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ACID-BASE BALANCE IN BUFFALO HEIFERS AS AFFECTED BY HEAT STRESS

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SUMMARY

Six buffalo heifers were used during summer (August 1997) to study Acid-base balance as affected by heat load. Blood samples were taken at 8.00 a.m and 12.00 noon, then the animals were exposed to heat stress until 3.00 p.m followed by resting period for two hours. Blood samples were drawn twice, one at 3.00 p.m (after heat stress) and the other one at 5.00 p.m (after resting period). Blood haemoglobin, haematocrit and serum bicarbonate were determined at each time. Also, thermoregulatory responses were measured (respiration rate and body temperature).

Obvious rises in rectal temperature were associated with shifts of the environmental temperature from 32.0 to 38.0 °C and respiration rate was markedly increased after exposure to heat stress, implying that the buffaloes were relatively heat tolerant in the absence of radiation. Serum bicarbonate values were highest after heat stress due to the marked increase in respiration rate, therefore respiratory alkalosis occurred. Blood haematocrit and haemoglobin values decreased after heat stress by (- 0.49 %) and (- 0.42 g/100 ml), respectively.

Keywords : Heat stress, buffalo, acid-base balance, bicarbonate store

INTRODUCTION

The blood acid-base status of farm animals exhibits similar types of changes as observed under submaximal heat load conditions (Nangia and Sukhija, 1981; Singh *et al.*, 1980; Upadhyay & Roa, 1985 and Upadhyay, 1993.). Buffaloes undergo moderate dgrees of metabolic respiratory alkalosis and increased respiratory activity involving a decline in PCO_2 and CO_2 levels in blood.

It is well known that the environmental temperature exerts a marked influence on the metabolism of animals. A number of workers has demonstrated that buffaloes are adversely affected by direct solar radiation due to their black or blackish colour and sparse hair coat (Badreldin and Ghany, 1954; Alim and Ahmed, 1957 and Mullick, 1960.).

High ambient temperature and humidity cause more deviation beyond normal limits, in certain blood constituents of animals. However the heat tolerant animals, show insignificant changes in the blood picture in the face of high ambient temperature and humidity stress (Shafie and Badreldin, 1962.).

In the present study, the effects of ambient temperature and relative humidity during summer and the effect of heat stress, by direct solar radiation, on acid-base balance of Egyptian buffalo heifers were studied. Respiration rate, body temperature and some hematological responses (haematocrit and haemoglobin) were determined and discussed in relation to acid-base balance.

MATERIALS AND METHODS

Six buffalo heifers were divided into two groups, group 1 consisted of 3 animals weighing 240-285 kg (low weight), and the other group consisted of 3 animals weighing 345- 380 kg (heavy weight). Heifers of the frist group were 1.5 years old while those of the second group were 2.8 years. The experiment was conducted during summer (August 1997). Animals were fed clover (Barseem) hay, 5 kg/head/day and 6 kg/head/day for the frist and second groups, respectively, plus concentrate at 5 kg/head/day, while rice straw, was offered ad libitum. The heifers were tethered in the shade through the day except when they were exposed to direct sun rays between 12.00 h and 15.00 h.

Data were obtained daily for ten consecutive days. The ambient temperature and relative humidity were recorded at sampling time. Respiration rate and body temperature were determined as physiological responses to the treatment, body temperature was measured as (F°) degrees and respiration rate as bearths/min. Blood samples were taken from the jugular vein at 08.00 h and 12.00 h, and lastly at 15.00 h after two hours post exposure to solar radiation. The animals were then kept for a resting period under shade for 2 hours and allowed to drink water. Blood samples were collected again at 17.00 h.

All samples were taken at each time under a thick layer (7 cm) of liquid paraffin, and centrifuged for 15 minutes, Serum was transferred to another tube under liquid paraffin to determine bicarbonate concentration. Serum bicarbonate concentration was determined according to the titration method of Van Slyke (1922) as reported by Oser (1965).

Another small heparinized blood sample was drawn into another heparin coated tube at each sampling time for the determination of haematocrit and haemoglobin concentrations. Haematocrits were determined by microhaematocrit centrifuging at 1200 rpm. for 5 minutes. Haemoglobin concentration was determined colorimetrically by the method based on formation of syanomethaemoglobin as described by Bauer (1970).

RESULTS AND DISCUSSION

a) Effects of environmental temperature on thermoregulatory responses in buffalo heifers:

The diurnal changes in ambient temperature and relative humidity during the study are shown in Table (1). It is clear that relative humidity was almost constant. Thus it was considered as having no particular effect on the body responses.

Changes of the mean ambient temperature increased from 25.5 to 32.4 °C between 08.00 h and 12.00 h, it reached the maximum at 15.00 h then dropped slightly at 17.00 h.

Table 1. Means ± S.E of diurnal ambient temperature and relative humidity at times of testing the reaction of the animals *

Time / Temperature	08:00 h	12:00 h	15:00 h	17:00 h
Ambient temperature, °C	25.5±0.62	32.4±1.39	38.9±0.91	37.3±0.42
Relative humidity, %	69.4±0.22	69.2±0.29	67.8±0.31	67.6±0.24

* Each mean represents 10 observations.

- Physiological response:

Results showed that the change of environmental temperature from 08.00 h to 12.00 h of about 6.9 °C caused a slight increase in body temperature of 0.79 °F and mean respiration rate was increased by 8.19 breath/min. (Table 2). Obvious rises in mean rectal temperature of 2.8 °F occurred when the heifers were exposed to heat stress by direct exposure to solar radiation from 12.00 h to 15.00 h, during which time the ambient temperature increased by 6.5 °C (32.4 - 38.9 °C) which was similar to the previous change that occurred between morning and noon. Respiration rate increased drastically by 47.37 breath/min which was almost 6 times greater than the change in respiration rate that occurred during the frist period (08.00 h to 12.00 h) (Tables 3 & 4). This pattern of response is attributed to the fact that buffaloes were relatively heat tolerant in the absence of direct solar radiation. This result is in agreement with those of Vercore *et al* ., (1985), who concluded that radiant heat load was relatively important in determining how long a drought buffalo could work each day. After the buffalo heifers were kept under shade, with access to drinking water, for a 2 hour resting period, when ambient temperature decreased only by 1.6 °C (from 15.00 h to 17.00 h), body temperature dropped by 1.5 °F (half of the increase due to heat stress), whereas mean respiration rate decreased by 47.5 breath/min, equal to the increasing value recorded after heat stress (47.5 breath/min.).

The increase of body temperature in relation to ambient temperature in Group 1 was more pronounced than in Group 2, since heifers of the second group were heavier and older than those of the frist group. Consequently, body temperature showed a greater increase after heat stress in the younger group than in the older one (2.9 ° F *vs.* 2.6 ° F). After heat stress, respiration rate in Group 2 showed a smaller increase than Group 1(48.54 *vs.* 46.2, respectively.). These higher values for respiration rates in the older heifers seem to be a mechanism for combating the rise in body temperature.

During the resting period, the respiration rate of both groups returned to the normal state (steady - state) more quickly and efficently than body temperature. Mean body temperature decreased by - 1.6 ° F in Group 1 and - 1.5 ° F in Group 2, while respiration rate decreased by 46.1 and 48.9 breath/min in Group 1 and Group 2, respectively. Body temperature was still higher than during the steady state before heat stress.

Table 2. Mean* ± S.E values for the parameters used to measure heat stress in buffalo heifers.

Time	Trait	Heifers					
		Group 1			Group 2		
		1	2	3	4	5	6
08.00	Body temperature (°F)	99.2 ± 0.30	99.1 ± 1.26	99.62 ± 0.24	99.87 ± 0.18	100.0 ± 0.37	99.89 ± 0.46
	Respiration rate (breath/min.)	40.0 ± 2.19	37.4 ± 2.17	40.0 ± 2.49	28.2 ± 1.59	38.2 ± 1.78	38.42 ± 1.95
	Haematocrit (%)	32.1 ± 1.37	31.0 ± 1.02	30.4 ± 0.98	31.7 ± 1.24	32.65 ± 1.6	30.5 ± 0.85
	Haemoglobin (g/100ml)	9.02 ± 0.4	8.72 ± 0.32	8.38 ± 0.38	8.83 ± 0.22	8.97 ± 0.23	8.02 ± 0.29
	Serum Bicarbonate (m.mol/l)	31.69 ± 0.99	31.0 ± 1.48	30.32 ± 1.35	30.18 ± 1.4	29.84 ± 1.25	31.57 ± 0.9
12.00	Body temperature (°F)	101.5 ± 0.35	100.7 ± 0.23	100.7 ± 0.33	100.3 ± 0.26	100.7 ± 0.4	100.4 ± 0.5
	Respiration rate (breath/min.)	46.8 ± 2.82	46.2 ± 2.79	48.4 ± 3.42	49.0 ± 3.3	43.8 ± 2.36	46.2 ± 1.97
	Haematocrit (%)	30.1 ± 1.04	28.1 ± 1.07	28.6 ± 0.85	30.1 ± 1.28	30.8 ± 1.7	30.0 ± 1.04
	Haemoglobin (g/100ml)	8.47 ± 0.35	8.21 ± 0.42	7.73 ± 0.28	8.68 ± 0.37	8.9 ± 0.25	7.58 ± 0.17
	Serum Bicarbonate (m.mol/l)	27.73 ± 1.27	29.37 ± 1.25	32.31 ± 1.65	29.04 ± 1.48	28.89 ± 1.53	29.91 ± 1.81

* Each mean represents 10 observations.

Table 3. Mean ± S.E values for the parameters used to measure heat stress in buffalo heifers at 15.00 h and after two hours in the shade (15.00-17.00 h) and following solar radiation (12.00-15.00h)*

Time	Trait	Individual animal					
		Group 1			Group 2		
		1	2	3	4	5	6
15.00	Body temperature (°F)	104.6 ± 0.41	103.6 ± 0.36	103.3 ± 0.26	102.5 ± 0.48	103.5 ± 0.39	103.6 ± 0.39
	Respiration rate (breath /min.)	105.4 ± 14.1	103.4 ± 11.3	84.2 ± 11.0	81.4 ± 8.06	99.8 ± 12.0	90.4 ± 11.0
	Haematocrit (%)	29.4 ± 0.85	29.2 ± 1.0	27.7 ± 1.37	29.6 ± 0.99	31.5 ± 1.11	27.4 ± 0.88
	Haemoglobin (g/100ml)	7.36 ± 0.25	7.72 ± 0.3	7.58 ± 0.16	8.43 ± 0.61	8.49 ± 0.33	7.43 ± 0.21
	Serum Bicarbonate (m.mol/l)	34.04 ± 1.27	36.27 ± 2.47	36.31 ± 1.54	34.88 ± 1.13	39.75 ± 1.44	34.21 ± 1.57
17.00	Body temperature (°F)	102.8 ± 0.31	102.3 ± 0.42	102.2 ± 0.29	101.3 ± 0.18	101.7 ± 0.22	101.7 ± 0.32
	Respiration rate (breath/min.)	49.4 ± 4.92	53.3 ± 3.66	46.2 ± 2.84	43.7 ± 1.9	40.8 ± 2.13	46.2 ± 3.23
	Haematocrit (%)	30.2 ± 1.16	28.1 ± 0.62	27.9 ± 0.91	30.4 ± 1.41	32.6 ± 1.17	29.7 ± 0.84
	Haemoglobin (g/100ml)	8.10 ± 0.6	7.21 ± 0.21	8.1 ± 0.22	7.69 ± 0.2	9.0 ± 0.61	7.28 ± 0.3
	Serum Bicarbonate (m.mol/l)	33.61 ± 1.55	32.5 ± 1.65	32.32 ± 2.07	30.15 ± 1.97	29.82 ± 1.82	31.33 ± 2.15

* Each mean represents 10 observations.

Table 4. Estimates of daily differences in the physiological reactions and blood parameters of buffalo heifers, in three daily periods, as affected by ambient temperature, direct solar radiation (heat stress) and recovery from heat stress

Item	Time Difference		
	12.00 minus 8.00 h (Rise of A.T)	15.00 minus 12.00 h (Heat stress)	17.00 minus 15.00 h (Recovery)
Ambient temperature (°C)	+ 6.90	+ 6.50	- 1.60
Relative humidity (%)	- 0.20	- 1.40	- 0.74
Body temperature (°F)	+ 0.79	+ 2.80	- 1.50
Respiration rate (breath/min.)	+ 8.19	+ 47.37	- 47.50
Haematocrit (%)	- 1.77	- 0.49	+ 0.69
Haemoglobin (g/100ml)	- 0.40	- 0.42	+ 0.06
Bicarbonate (m.mol/l)	- 1.23	+ 5.87	- 3.79

b) Effects of environmental temperature on bicarbonate store and blood parameters:

1) Bicarbonate store:

The value for bicarbonate concentration in the blood was greater in the morning, i.e. at 08.00 h (mean values of 31.0 & 30.53 m.mol/l for Group 1 and Group2, respectively) than that at noon 12.00 h, (29.8 & 29.3 m.mol/l for in Group 1 and Group 2, respectively) in (Table 2 and Fig. 1). It is well known that the physiological activities of animals during the night are less than during the day and this is the reason for the higher values for plasma bicarbonate in the morning. Steady state values are generated by normal reabsorption of $NaHCO_3$ by the kidneys (Harrington *et al.*, 1982, in humans).

Acid base balance:

With the rise in daily activity and increased ambient temperature, the respiratory component of blood, and the values for haemoglobin and haematocrit were reduced thus leading to a comparable drop in plasma bicarbonate (Tables 2 & 4).

The severe heat stress, (summer direct solar radiation), as imposed on the heat balance of the body was counteracted by augmenting the rise in respiration rate (more than double that at morning steady state; Tables 2 & 3). This severe rise in respiration rate caused a greater wash off of CO_2 with a drop in carbonic acid H_2CO_3 and a rise in bicarbonate $H_2CO_3^-$ as clearly illustrated by the values in Tables (4 & 6). This upset in respiration rate and bicarbonate concentration was rapidly corrected by shading the heifers (Tables 3, 4 & 6).

The present results agree with those of Neama (1994) in sheep and Schneider (1988) in cows, in which they recorded that serum bicarbonate was higher after than before exposure to heat stress.

Table 5. Mean ± S.E of the physiological response of buffalo heifers as affected by age

Time	Item	Body temperature (°F)	Respiration rate (breath/ min.)	Haematocrit (%)	Haemoglobin (g/100ml)	Bicarbonate (m.mol/l)
08:00 h	G1	99.57 ± 0.20	99.47±1.25	31.00±0.62	8.47±0.21	31.19±0.62
	G2	99.66±0.43	37.60±1.05	31.78±0.74	8.84±0.15	30.34±0.78
12:00 h	G1	100.9±0.24	47.13±1.57	29.57±0.56	7.93±0.17	29.98±0.95
	G2	100.6±0.17	46.33±1.63	29.67±0.80	8.60±0.21	29.10±0.80
15:00 h	G1	103.8±0.23	93.33±6.96	28.17±0.61	7.46±0.12	34.85±0.84
	G2	103.2±0.25	94.87±6.17	30.10±0.61	8.22±0.25	35.97±1.00
17:00 h	G1	102.2±0.19	47.27±2.12	29.27±0.58	7.82±0.24	32.42±1.09
	G2	101.7±0.18	45.93±1.79	30.37±0.81	7.97±0.26	30.82±1.04

G1 = Group 1 for animals weighing 240-285kg & Aging 1.5 year
G2 = Group 2 for animals weighing 345-380kg & Aging 2.5 year

Table 6. Estimates of the changes in the parameters of heat stress in buffalo heifers of two ages, 1.5 year (G1, n=3) and 2.5 year (G2, n=3)

Time	Item	Body temperature (°F)	Respiration rate (breath/ min.)	Haematocrit (%)	Haemoglobin (g/100ml)	Bicarbonate (m.mol/l)
12:00-08:00 h	G1	+1.33	+ 7.66	- 1.43	- 0.54	- 1.21
	G2	- 0.94	+ 8.73	- 2.11	- 0.24	- 1.24
15:00- 12:00 h	G1	+ 2.90	+ 46.20	- 1.40	- 0.47	+ 4.87
	G2	+ 2.60	+ 48.54	+ 0.43	- 0.38	+ 6.87
17:00- 15:00 h	G1	- 1.60	- 46.06	+ 1.10	+ 0.36	- 2.43
	G2	- 1.50	- 48.94	+ 0.27	- 0.25	- 5.15

G1 = Group 1 for animals weigh 240-285kg,
G2 = Group 2 for animals weigh 345-380kg.

Serum bicarbonate values in Group (2), which the oldest and heaviest animals, was more markedly affected by heat stress than Group (1). That was associated essentially with an increase in respiration rate in adult animals, to check the rise in body temperature (Table 6). After the resting period, in shade, Group (2) animals responded better than Group (1) by sharp a greater decrease in bicarbonate concentration (Table 6 and Figure 1), the drop in the values being 5.15 m.mol/l in Group 2 versus 2.43 m.mol/l in Group 1.

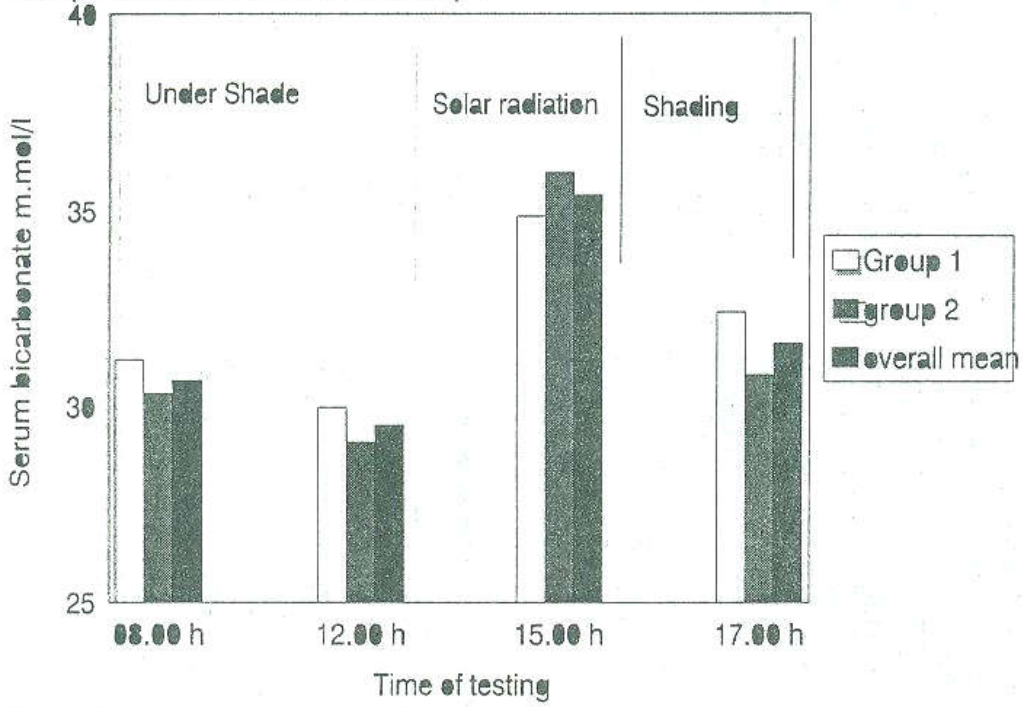

Fig. 1. Serum bicarbonate in buffalo-heifers as affected by heat stress and body weight.

2) Haematocrit and Haemoglobin:

Haematocrit (Ht) and haemoglobin (Hb) concentrations showed slight decreases with the increase in ambient temperature. The values for Hb and Ht were higher in the morning, (Table 2). After heat stress, Ht % and Hb (g/100 ml) values were decreased at noon by -0.49 and -0.42, respectively. This result is in agreement with that of Neama (1994) who noted that haematocrit and haemoglobin values in sheep were lower after exposure to solar radiation than before exposure. This may be due to a change in circulating red blood cells in the systemic circulation, (Table 4), most probably by increasing storage in the spleen. Concentration of red blood cells in the spleen occurs when more red blood cells are needed (Reece, 1991). Ashour & Shafie (1993) found that solar radiation caused rapid movement of minerals together with water to the extracellular fluid to create a further increase of interstitial fluid volume and maintain plasma volume with normal osmolarity. Chaiyabutr, *et al.* (1987) found that an increase in blood volume during acute heat stress occurred with an increase of both plasma and cell volume of Swamp buffalo, suggesting that the increase in plasma water during heat exposure came from extravascular tissue space

and / or from the digestive tract. Also, Saxena and Joshi (1980) indicated that, in calves of Hariana cattle in India and their crosses with Holstein-Friesian, Brown Swiss and Jersey, the extracellular water increased at an ambient temperature of 37 °C mainly due to an increase in plasma volume. Neama (1987) and Shafie *et al.* (1994) found that the values for Ht and Hb in Egyptian native sheep (Rahmani and Merino) were lower in summer than in the other seasons. They suggested that the reduction of the haematocrit in the summer by a greater value than that of haemoglobin denotes that the majority of the reduction is due to dilution of blood through more water intake in order to furnish evaporative cooling of the body. Moustafa *et al.* (1977) found that in cattle and buffaloes haemoglobin content was definitely increased during summer months, when the environmental temperature increased in Upper Egypt to 29 °C and the air was comparatively dry (relative humidity 55.5 %). This seems to be a long term adaptability of these animals to hot weather, as opposed to the daily short time exposure (acute heat stress).

At all sampling times in this study, it was noted that the haematocrit and haemoglobin values were higher in Group (2) than in Group (1) (Figures 2 & 3 and tables 5 & 6). Haemoglobin concentration decreased in both groups after heat stress, however the level of decrease was higher in Group 1(Table 6). On the other hand the haematocrit, after heat stress, decreased in Group (1) and slightly increased in Group (2). This may be due to destruction of erythrocytes under heat stress especialy in small animals which were sensitive to a rise in ambient temperature. The small animals (Group 1) were better able to compensate for the decreased value than Group 2 (Figures 2 & 3).

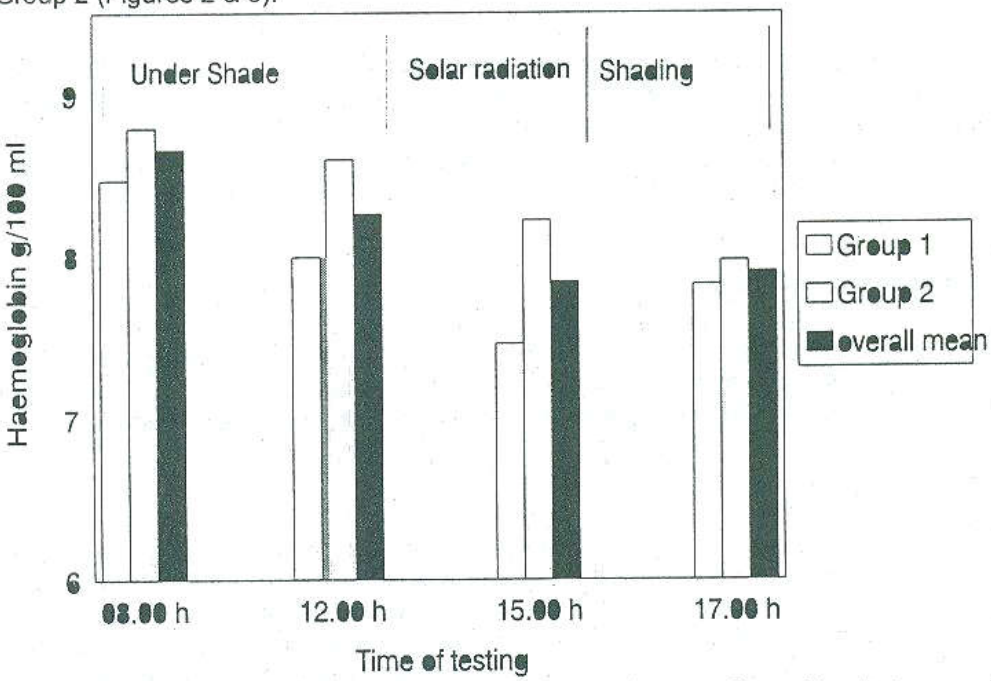

Fig. 2. Blood haemoglobin concentration in buffalo-heifers as affected heat stress and body weight.

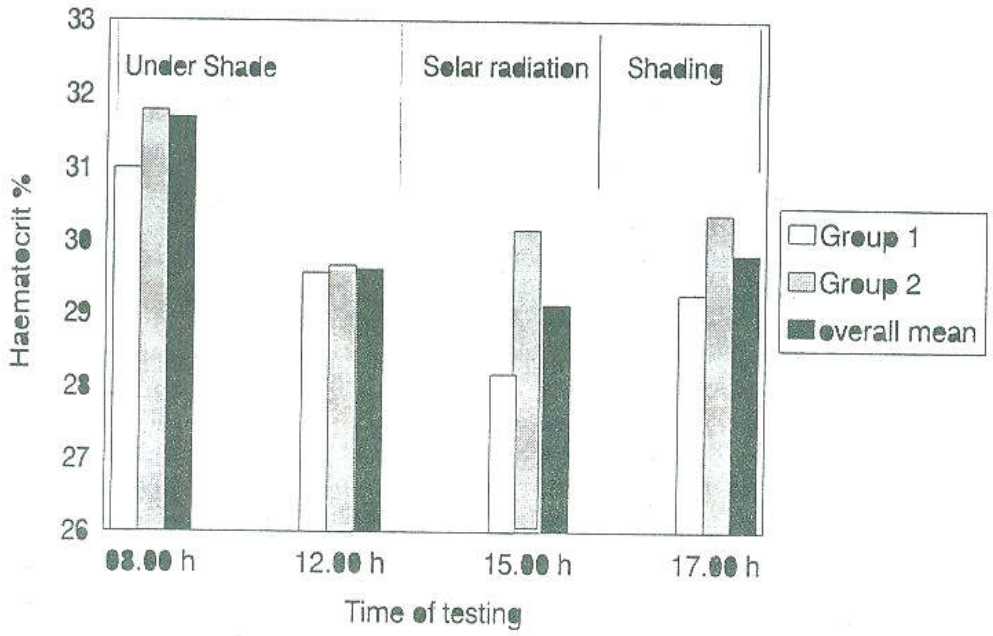

Fig. 3. Blood haematocrit concentration in buffalo-heifers as affected heat stress and body weight.

It is concluded that, the blood acid-base status and physiological responses of buffaloes are changed by shifts in the environmental conditions especially changes in ambient temperature (Upadhyay & Roa 1985 and Singh *et al.* , 1980) indicating that buffaloes undergo a moderate type of metabolic respiratory alkalosis and increase activity which washes off some CO_2, lead up to a decline in PCO_2 and CO_2 levels in blood.

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التوازن الحامضى القلوى فى عجلات الجاموس المعرضة للإجهاد الحرارى.

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أجريت هذة الدراسة فى معمل فسيولوجيا الحيوان بكلية الزراعة جامعة القاهرة لدراسة التوازن الحامضى القلوى فى العجلات المعرضة للإجهاد الحرارى. وقد تمت الدراسة على ٦ عجلات جاموسى خلال موسم الصيف (أغسطس ١٩٩٧) وكانت مقسمة لمجموعتين حسب الوزن والعمر المجموعة الأولى: الأصغر فى الوزن ومكونة من ٣ عجلات يتراوح وزنها بين ٢٤٠ - ٢٨٥ كجم وأصغر فى العمر (١,٥ سنة) والمجموعة الثانية: وهى مكونة من ٣ عجلات يتراوح وزنها بين ٣٤٥ - ٣٨٠ كجم وأكبر فى العمر (٢,٨ سنة). وقد غذيت هذة العجلات على دريس برسيم ، علائق مركزة ، قش أرز خلال فترة التجربة. عينات الدم تم سحبها من الوريد الوداجى عند ٤ أوقات من اليوم : ٨ صباحا ، ١٢ ظهرا ، ثم ٣ بعد الظهر (بعد تعريض الحيوانات لأشعة الشمس المباشرة لمدة ٣ ساعات) ، تنقل العجلات بعد ذلك تحت المظلات ويوضع لها ماء الشرب لمدة ساعتين (فترة الراحة) ثم تسحب عينات الدم مرة أخرى عند الساعة ٥ بعد الظهر. تم تقدير تركيز البيكربونات و الهيموجلوبين و الهيماتوكريت فى عينات الدم وعند أخذ هذة العينات يتم تقدير عدد مرات التنفس / الدقيقة / حيوان، درجة حرارة المستقيم، تسجيل درجة حرارة البيئة المحيطة، الرطوبة النسبية.

وكانت أهم النتائج

١) الإستجابة الفسيولوجية : أوضحت النتائج أن التغير فى درجة حرارة البيئة المحيطة من الساعة ٨ إلى الساعة ١٢ بمقدار ٦,٩ ° م سببت زيادة بسيطة فى درجة حرارة الجسم ٠,٧٩ ° ف ، ولكن متوسط معدل التنفس زاد بمقدار ٨,١٩ مرة/دقيقة. ولكن عند تعريض العجلات للإجهاد الحرارى من ١٢ - ٣ ظهرا رغم أن درجة حرارة البيئة لم تزد إلا بمقدار ٦,٥ ° م إلا أن معدل التنفس زاد بمقدار ٤٧,٣٧ مرة/دقيقة (حوالى ٦ مرات قدر التغير الحادث من ٨ - ١٢

ظهراً) أثناء فترة الراحة معدل التنفس عاد للمدى الطبيعى لـه فى كلا المجموعتين وبصورة أسرع من درجة حرارة المستقيم.

٢) مخزون البيكربونات : كان تركيز البيكربونات فى الدم أعلى فى الصباح (الساعة ٨) عنها عند الساعة ١٢ . بعد تعريض العجلات لأشعة الشمس المباشرة زاد تركيز البيكربونات فى المجموعتين ولكن قيم البيكربونات فى المجموعة الثانية (الأكبر فى العمر والوزن) كانت أكثر تأثراً بالإجهاد الحرارى عن المجموعة الأولى. أثناء فترة الراحة تحت المظلات أظهرت عجلات المجموعة الثانية إستجابة أسرع من المجموعة الأولى حيث إنخفضت قيم تركيزات البيكربونات فيها بدرجة أوضح.

٣) التوازن الحامضى القلوى: مع زيادة النشاط اليومى ومع زيادة درجة حرارة البيئة المحيطة ، مكونات التنفس فى الدم وقيم الهيموجلوبين والهيماتوكريت تقل وهذا النقص يكون متوازيا مع النقص فى بيكربونات البلازما.

الإجهاد الحرارى يؤثر على التوازن الحرارى فى الجسم مسببا زيادة فى معدل التنفس (أكثر من الضعف) وهذة الزيادة الشديدة فى معدلات التنفس تسبب فقد كبير فى ثانى أكسيد الكربون مع نقص فى بيكربونات البلازما وهذا ماتوضحة نتائج هذة الدراسة.

معدلات التنفس وتركيز البيكربونات فى البلازما يحدث لها تعديل سريع عند وضع العجلات تحت المظلات.

٤) الهيماتوكريت والهيموجلوبين: أوضحت النسب المئوية للهيماتوكريت وتركيزات الهيموجلوبين أوضحت نقصاً بسيطاً مع زيادة درجة حرارة البيئة حيث أن القيم كانت مرتفعة عند الصباح الساعة ٨ . ولكن بعد تعريض العجلات لأشعة الشمس المباشرة فإن تركيزات الهيموجلوبين إنخفضت بوضوح فى المجموعتين وكان مستوى النقص أكثر وضوحا فى المجموعة الأولى.

أما الهيماتوكريت فقد حدث نقص فى النسب المئوية للهيماتوكريت فى المجموعة الأولى وزيادة بسيطة فى المجموعة الثانية عقب التعريض لأشعة الشمس.