than in heat stress.

CONCLUSION

The results of the present study indicated that the addition of the electrolytes to the diet of heat stressed rams alleviated the adverse effect of heat stress during solar exposure as indicated by decreasing rectal temperature and skin temperature. Also, dietary salts affected beneficially gas exchange parameters (respiration rate, gas volume, tidal volume, volume oxygen consumption and volume carbon dioxide production). The increase of gas volume and tidal volume and at the same time reduction in respiration rate and rectal temperature of the treated animals was accompanied with increase oxygen consumption volume to maintain metabolic processes and tolerant the adverse effect of heat stress under solar exposure conditions.

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تأثير الإضافات المعدنية لغذاء الكباش المعرضة لأشعة الشمس خلال الصيف على الوظائف الحرارية الهيماتولوجية والتنفسية

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استخدم فى هذه الدراسة عدد 15 كبش ناضج من أغنام الفرافرة وقد قسمت إلى 5 مجموعات متساوية بكل مجموعة منها 3 حيوانات وقد تم تقسيم هذه الحيوانات تبعا للعمر ووزن الجسم إلى خمسة مجاميع الكنترول، المعاملة الأولى أضيف ألي علائقها 1% ملح بيكربونات صوديوم ، المعاملة الثانية أضيف إلى علائقها 1% كربونات بوتاسيوم ، المعاملة الثالثة أضيف ألي علائقها 0.5 % بيكربونات صوديوم + 0.5 % كربونات بوتاسيوم ، المعاملة الرابعة أضيف إلى علائقها 1% بيكربونات صوديوم + 1% كربونات بوتاسيوم. تم تسجيل درجة حرارة الجو وكذلك نسبة الرطوبة بانتظام قبل وبعد التعرض لأشعة الشمس خلال فترة التجربة من 15 يوليو إلى 30 أغسطس. الاستجابة الحرارية وبعض مقاييس الدم والأنشطة التنفسية تم دراستها فى الكباش قبل التعرض لأشعة الشمس من الساعة 11-12 صباحا وبعد التعرض لدرجة حرارة الشمس من الساعة 3-4 مساء وذلك فى نهاية فترة التجربة حيد تم دراسة التأثير التراكمي لمدة 45 يوم للأملاح المضافة الى العلائق. وقد أظهرت النتائج أن الحيوانات المعاملة بالمقارنة بحيوانات الكنترول سجلت انخفاضا معنويا (0.05 %) فى درجة حرارة المستقيم ودرجة حرارة الجلد وانخفاض فى درجة حرارة الأذن قبل وبعد التعرض للشمس. وأيضا أدت المعاملات إلى حدوث انخفاض معنوي (0.05%) فى المكونات الخلوية للدم قبل وبعد التعرض للشمس بالمقارنة بالمعاملة الكنترول بالإضافة إلى ذلك فان أضافه الأملاح إلى العلائق أدت إلى ارتفاع معنوي فى تركيز الجلوكوز والبروتين الكلى فى سيرم الدم قبل وبعد التعرض للشمس بالمقارنة بالمعاملة الكنترول . كما أن الحيوانات المضاف ألي علائقها الأملاح سجلت زيادة معنوية (0.05%) فى تركيز الصوديوم والبوتاسيوم وكذلك التوازن الالكتروليتى للدم وأيضا زيادة طفيفة في تركيزات هرمونات الغدة الدرقية قبل وبعد التعرض لأشعة الشمس بالمقارنة بالمعاملة الكنترول. وفى نفس الوقت أدت إضافة الأملاح ألي علائق الحيوانات الى انخفاض معنوي (0.05% أو 0.01%) في معدل التنفس والنسبة التنفسية وكمية ثاني أكسيد الكربون المنتج وإلى ارتفاع فى حجم الغاز المنتج لكل دقيقة وكمية الأكسجين المستهلك قبل وبعد التعرض لأشعة الشمس بالمقارنة بالمعاملة الكنترول.

ومن هذه الدراسة أمكن استنتاج أن إضافة الأملاح إلى علائق الحيوانات المعرضة لدرجة حرارة الشمس يؤدى إلى تخفيف العبء الحراري عن جسم الحيوان كما يتح من خفض درجة حرارة المستقيم ودرجة حرارة الجلد وفى نفس الوقت كان هناك تأثير مفيد على التوازن الالكتروليتى وأيضا التبادل إلغازي.