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THE ROLE OF BLOOD IN REGULATING BODY HEAT IN BOVINES

By

M.M. SHAFIE (1) AND A.L. BADRELDIN, (2)

SUMMARY

This work was carried out at the Faculty of Agriculture, Cairo University, Egypt U.A.R. The aim of the study was to find out the breed differences in blood characteristics and to explain the role in body heat regulation in bovines under the subtropical conditions. Four bulls of each of buffaloes, native cattle and Shorthorn crosses and three bulls of pure Dairy Shorthorn were used. Blood samples were collected from each fasting animal at morning once monthly in order to study the effect of environmental temperature. A special experiment was carried out to measure the effect of heat stress of direct exposure to summer sun rays on the different blood breeds. Physical characteristics, chemical constituents and haematological picture were estimated for each blood sample.

The results proved breed difference in the blood characteristics values. In most cases native cattle showed the lowest values, while buffaloes showed the highest ones. Shorthron blood was nearly similar to that of buffaloes while the Shorthorn crosses were in-between their two parents in this respect.

The effect of rise in body temperature on blood characters was mostly apparent between 38° and 39°C.

Exposure to direct solar radiation had a greater effect on Shorthorns and buffaloes than on Shorthorn crosses, while native cattle was the least affected breed. These results coincide with the previous researches on the adaptability of these breeds. The most important variations in the blood properties and constituents were the decrease in both viscosity and haemoglobin content, the increase in sugar and creatinine in all breeds. The plasma CO_2 decreased in buffaloes and native cattle, while it increased in Shorthorn and its crosses.

The results are discussed in relation with the previous work on the adaptability and adaptive mechanism of these breeds to hot climates. In all cases, native cattle proved to possess the most efficient blood characteristics and has a well balanced physiological and histological systems for heat regulation through skin and respiratory systems.

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(1) Lecturer,
(2) Professor Chairman,
Animal Production Dept., Faculty of Agric., Cairo University.

Introduction

Studies on the adaptability of different bovine breeds to hot climate in Egypt had revealed that native cattle are more adaptable than either buffaloes, Dairy Shorthorn, Jersey or crossbred animals (Badreldin et al., 1951 and Ragab et al., 1953). Experiments concerning exposure to direct solar radiation also proved that native cattle are the most heat tolerant animals (Asker et al., 1952 and Badreldin and Ghany, 1954). A definite and concrete explanation for such behaviour was lacking. Aside of the difference in the activities of the sweat glands, the blood circulation system was thought to be of a great importance in this respect.

The studies of the heat stress effect on the characteristics and constitutions of the blood of temperate and tropical cattle breeds showed somewhat conflicting results. Manresa and Falson (1939) reported that haemoglobin declines with increasing temperature. Rusoff et al. (1934 & 1936) found no effect of outdoor temperature in Louisiana on the composition of Jersey blood. Rieck and Lee (1948 a & b) found a drop in calcium, inorganic phosphate and

sugar in Jersey cows blood when the ambient air temperature was raised from 85° to 110°F. Brody (1949) stated that plasma CO_2 content declined at 85°F., the high temperature of 105°F. induced some decline in calcium, cholesterol and fatty acids, and a great increase in creatinine with no effect on non-protein-nitrogen. Both haemoglobin and haematocrit values showed slight increase while the variation in red and white blood cells count had no trend (Brody, 1949 and Blinco et al., 1951). Dale et al. (1956) found that the exposure of cows to high temperature caused an increase in serum and blood volumes with no consistent trend in serum water or water space in the body.

The purpose of this study was to find out the breed difference between native cattle, buffaloes, Shorthorn and Shorthorn crosses in the properties of their blood, and the effect of rise in air temperature and direct solar radiation on these properties. The results are discussed in relation to the different physiological functions participating in the adaptability of farm animals to hot climates.

Materials and Methods

This work was carried out at the Faculty of Agriculture, Cairo University, Egypt, U.A.R. Three pure Dairy Shorthorn bulls and four adult ones from buffaloes, native cattle and Shorthorn crosses were used.

Blood samples were drawn out from the animals at 7 a.m. before the morning meal, to avoid the effect of feed increment heat. At the mean time air temperature, body temperature, respiration rate and the arterial blood pressure were recorded.This was repeated for each animal at monthly intervals from March till November 1956.

The mean value of each item, either of the blood characteristics or the physiological reactions, for the overall

experimental period was considered as the natural specific value for each breed (section A in the results). To find out the response of blood to body temperature in the different breeds, the successive monthy values were studied in relation to the corresponding body temperature, (Section B in the results). To study the effect of direct exposure to solar radiation, two bulls from each breed were exposed to direct sunrays of August for 2 hours from noon to 2 p.m. at the same time two other bulls from the same breed were kept under shade (unfortunatly it was not possible to measure the radiation), temperature in shade was 35 c.g. The status of the two groups was reversed at the same time on the next day. Blood samples were drawn at 2 p.m. from both the exposed and shaded animals. The difference in blood values between the two groups is attributed to the caused by solar radiation effect, the difference was computed in percentage to the basic values of the shaded animals (Section C in the results).

Blood samples were collected from the jugular vein by means of a stainless steel bleeding needle ; 20 ml. were oxalated, 2 ml, heparinated and 10 ml. were collected under paraffin oil, without exposure to air, and mixed with potassium oxalate. This last portion was used in the extimation of plasma CO_2 content after Van Slyke (1922), at the meantime the pH value was measured by a pH meter. The plasma concentration was estimated by the refractive index of the plasma of the heparinated blood. The viscosity of the oxlated blood was evaluated relatively with water expressed in poise units by an Ostwaid Viscometer in a water bath at 37°C. The chemical analysis was carried out after Hawk et al. (1952). The haematological values were obtained by the usual methods after Fowler (1949). Statistical estimates were obtained according to Snedecor (1953).

RESULTS

A.—Breed Difference in Blood Characteristics

Physical properties :

The blood viscosity was greater in buffaloes and smaller in native cattle than in Shorthron or its crosses ; the difference being highly significant. There was no distinct breed variation in the plasma concentration. The pH value was significantly higher in buffaloes than in cattle breeds and crosses.

Haematological picture :

There was no breed difference in the haematocrit value which ranged between 36.8 to 39.4 The percentage value of the leucocyte forms showed nearly the same trend in the cattle breeds. The lymphocytes, monocytes and eosinophils percentages were greater in cattle than in buffaloes. On the other hand, buffaloes possess a significantly higher percentage value of neutrophils than cattle breeds.

Chemical constituents :

Buffaloes had the highest while native cattle had the lowest values of fibrinogen, N.P.N., creatinine and inorganic phosphate. Shorthorn possessed the highest values of total protein, albumin and total phosphates ; its crosses blood contained about 14 gm. haemoglobin content which was higher by 2 gm. than in both native cattle and Shorthorn crosses. Buffaloes had the highest while Shorthorn had the lowest balues of both plasma CO_2 content and blood sugar. However, the breed difference was significant only in case of N.P.N., creatinine, HB and CO_2 content (Table 1).

TABLE 1.—Mean Values of Blood Characteristics and Constitutuents in Bovines (chemical constituents per 100 ml. of blood).

Items	Buffaloes	Egyptian cattle	Shorthorn crosses	Dairy Shorthorn
Physical characteristics :				
Viscosity	5.2 ±0.3	3.9 ±0.2	4.3 ±0.2	4.7 ±0.1
Plasma concentration	1.5039	1.5039	1.5042	1.5031
pH	7.7	7.6	7.6	7.6
Chemical constituents :				
Total protein,gm. ...	7.9 ±0.3	7.9 ±0.4	8.4 ±0.3	8.4 ±0.3
Albumin, gm.	3.8 ±0.2	3.9 ±0.3	3.6 ±0.2	4.5 ±0.2
Globulin, gm.	3.3 ±0.2	3.5 ±0.2	3.9 ±0.3	3.2 ±0.2
Fibrinogen, gm. ...	0.8 ±0.1	0.7 ±0.1	0.7 ±0.1	0.7 ±0.1
N.P.N., mgm.	48.2 ±2.3	41.8 ±2.1	37.4 ±1.7	39.4 ±1.5
Cretinine, mgm. ...	2.3 ±0.3	1.9 ± .03	1.7 ±0.2	2.0 ±0.3
Haemoglobin, gm. ...	14.6 ±0.4	12.4 ±0.3	12.8 ±0.4	14.7 ±0.4
Sugar, mgm.	63.5 ±2.7	62.4 ±2.5	60.3 ±2.3	57.6 ±2.2
Total phosphates mgm	54.1 ±2.9	54.3 ±3.7	48.9 ±2.8	59.6 ±4.4
Inorganic phosphates mgm.	4.7 ±0.3	4.0 ±0.2	4.4 ±0.3	4.5 ±0.4
CO_2, cm.	53.3 ±0.7	51.8 ±1.4	53.4 ±0.5	47.9 ±1.6
Haematological picture:				
Haematocrit	36.8 ±0.7	36.6 ±0.8	37.3 ±0.9	39.4 ±0.9
R.B.C. count (x1000)	7563 ± 51	6700 ±144	7233 ±185	7192 ±202
W.B.C. count (x10)	1343 ± 51	1195 ± 50	1244 ± 59	1301 ± 71
Lymphocytes,% ...	43.5 ±2.8	50.2 ±2.6	45.1 ±3.3	51.2 ±3.2
Lymphocytes, % ...	43.5 ±2.8	50.2 ±2.6	45.1 ±3.3	51.2 ±3.2
Monocytes, %	25.3 ±1.9	31.8 ±2.8	29.4 ±2.7	31.1 ±2.9
Eosinophils, % ...	1.7 ±0.3	2.7 ±0.3	3.3 ±0.5	2.6 ±0.6
Basophils, %	0.7 ±0.1	0.5 ±0.2	0.6 ±0.2	0.3 ±0.1
Neutrophils, % ...	28.9 ±2.2	14.8 ±1.4	21.7 ±2.0	14.7 ±1.7

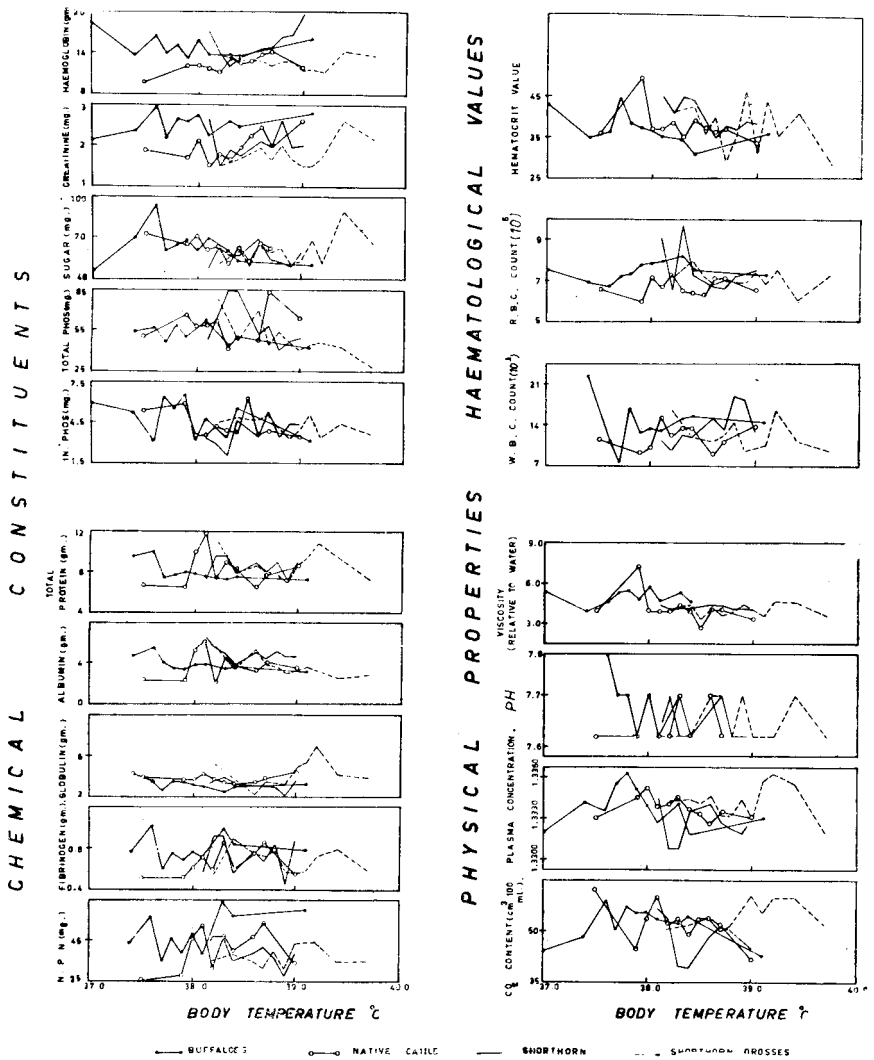

FIG 1.—Effect of rise in body temperature on the properties and constituents of Bovine's blood.

B.—Effect Of Rise In Body Temperature On Blood Characteristics

The rise of body temperature had no effect on the blood viscosity, pH and plasma concentration. While the increase in body temperature did not affect the RBC and WBC contents. It induced a decrease in the haematocrit value, in all the breeds, which was significant in the case of the Shorthorn and its crosses.The effect of rise in body temperature on the blood chemical constituents was mostly apparent at 38° to 39°C. ; within this range, there was a steady increase in creatinine of cattle breeds while buffaloes were not affected, and a decrease in total phosphates in Shorthorn and its crosses. The increase of body temperature produced a significant increase in N.P.N. in buffaloes, a decrease in CO_2 in native cattle, and a decrease in fibrinogen in Shorthorn crosses (Fig. 1).

C.—Effect Of Direct Exposure To Solar Radiation On Blood Characteristics

Exposure of buffaloes and cattle breeds to the direct sun rays impose a heat stress on its heat regulating mechanism and affect the boold physical properties, haematological picture and chemical constitution. The viscosity of the blood decreased in all breeds but with high values in both buffaloes and Shorthorn, and very slight value in native cattle. The plasma concentration was not affected (Table 2). The RBC and WBC decreased greatly in both buffaloes and Shorthorn crosses, while they were nearly unaffected in native cattle and the pure Shorthorn. While the lymphocytes increased and the neutrophils decreased in the native cattle blood, the contrary happened in the other breeds. Total protein, globulin, N.P.N. decreased in both buffaloes and Shorthorn, the value of decrease for Shorthorn

TABLE 2.—Percentage Variation in Mean Values of Blood Characteristics of Animals Exposed to Direct Sunrays for 2 hrs from that Under Shade. (air temp. in shade 35 C.).

ITEMS	Buffaloes	Native cattle	Shorthorn crosses	Shorthorn
Physical Characteristics :				
Viscosity	— 7.2	— 0.7	— 4.4	—11.7
Plasma concentration	0.0	0.0	0.1	0.0
pH	— 0.6	0.3	0.0	— 1.1
Chemical Constituents :				
Total protein, gm. ...	—11.9	4.4	28.6	—29.4
Albumin, gm.	1.8	— 2.5	16.4	13.4
Globulin, gm.	—24.2	7.4	49.3	—51.7
Fibrinogen, gm. ...	0.0	32.7	— 4.5	15.7
N.P.N., mgm.	—11.3	— 1.3	28.7	—32.3
Creatinine, mgm. ...	8.2	— 6.0	10.0	5.6
Haemoglobin, gm. ...	— 2.4	— 2.2	— 3.7	— 8.1
Sugar, mgm.	—15.7	3.6	14.5	6.2
Total phosphates mgm	50.3	5.7	9.7	— 3.4
Inorg. phosphates mgm.	85.3	12.4	4.5	1.2
CO_2, cm	— 8.4	— 7.2	3.7	4.6
Haematological picture:				
Haematocrit	— 7.2	— 1.8	0.0	—12.9
R.B.C. count (x1000)	— 6.1	0.3	14.9	— 1.2
W.B.C. count (x10) ...	— 3.2	— 1.8	16.6	0.0
Lymphocytes % ...	— 6.7	8.0	—12.0	— 4.7
Monocytes %	—11.5	3.0	44.6	—22.1
Eosinophils %	—40.0	0.0	600.0	—14.1
Basophils %	133.3	100.0	75.0	—100.0
Neutrophils %	56.6	—21.9	55.0	90.0

was three times that of buffaloes. Sugar increased greatly in buffaloes, Shorthorn and its crosses, but slightly in native cattle. Creatinine increased in all breeds except in native cattle where it decreased. The haemoglobin decreased in all breeds, the highest value occurred in case of pure Shorthorn followed by Shorthorn crosses. The plasma CO_2 content decreased in buffaloes and native cattle while it increased in Shorthorn and its crosses. Phosphates showed a great increase in buffaloes and a slight increase in native cattle, while Shorthorn and its crosses expressed a decrease in total and inorganic phosphates respectively.

Discussion

Buffaloes stand apart from the cattle types in their blood characteristics. This is certainly due to phylogenetic difference. However, Shorthorn is the closest breed to buffaloes in its blood characteristics. The most specific characters of buffaloe's blood are the high viscosity and the sedimentation which did not occur in the studied cattle blood. The higher haemoglobin value in buffaloes and Shorthorn than in native cattle and Shorthorn crosses increases the metabolic heat production due to the high oxygen tension of blood. This is a drawback for adaptation to hot climates where the animals mostly try to keep their metabolic rate at a low level. The high value of creatinine content in buffaloes and Shorthorn asserts this view and indicates the highest metabolic rate in these two breeds.

The heat stress of exposure to direct summer sun rays induced a decrease in blood viscosity in buffaloes, Shorthorn and Shorthorn crosses to a value very near to that of native cattle. This reduction of viscosity facilitates the mobilization of the blood towards the animal surface and skin capillaries which affects heat exchange between animal surface and ambient air or surroundings through conduction

and radiation. However, this way of heat dissipation is of no or very little value especially in buffaloes and Shorthorn in which the skin temperature is nearly equal to the internal body temperature at this state (Shafie, 1958). All the animals reduced the haemoglobin content in their blood in order to check the metabolic rate. The greatest decrease in case of pure Shorthorn indicates more reliance on chemical regulation of body temperature because of the poor efficiency of the physical characteristics and anticipating physiological system. The decrease of CO_2 plasma content in native cattle seems to be caused by effective airiation of deep breathing since the increase in respiration rate was slight in comparison to the other breeds (Shafie, 1958). The contrary occurred in case of Shorthorn and crosses; the great increase in respiration rate was accompanied by an increase in CO_2 plasma content which indicates that its rapid respiration was very shallow with no effect on the tidal air volume. While the creatinine content decreased in case of native cattle, it increased greatly in buffaloes and Shorthorns indicating an increase in metabolism adding a new burden of heat. This increase in creatinine must be produced by the active muscles achieving the fast respiration rate.

It is clear from this study that native cattle possess the most efficient blood characteristics for adaptation to hot climates from both physical and chemical points of view. The low blood viscosity facilitates blood circulation in skin which in co-operation with the great capillary surface (Shafie, 1958) enlarges the circulating volume of blood per unit skin surface per unit time. This adaptive physiological and anatomical construction increases the efficiency of heat dissipation through the physical law of radiation convection and conduction. The low value of haemoglobin and RBC count in native cattle blood is an adaptive

character to lessen the metabolic heat production ; this result coordinates with results on Indian and European breeds. Mukherjee and Bhattacharya (1952) reported a 7.72 - 8.93 gr.% haemoglobin in Indian bulls, while most of the authors recorded about 14 gr.% haemoglobin in European breeds blood (Brody, 1949).

The blood characteristics of Shorthorn crosses and their reaction to heat stress in similar to native cattle in most cases. In some cases it stands between the native cattle and pure Shorthorn.

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الملخص

أهمية الدم فى تنظيم حرارة الجسم
فى الماشية البقرية

أجريت سلسلة من التجارب بغرض الكشف عن الدور الذى يلعبه الدم فى تنظيم درجة حرارة الجسم فى الماشية البقرية تحت ظروف المناطق شبه الحارة . وقد شملت التجارب أربعة ثيران من كل من الماشية البقرية المصرية والجاموس وخليط الشورتهورن مع الماشية المصرية بالإضافة إلى ثلاثة ثيران أصيلة من نوع الشورتهورن . وأخذت عينات دم فردية من هـذه الحيوانات مرة كل شهر والحيوانات فى حالة صيام كما سجلت درجات الحرارة الجوية والجسمية على مدار العام هذا بالإضافة إلى عمل تجارب عن الاحتمال الأقصى لدرجات الحرارة الجوية العالية على هذه الحيوانات وذلك بتعريضها لأشعة الشمس المباشرة . وقد تم تحليل الدم من حيث صفاته الطبيعية ومركباته الكيماوية وكذلك صفاته الأخرى فى العينات المأخوذة .

وقد تبين من هذه التجارب وجود فروق معنوية وظاهرة بين الأنواع المستعملة فى هذه التجارب من حيث تحليل الدم بكافة مشتملاته وكانت صفات الدم فى الماشية المصرية فى أقل مستوى بينما كانت هذه الصفات فى أعلى مستوى بالنسبة للجـاموس وقد قاربت ماشية الشورتهورن الجاموس فى ذلك الاعتبار بينما كانت الماشية الخليطة وسطاً فى صفاتها بين أبويها من الماشية المصرية والماشية الشورتهورن الأصيلة .

وقد اتضح بصورة جلية أثر ارتفاع درجة حرارة الجسم على مكونات الدم وصفاته عندما وصلت الحرارة بين ٣٨ و٣٩° مئوية . وعندما تعرضت الحيوانات لأثر أشعة الشمس المباشرة ظهر أن ماشية الشورتهورن والجاموس أكثر تأثراً من الماشية الخليط ، أما الماشية المصرية فقد كانت الأقل تأثراً . وتتفق هذه النتائج

مع ما سبق الوصول إليه فى الأبحاث السابقة الخاصة بأقلمة الحيوانات وكان أهم تغيير لوحظ فى خواص الدم وصفاته هو انخفاض اللزوجة ومعامل الهيموجلوبين وكذلك زيادة السكر والكريتانين فى كل أنواع الحيوانات نتيجة لارتفاع درجة الحرارة الجوية . وقد لوحظ أيضاً أن ثانى أوكسيد الكربون الموجود فى بلازما الدم انخفض فى الجاموس والماشية المصرية بينما ازداد فى ماشية الشورتهورن والماشية الخليط .

وتؤيد هذه النتيجة ما سبق الوصول إليه من أن الماشية المصرية هى أكثر أنواع الماشية تحملاً للحرارة تحت الظروف المحلية تليها الماشية الخليط ثم الشورتهورن والجاموس وهذا يرجع إلى خصائص كل نوع من حيث الدم ومكوناته وسائر الصفات الفسيولوجية والهستولوجية الخاصة بتنظيم الحرارة فى الجلد والجهاز التنفسى .