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Effect of Different Dietary Electrolyte Balance Levels on Physiological Responses and Metabolic Rate of Rams Exposed to Heat Stress Conditions

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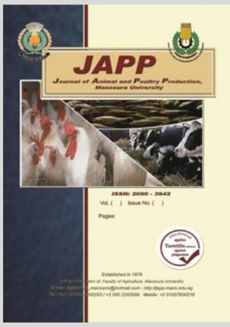

ABSTRACT

This study was conducted to evaluate the effects of supplementation of different dietary electrolyte l (DEB, as the equation of Na+K-Cl milliequivalents (meq) /kg of dry matter) levels on physiological respon metabolic rate of rams exposed to heat stress and to determine which DEB level is the optimum. A total of 20 mature rams were used in this trail. These animals were divided into Four equal homogenized groups (5 e control (received basal diet only and its DEB was 98 meq/kg of feed DM), **T_1:** DEB 200 meq/kg DM, **T_2:** D meq/kg DM and **T_3:** DEB 400 meq/kg DM. Different DEB content of the three treatments was achieved by sodium bicarbonate by a rate of 0.74%, 1.48% and 2.22% of kg DM in T_1, T_2 and T_3, respectively. Thermal r parameters, blood constituents, and respiratory activities were determined during the experimental period bef 12 am) solar exposure and after 3 hours of solar exposure (3-4 pm). The results revealed that supplementa different DEB levels reduced rectal and skin temperatures and respiration rate before and after solar ex However, gas volume per minute (GV) and tidal volume (TV) increased significantly in all treated Volume of oxygen consumption (VO_2) and metabolic rate tended to increase by treatment. Also, serum DE (Na+K-Cl) increased significantly in all treatments. In conclusion, supplementation of different DEB lev beneficial effects on the thermal responses, respiratory activities and gas exchange parameters of heat expose and the optimum DEB level is 300 meq/kg of DM.

Keywords: Dietary electrolyte balance, physiological responses, metabolic rate, rams, heat stress.

INTRODUCTION

Globally, small ruminants play a major role in the economy of million people of impoverished families, especially in the developing countries such as Egypt. These animals are well adapted under different geographical and environmental conditions including extreme and harsh climates than other domesticated ruminants (Conte *et al.* 2018). In Egypt, sheep suffered from heat stress in summer, particularly the animals that live in hot conditions like the desert regions and Upper Egypt and that forced to walk long distances under direct solar exposure.

Nowadays, heat stress (HS) is the most concerning issue in the ever-changing climatic scenario. It poses a significant problem affecting animal performance and decreased growth, production, reproduction and increased health issues and mortality (Al-Dawood, 2017). Animals become heat-stressed when the body temperature is higher than the optimal range specified for the normal activity because the total heat load is greater than the capacity for heat dissipation (Bernabucci *et al.* 2010). During direct solar exposure, heat stress adversely affected some thermal responses such as rectal and skin temperature and respiratory activities and gas change (respiration rate, gas volume, tidal volume, oxygen consumption and carbon dioxide production) in addition to the disruption of metabolic rate (Abd El Khalek, 2002; Tsigos and Chrouso, 2002; Beatty *et al.* 2007). There are three mitigation strategies have been identified to minimize the adverse effects of heat stress including physical modification of the environment, genetic development of heat-tolerant breeds and improved feeding and nutritional management practices (Conte *et al.* 2018).

Minerals are essential for almost all biological functions occurred in the animal body. These minerals are cations "positively charged" such as sodium and potassium or anions "negatively charged" such as chloride and sulfur. The concept of DEB refers to the difference between cations and anions of the diet and also it called dietary cation-anion balance (DCAB) or dietary cation-anion differences (DCAD) (Delaquis and Block, 1995). Mongin defined DEB as the equation of (Na + K) - Cl (meq/kg DM) (Mongin, 1980). During heat stress, the demand for cations (particularly Na and K) increased by the kidney. It has been reported that the excretion of Na and K was elevated by 80% and 18% under hot conditions compared to normal cooler conditions (Sanchez *et al.* 1994). Also, Na, K and Cl are key minerals for the maintenance of acid-base balance which is crucial to ensure normal metabolic and enzyme processes (Al-Dawood, 2017). Many studies reported that supplementation and adjustment of DEB during heat stress conditions positively affected animal productive and reproductive performance (Sanchez *et al.* 1994; Sanchez, 2003; El-Barody *et al.* 2010; Abdel khalek *et al.* 2011; Hashemi *et al.* 2012). The optimal DEB for different ruminants or stages of production and reproduction and different environmental conditions have not yet been fully researched (Al-Dawood, 2017). Regarding sheep, few data were available about the effect of DEB supplementation and its optimum level, especially when exposed to heat stress. So, this study aimed to investigate the

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effect of different dietary electrolyte balance on physiological responses and metabolic rate of sheep exposed to heat stress conditions and to determine the optimum DEB level achieved beneficial results.

MATERIALS AND METHODS

- **Experimental animals and management**

Twenty healthy mature Farafra rams aged 2-3 years and with average weight of 56.5 ± 1.7 kg were included in this investigation. The trial was carried out in Minia Governorate, Upper Egypt during summer season (July and August). The included rams were divided into Four equal homogenized groups according to age and weight (n=5 rams/group). Before the beginning of the experiment, feedstuffs were analyzed for chemical composition (Table 1) and for major electrolyte minerals (Na, K and Cl) and the dietary electrolyte balance of the basal diet (control diet) was 98 meq/kg of feed DM "calculated as meq of Na+K- Cl per kilogram of feed DM according to Mongin (1980) "and sodium bicarbonate was added to adjust and achieve the DEB for different treatment. The DEB content for groups was as follow:

- **Control:** received basal diet only and its DEB was 98 meq/kg of feed DM.
- **T_1:** received basal diet + 0.74% sodium bicarbonate and its DEB was 200 meq/kg of DM.
- **T_2:** received basal diet + 1.48% sodium bicarbonate and its DEB was 300 meq/kg of DM
- **T_3:** received basal diet + 2.22% sodium bicarbonate and its DEB was 400 meq/kg of DM

Table 1. Approximate analysis of the used feedstuffs.

Item	Moisture	Dry matter composition (%)					
		OM	CP	CF	EE	NFE	Ash
Concentrate feed mixture (CFM)	9.3	92.7	14.6	15.1	4.9	58.1	7.3
Rice straw	9.1	84.1	4.0	33.4	1.6	45.1	15.9

Rams were housed in groups in semi-open pens and were fed according to NRC, (2007). Sodium bicarbonate was mixed well with the concentrate feed mixture before introducing to the animals. Animals were fed the experimental diets for two weeks before the beginning of the experiment as an acclimation period. Animals were weighed biweekly and the amount of feed was adjusted according body weight changes. During the experimental period, animals were exposed to direct solar radiation "under direct sun radiation". Thermal responses parameters, respiratory activities measurements and blood samples were taken before solar exposure (11-12 am) and after three hours of solar exposure (3-4 pm) to determine the cumulative effect of dietary different DEB content on thermal responses, blood parameters and respiratory activities under acute heat stress conditions.

Ambient temperature and relative humidity were recorded before and after solar exposure using the conventional methods and the temperature-humidity index (THI) was calculated according to Hahn *et al.* (2003):

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

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

- **Thermal responses and respiratory activities**

Rectal temperature (RT, ^oC) was measured by a clinical thermometer before and after sun exposure. Skin temperature (ST, ^oC) was measured by a portable infrared thermometer designed for temperature measurements (Radioshack company). Respiration rate (RR) was measured and expressed as the number of breaths per minute. Respiratory minute volume (GV) of exhaled air/minute was measured by Dry Gas Meters (liters). The volume of oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured with the open-circuit technique by the gas analyzer (Servomex 570). The percentages of true VO_2 and VCO_2 were calculated and then, the metabolic rate was calculated 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.

Metabolic Rate = [VO_2 * (3866 + (GV adjusted to STPD * VCo_2*1200)) * (1.163*60*24 / POWER (Body Weight, 0.75))]/1000

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.

- **Blood metabolites and hormones**

A volume of 8 ml of the blood sample was collected from each ram via the jugular vein before and after solar exposure. These blood samples were divided into two parts (heparinized and non-heparinized). The heparinized blood sample was used to determine hematocrit (Ht) by micro hematocrit capillary tubes using a hematocrit centrifuge and the other non-heparinized sample was centrifuged at 3000 rpm for 15 min for serum separation, which was stored thereafter at -20^{o}C until analyses of blood metabolites and hormones. Blood metabolites (Total protein and glucose) and electrolytes (Na, K and Cl) were measured by a colorimetric method using commercial kits. Serum triiodothyronine (T3) and thyroxine (T4) were determined by the direct radioimmunoassay (RIA) technique according to Bates (1974) and Albertini (1982), respectively.

- **Statistical analysis**

Data were statistically analyzed using SPSS v. 21.0 for Windows (SPSS Inc., Chicago, IL). One-way ANOVA test was used and the significance among means were determined by Duncan's New Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

Regarding the metrological data during the experimental period, the mean ambient temperature before solar exposure (11-12 a.m.) was 33.7 ± 0.51 and after solar exposure (3-4 p.m.) "under direct sun" was 39.8 ± 0.62, the mean relative humidity % before solar exposure was 43.6 ± 2.5 and after solar exposure was 23.5 ± 1.32 and the mean

THI before solar exposure was 88.1 ±1.4 and after solar exposure was 102.9 ± 1.2

- **Thermal responses**

The present results revealed that different DEB supplementation reduced rectal temperature before and after solar exposure and this reduction was significant in T_2 (300 meq) compared to control before solar exposure (38.82 ± 0.05 *vs.* 39.20 ± 0.07) and in both T_2 (300 meq) and T_3 (400 meq) compared to control after solar exposure (39.58 ± 0.07 & 39.64 ± 0.10 *vs.* 39.92 ± 0.07). Also, a similar trend of results was noticed in skin temperature, it decreased by DEB supplementation and the obvious reduction was recorded in T_2 and T_3 after solar exposure. It is well documented by many authors that animal exposure to heat stress increases body temperature of (Khalifa *et al.* 2000 ; Tsigos and Chrouso, 2002). Our results are in line with those of Abdel khalek *et al.* (2011), who examined the effects of different dietary DEB content on thermal responses of sheep during the summer season were 115, 246, 276, 257 and 407 meq/kg of DM. They found that DEB supplementation significantly decreased rectal and skin temperature on both rams and ewes afternoon (12-2 pm) and the best effect was in the 257 meq group. These results are in line with previous study by Coppock *et al.* (1982), who found that sodium bicarbonate supplementation (by 1.5% of feed DM) decreased significantly body temperature of cows during summer season. This positive effect of dietary electrolyte balance in lowering body temperature may be due to the improvement in acid-base balance and fluid balance between body tissues. In a previous study, Schneider *et al.* (1988) reported that electrolytes supplementation to heat-stressed dairy cows had a beneficial effect in terms of regulation of acid-base balance and lowering body temperatures.

- **Respiratory activates and gas exchange parameters**

Our results revealed that the respiration rate decreased ($P<0.05$) before solar exposure in T_2 and T_3 compared to the control group however after solar exposure, it decreased significantly in T_1, T_2 and T_3 by 10.5%, 13.4% and 10.9%, respectively compared to control group. These results agreed with Abdel Khalek *et al.* (2011) who found that respiration rate decreased significantly ($P<0.05$) by DEB supplementation in sheep diet and the obvious reduction in RR was recoded in 257 meq group (14.7%). Also, similar findings were reported in cows by West *et al.* (1991), West *et al.* (1992); Jackson *et al.* (1992) and Ross *et al.* (1994), they found that increasing DEB during heat stress decreased respiration rate. In this study, altering DEB using sodium bicarbonate achieves an additional effect by insuring HCO_3 besides Na ion. It has been reported that during heat stress, accelerated panting occur. Consequently blood CO_2 decrease as a result, here the supplementation of HCO_3 ion is beneficial because it transformed to CO_2 and H_2O and compensates blood CO_2 and the respiration rate decreases as a result of increased blood CO_2. Also, HCO_3 maintains buffering capacity and acid-base balance return towards normal and this also decreases respiration rate (Lunn and McGuirk, 1990). A study by Haydon *et al.* (1990), they found that blood HCO_3 and CO_2 increased linearly by increasing DEB level.

The present results indicated that gas volume per minute was slightly higher in treated groups before solar exposure. Still after solar exposure, it increased significantly in all treated groups by 22.4%, 28.3% and 23.2% in T_1, T_2 and T_3, respectively, compared to the control group. At the same time, no significant differences were noticed among the three treated groups. Also, tidal volume was significantly higher in all treated groups before and after solar exposure. The increase in GV is attributed to the significant increase in TV. These results "increasing GV and TV" in treated animals indicate increasing respiratory evaporative heat loss and indicated that these animals suffered less from the acute heat stress than untreated ones. It has been reported that respiratory evaporation "as indicated by GV" was significantly ($P<0.01$) higher under heat stress to keep body temperature within the normal range by increasing evaporative heat loss (Abd El-Khalek, 2002). Also, the higher obtained TV (ml/breathe) values together with lower RR values in treated animals indicate that these animals could better regulate the respiratory efficiency and activities during heat stress. These results agreed with Abdel Khalek *et al.* (2011) who found that both GV and TV was significantly higher in DEB supplemented groups compared to un-supplemented and they found that DEB levels of 257 and 276 meq were the better levels.

The volume oxygen consumption (VO_2), it tended to increase in treated groups before and after solar exposure "this increase was significant in 300 meq group". Simultaneously, volume carbon dioxide production (VCO_2) was not affected by treatment before and after solar exposure. The increase in VO_2 in treated groups was strongly attributed to the increase in TV due to DEB supplementation that could indicate that the treated animals were more tolerant. Gryg and Milligan (1982) reported that that VO_2 of rams decreased under heat stress conditions. Furthermore, Brosh *et al.* (1998) found that VO_2 of goats exposed to heat stress was lower by 15% compared to non-exposed goats. These results agreed with Abdel Khalek *et al.* (2011) who found that DEB supplemented animals had significantly higher VO_2 values compared to control ones "with no significant difference among different DEB groups", but they found a slight decrease in VCO_2 values in treated animals.

- **Metabolic rate**

The present results revealed that the metabolic rate tended to be higher in treated groups before and after solar exposure compared to the control group ($P<0.05$ in T_2 only). This result may be explained by DEB maintained the metabolic rate of treated animals from the reduction which actually occurs during heat stress conditions. Many authors reported that animals' metabolic rate decreased during heat stress conditions, which was mainly due to decreasing feed intake and negative energy balance (West *et al.* 1992; Schrama *et al.* 1994 and Brosh *et al.* 1998). It has been reported that animals fed high DEB diets had high energy ba1ance due to the higher dry matter intake due to the favorable effects of DEB supplementation on rumen pH (Tucker *et al.* 1992) and blood buffering capacity (Block, 1994). Also, Moore *et al.* (2000) studied the effect of altering DEB on energy metabolism of prepartum cows. They found that energy balance increased in cows fed high DEB levels. In addition, Mohammed, (2005) observed that lactating buffaloes fed high DEB diet (the source was $NaHCO_3$) showed higher energy balance than those fed a negative DEB diet. Dersjant *et al.* (2002) studied the effect of dietary 2 DEB levels (-135 and 145 meq/kg DM) on metabolic rate and heat production on piglets. They found that both the total heat production and metabolic rate tended (*P*< 0.01) to be higher in the 145 meq group.

- **Blood constituents.**

The results revealed that Hematocrit values almost were not affected by treatment before solar exposure. Still after solar exposure, Ht values tended to decrease significantly in all treatments versus control. These results are in agreement with Abd El-Moty *et al.* (2010) who reported that increasing DEB content in the sheep diets led to a significant (P<0.05) decrease in blood Ht values. This result may be attributed to sodium bicarbonate content in the diet of treated animals may increase the water intake of these animals to overcome the increase in sweating rate. Also, the higher value of blood Ht of the control group may reflect that these animals were subjected to heat stress. Kume *et al.* (1998) reported that blood Ht of heifers were increased by heat stress. Also, these results agreed with Kilmer *et al.* (1981) and Escobosa *et al.* (1984) who found that increasing DEB level decreased blood Ht.

Table 2. Effect of different DEB supplementation on thermal responses, respiratory activities and metabolic rate.

Parameters		Treatments			
		Control (98 meq)	**T_1 (200 meq)**	**T_2 (300 meq)**	**T_3(400 meq)**
Rectal temperature (C°)	BSE	39.20^{a} ± 0.07	39.08^{ab} ± 0.07	38.82^{b} ± 0.05	39.00 ±^{ab} 0.17
	ASE	39.92^{a} ± 0.07	39.76^{ab} ± 0.04	39.58^{b} ± 0.07	39.64^{b} ± 0.10
Skin temperature (C°)	BSE	36.22^{a} ± 0.47	34.66^{ab} ± 0.34	34.46^{b} ± 0.58	34.54^{b} ± 0.50
	ASE	38.12^{a} ± 0.45	37.22^{ab} ± 0.26	35.82^{c} ± 0.55	36.2^{bc} ± 0.44
Respiration rate (breathes / minute)	BSE	54.80^{a} ± 2.8	48.1^{ab} ± 1.7	45.40^{b} ± 2.8	46.60^{b} ± 1.5
	ASE	106.4^{a} ± 2.9	95.2^{b} ± 2.2	92.1^{b} ± 1.4	94.8^{b} ± 4.7
Gas volume (L/minute)	BSE	4.04 ± 0.17	4.66 ± 0.18	4.76 ± 0.25	4.60 ± 0.42
	ASE	5.08^{b} ± 0.31	6.22^{a} ± 0.35	6.52^{a} ± 0.21	6.26^{a} ± 0.30
Tidal volume (ml/breathe)	BSE	74.1^{b} ± 2.3	97.4^{a} ± 4.4	106.9^{a} ± 10.2	98.5^{a} ± 6.7
	ASE	47.9^{b} ± 3.4	65.2^{a} ± 2.1	71.1^{a} ± 3.0	66.9^{a} ± 5.1
VO_2	BSE	0.15^{b} ± 0.007	0.17^{ab} ± 0.009	0.18^{a} ± 0.013	0.19^{a} ± 0.012
	ASE	0.12^{b} ± 0.009	0.14^{ab} ± 0.007	0.15^{a} ± 0.012	0.14^{ab} ± 0.011
VCO_2	BSE	0.16 ± 0.011	0.17 ± 0.014	0.16 ± 0.010	0.18 ± 0.016
	ASE	0.15 ± 0.008	0.15 ± 0.008	0.16 ± 0.013	0.16 ± 0.010
Metabolic rate (Kcal/day)	BSE	67.4^{b} ± 3.3	75.2^{ab} ± 2.1	78.4^{a} ± 2.7	76.0^{ab} ± 3.9
	ASE	64.4^{b} ± 2.1	69.4^{ab} ± 1.7	70.4^{a} ± 1.7	69.6^{ab} ± 1.6

Control (98 meq/kg of feed DM). T_1 (200 meq/kg of feed DM). T_2 (300 meq/kg of feed DM). T_3 (400 meq/kg of feed DM).
BSE = before solar exposure ASE = after solar exposure
a,b,c Means in the same row with different superscripts are significantly different (P≤0.05).

The serum glucose level was higher (P< 0.05) after solar exposure by 16.6%, 22.5% and 23.9% in T_1, T_2 and T_3, respectively as compared to the control group. Also, a similar trend of results was recorded in serum total protein level, it recorded a significant increase by treatment. This increase was obvious after solar exposure compared to before solar exposure. These results are in agreement with Abd El-Moty *et al.* (2010) who found that serum glucose and total protein levels were significantly higher in DEB supplemented groups than in un-supplemented control. They found that DEB levels of 257 and 276 meq had the higher glucose and total protein levels. These results may be explained by that DEB maintained blood glucose level of the treated groups from reduction compared to control and the higher metabolic rate in treated groups which reflects positive energy balance. Escobosa *et al.* (1984) found that dietary sodium bicarbonate during heat stress increased blood glucose level of cows and they reported that this increase may be due to higher feed intake in high sodium bicarbonate group. Li *et al.* (2013) found that increasing DEB level in rabbits' diet (up to 500 meq) increased feed intake, N metabolism and blood total protein. It has been reported that blood proteins play a basic role of intracellular buffers within the body tissues to provide a reserve buffering capacity (Cunningham, 2002) and this is indicated that increasing blood total protein concentrations by DEB supplementation had a beneficial effect on acid-base balance. Furthermore, the increase in TP levels by BEB supplementation may be attributed to the beneficial effect of sodium bicarbonate on crude protein digestibility coefficients which was reported by many authors (Hashemi *et al*. 2012; Al-Dawood, 2017).

Concerning serum major electrolyte minerals, serum Na level tended to increase in the treated groups before and after solar exposure (P<0.05 in T_3). However, serum K recorded a slight increase and serum Cl recorded a slight decrease in all treatments compared to control before and after solar exposure. Blood DEB (Na+K-Cl) was significantly higher in all treated groups before and after solar exposure (P<0.01) with no significant difference among treated groups. These results are in agreement with Abd El-Moty *et al.* (2010) who found that serum NA and DEB increased significantly (p<0.05) by increasing DEB in sheep diet. While, they found that serum K concentration recorded a significant elevation and serum Cl recorded a significant reduction by DEB supplementation.

Regarding the results of Na in the current study, these results are expected because of the supplementation of sodium bicarbonate led to an increase in circulating blood sodium concentrations and it has a beneficial effect to compensate the loss of sodium ion through kidney during heat stress conditions (Sanchez *et al.* 1994). Also, increasing blood DEB of the treated groups in this study was expected due to increasing serum Na in these groups (the main part of the equation) and it had a positive role in regulating acid-base balance especially during heat stress conditions (Sanchez *et al.* 1994, Sanchez, 2003, El-Barody *et al.* 2010; Hashemi *et al.* 2012). Also, Haydon *et al.* (1990) and West *et al.* (1992) found similar results as regards Na, k and DEB. Holly (2002) reported that increasing dietary cations "like

Na and K" during heat stress is a common practice and the goal should be a higher DEB and higher levels of these key minerals to compensate the high loss. It has been reported that the loss of HCO_3 may cause a relative increase in blood Cl (Escobosa *et al.* 1984) and this means that treated animals in our study avoided this problem.

The results of the effect of different DEB levels on thyroid hormones (T3 and T4) are presented in Table (3). The current results revealed that DEB supplementation caused a slight insignificant increase in these hormones in both before and after solar exposure. These results agreed with Abd El-Moty *et al.* (2010) who found that increasing DEB level in sheep diets during heat stress slightly increased both serum T3 and T4. Also, these results are in a harmony with Vicini *et al.* (1987) who found that supplementation of 2% sodium bicarbonate in dairy cows' diet caused an insignificant increase in thyroid hormones concentration. Besides, these results agreed with Cheirecato *et al.* (2003) on rabbits and Rizzi *et al.* (2004) on bucks. The slight increase in thyroid hormones in the treated group may be correlated with the high metabolic rate in these groups as it has been reported that there was a positive relationship between energy intake and the concentrations of the thyroid hormones (Tiirates, 1997; Ahmed, 2003).

Table 3. Effect of different DEB supplementation on blood constituents.

Parameters		Treatments			
		Control (98 meq)	T_1 (200 meq)	T_2 (300 meq)	T_3 (400 meq)
Hematocrit (%)	BSE	31.60 ± 1.81	29.40 ± 0.51	30.80 ± 0.58	29.60 ± 0.75
	ASE	34.20^{a} ± 0.66	31.00^{b} ± 0.55	30.00^{b} ± 1.10	30.80^{b} ± 1.07
Glucose (md/dl)	BSE	61.0 ± 3.52	69.6 ± 3.66	69.2 ± 3.62	70.8 ± 2.31
	ASE	54.2^{b} ± 3.18	63.2^{a} ± 1.93	66.4^{a} ± 3.41	67.2^{a} ± 2.65
Total Protein (g/dl)	BSE	5.58 ± 0.36	6.16 ± 0.39	6.33 ± 0.36	6.46 ± 0.25
	ASE	5.14^{b} ± 0.28	5.72^{ab} ± 0.19	6.04^{a} ± 0.29	5.98^{a} ± 0.29
Sodium (mEq/l)	BSE	134.4^{b} ± 3.49	145.4^{ab} ± 3.79	147.2^{ab} ± 4.26	150.4^{a} ± 5.36
	ASE	129.8^{b} ± 4.01	141.2^{ab} ± 3.02	142.0^{ab} ± 3.90	145.8^{a} ± 6.34
Potassium (mEq/l)	BSE	5.16 ± 0.13	5.30 ± 0.14	5.48 ± 0.16	5.40 ± 0.19
	ASE	5.06 ± 0.14	5.24 ± 0.12	5.44 ± 0.12	5.32 ± 0.15
Chloride (mEq/l)	BSE	96.6 ± 3.81	92.0 ± 2.50	92.60 ± 2.66	91.00 ± 2.88
	ASE	91.6 ± 2.03	88.21 ± 1.52	85.8 ± 2.08	89.40 ± 3.80
DEB (mEq/l)	BSE	42.9^{b} ± 4.54	58.7^{a} ± 5.37	60.1^{a} ± 5.24	64.8^{a} ± 6.34
	ASE	43.3^{b} ± 4.43	59.44^{a} ± 4.10	61.6^{a} ± 3.40	61.7^{a} ± 6.44
Triiodothyronine (ng/dl)	BSE	4.71 ± 0.31	5.04 ± 0.33	5.15 ± 0.33	5.10 ± 0.22
	ASE	4.50 ± 0.34	4.83 ± 0.19	5.08 ± 0.43	5.12 ± 0.19
Thyroxin (µg/dl)	BSE	79.5 ± 5.01	85.1 ± 2.66	85.3 ± 6.99	82.7 ± 3.25
	ASE	74.1 ± 6.42	77.3 ± 3.04	81.3 ± 6.83	80.5 ± 4.00

Control (98 meq/kg of feed DM). T_1 (200 meq/kg of feed DM). T_2 (300 meq/kg of feed DM). T_3 (400 meq/kg of feed DM).
BSE = before solar exposure ASE = after solar exposure
a,b,c Means in the same row with different superscripts are significantly different ($P \leq 0.05$).

CONCLUSION

In conclusion, the current results revealed that supplementation of different DEB levels had a beneficial effect on the thermal responses and respiratory activities and gas exchange parameters of heat exposed rams in terms of reducing rectal and skin temperatures accompanied with maintaining gas and tidal volumes, VO_2 and metabolic rate in addition to regulating blood buffering capacity and acid-base balance by providing chef electrolyte minerals. All of these factors alleviated the adverse effects of heat stress on the animal. Also, the study revealed that the optimum DEB level is 300 meq/kg DM "by the addition of 1.48% sodium bicarbonate".

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تأثير إستخدام مستويات مختلفة من التوازن الإلكتروليتى على الأداء الفسيولوجي ومعدل الميتابولزم للكباش المعرضة للإجهاد الحراري

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تهدف هذه الدراسة لتقييم تأثير استخدام مستويات مختلفة من التوازن الإلكتروليتى (وهو عبارة عن ناتج المعادلة التالية: الصوديوم + البوتاسيوم ـ الكلور "مللميكافئ / كيلو جرام مادة جافة مأكولة") على الاستجابات الحرارية والأنشطة التنفسية ومعدل الميتابولزم للكباش المُعرضة للإجهاد الحراري، وأيضا تحديد معدل التوازن الإلكتروليتى الأمثل للإضافة. استخدم في هذه التجربة عدد ٢٠ كبش فرافره بمتوسط وزن ٥٦,٦ ± ١,٧ كجم وعمر ٢-٣ سنه. قُسمت الكباش إلى أربعة مجموعات متجانسة (٥ لكل مجموعة) كالتالي: المجموعة الضابطة أو الكنترول: والتي غُذيت على العليقة الأساسية فقط ، والتي كان مقدار التوازن الإلكتروليتى لها ٩٠ مللميكافئ / كجم مادة جافة، المعاملة الأولى (ت١): والتي كان مقدار التوازن الإلكتروليتى لها ٢٠٠ مللميكافئ / كجم مادة جافة ، المعاملة الثانية (ت٢): والتي كان مقدار التوازن الإلكتروليتى لها ٣٠٠ مللميكافئ / كجم مادة جافة، المعاملة الثالثة (ت٣): والتي كان مقدار التوازن الإلكتروليتى لها ٤٠٠ مللميكافئ / كجم مادة جافة (وتم تعديل التوازن الإلكتروليتى للمعاملات الثلاثة ت١, ت٢, ت٣ عن طريق إضافة بيكربونات الصوديوم على العليقة الأساسية بمقدار ٠,٧٤%, ١,٤٨% و ٢,٢٢% من المادة الجافة المأكولة للمجموعات الثلاث على التوالي). تم قياس وتقدير الاستجابات الحرارية وبعض مكونات الدم والأنشطة التنفسية والتبادل الغازي خلال فترة التجربة، وذلك قبل تعريض الكباش للشمس (١١-١٢ صباحا)، وكذلك مرة أخرى بعد تعريض الكباش للإجهاد الحراري الشديد تحت أشعة الشمس المباشرة لمدة ٣ ساعات (٣-٤ عصرا). وأظهرت النتائج أن الحيوانات المُعاملة سجلت انخفاضا فى درجة حرارة المستقيم، وكان هذا الانخفاض معنويا فى ت٢ (٣٠٠ ملليمكافىء) وت٣ (٤٠٠ ملليمكافىء) مقارنة بالكنترول بعد التعرض للشمس. وأيضا تم الحصول على نتائج مشابهة بالنسبة لدرجة حرارة الجلد، فقد انخفضت فى الحيوانات المعاملة مقارنة بالكنترول، وكان هذا الانخفاض معنويا فى مجموعة ت٢ وت٣ بعد التعرض للإجهاد الحراري. سجل معدل التنفس انخفاضا معنويا (P<0.05) بعد التعرض للشمس بمقدار ١٠,٥%, و١٣,٤% و ١٠,٩% في المعاملات الثلاث على التوالي مقارنة بالمجموعة الضابطة. وفى نفس الوقت فقد ارتفع مقدار حجم الغاز المتنفس فى الدقيقة بعد التعرض للشمس معنويا بمقدار ٢٢,٤% و ٢٨,٣% و ٢٣,٢% في المعاملات الثلاث على التوالي مقارنة بالمجموعة الضابطة، وأيضا ارتفع مقدار حجم التنفسه الواحدة (مل/تنفسه) للحيوانات المعاملة مقارنة بالمجموعة الضابطة قبل وبعد التعرض للشمس. وقد أوضحت النتائج أن حجم الأوكسجين المستهلك ارتفع فى المجموعات المعاملة مقارنة بالكنترول قبل وبعد التعرض للشمس وكان هذا الارتفاع معنويا فى ت٢ (٣٠٠ ملليمكافىء)، فيما لم يسجل حجم ثانى أكسد الكربون الخارج تغيرا معنويا بين المعاملات المختلفة والمجموعة الضابطة سواء قبل أو بعد التعرض للشمس. أوضحت النتائج أن معدل الميتابولزم كان أعلى للحيوانات المعاملة مقارنة بالكنترول (وكان هذا الارتفاع معنويا فى المجموعة ت٢). بالنسبة لبعض مكونات الدم، فقد سجلت مستويات الجلوكوز والبروتين الكلى ارتفاعا ملحوظا فى المجموعات المعاملات الثلاثة (خاصة بعد التعرض للشمس)، وأيضا سجل مستوى عنصر الصوديوم بالدم ارتفاعا ملحوظا نتيجة المعاملات المختلفة، فى حين كان هناك ارتفاعا طفيفا لمستويات عنصر البوتاسيوم فى الدم نتيجة المعاملة، بينما لم يتأثر تقريبا مستوى الكلور بالدم نتيجة المعاملة، وسجل مستوى التوازن الإلكتروليتى فى الدم (الصوديوم + البوتاسيوم ـ الكلور) ارتفاعا ملحوظا فى المعاملات الثلاث مقارنة بالكنترول، وهذا يدلل على ارتفاع التوازن الحامضى القاعدى للدم نتيجة المعاملة. لم تتأثر مستويات هرمونات الغدة الدرقية (الترايأيودوثيرونين والثيروكسين) بشكل معنوي بالمعاملة. ونستخلص من خلال النتائج السابقة أن إضافة التوازن الإلكتروليتى بأيِ من مستوياته المختلفة كان له تأثيرا جيدا على الاستجابة الحرارية والنشاط التنفسي ومعدل الميتابولزم وأيضا على بعض مكونات الدم للكباش المعرضة للإجهاد الحراري بما يؤدى إلى تخفيف العبء الحراري وآثاره السيئة على الحيوان. وأيضا أوضحت النتائج أن المستوى الأمثل للتوازن الأليكتروليتى المستخدم كان ٣٠٠ مللميكافئ / كيلو جرام من المادة الجافة.