UNIVERSITI PUTRA MALAYSIA

THE PHYSIOLOGICAL RESPONSES OF DAIRY CATTLE DURING EXPOSURE TO ENVIRONMENTAL TEMPERATURE

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ABSTRACT

Eight three year old dairy cows consisting of four Friesians and four Friesian X Local Indian Dairy cattle were placed under shade and exposed to direct solar radiation,one week for each treatment.The effects of heat stress on the cardiorespiratory activities,rectal and skin temperatures,hematological parameters and milk production were observed.

As ambient temperature increased,both breeds showed significant elevations in respiratory rate,rectal temperature,pulse rate and skin temperatures.The increments were more pronounced when the animals were exposed to direct solar radiation.Total daily milk production decreased significantly when both breeds were exposed to direct solar radiation.

During exposure to direct solar radiation, the crossbreds showed significant reductions in the erythrocyte count,hemoglobin level and the packed cell volume.Blood pH of both breeds increased significantly with the increase in ambient temperature,and generally the values were significantly higher for the purebreds.

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INTRODUCTION

As a developing country,Malaysia will inevitably confront a problem of keeping food production abreast with her rapid population growth.Dairy industry,though still in its cradle stage of development,has a lot to offer for the enhancement of food production.Good dairy breeds are being imported to stimulate the growth and expansion of this industry.

With the introduction of these temperate animals into our hot and humid climate,their performances in term of milk production,reproductive efficiency and resistance to diseases are below expectation.Heat stress had been shown to be one of the factors responsible for the depression of their true potentials.In view of the importance of this problem for the future of dairy industry in the tropics, considerable research has to be carried out to determine the exact role of heat stress in milk production,reproduction and the physiology of the animals,and to develop methods of alleviating its effects.

The present study reports the changes in cardio-respiratory activities,rectal and skin temperatures,hematological parameters and milk production of Friesians and Friesian X L.I.D kept under shade and when exposed to direct solar radiation.

LITERATURE REVIEW

The performance of dairy cattle has been shown to be adversely affected by high environmental temperature, humidity and solar radiation (Thatcher,1973).Lactating dairy cows are particularly sensitive to adverse thermal stress probably due to their specialized productive functions and to their high efficiency of feed utilization (Hodgson,1973).A fall in milk production is also closely related to an increase in the body temperature (Okamoto *et al*,1965).

Dairy cattle increase their respiratory rate and rectal temperature when exposed to high environmental temperature (Gaalas,1945; and Ingraham *et al*,1974).Animals pant to dissipate body heat by increasing respiratory evaporative cooling (Wolff and Monty,1974).However,with the increasing respiratory rate,the animals had been shown to develop respiratory alkalosis (Bianca and Findlay,1962).

According to Bianca(1959),cattle increase their heart rate during short term exposure to heat and decrease with long term exposure.By increasing the pulse rate,excessive body heat could be lost by vaporization of sweat.

Kamal(1965) showed that rectal temperature in European evolved cattle began to increase at ambient temperatures above 23.9° C.Skin temperatures varied more

closely with changes in the ambient temperature (Berman and Zamsky,1971).Shining coat increases the efficiency of heat regulation in cattle,and cattle with coarse and dark coat might experience greater radiant heat load (Stewart and Brody,1954).

Hammersma (1937) and Pal et al (1945) have all observed the existence of seasonal variations in the hemoglobin concentration of cattle,and the hemoglobin values decrease under heat stress (Razdan,1969).The packed cell volume(PCV) of cattle also decreases with exposure to hot and humid environment (Bass and Henschel,1956) and Razdan (1969) showed that PCV is significantly correlated with ambient temperature.The erythrocyte values were lower (Razdan,1969) and during summer,there was a significant reduction in the erythrocyte count (Mehrota et al,1954).

MATERIALS AND METHOD

ANIMALS

Four three year old locally born and raised Friesian and four Friesian X Local Indian Dairy cows were used.For the purebreds,their lactation period ranged from 98 to 208 days,while for the crossbreds,it was from 35 to 168 days and one cow was dry.

The cows were fed daily with grass and water ad libitum and supplemented with six kilogrammes of concentrates after the morning milking.Mineral blocks were provided.

EXPERIMENTAL

The duration of the study was two weeks for each breed of the dairy cattle.In the first week,the animals were housed in the shed for the duration of each day except at the time of milking.In the second week,they were exposed to direct solar radiation for the whole daylight hours, haltered in the open corral.The animals were haltered with minimal allowance for lateral movements but with no restriction for lying down.

Five readings at three-hourly intervals,were made beginning at 0600 hours,and the following parameters were determined:-

i. Respiratory rate - this was measured by counting flank movements.

ii. Pulse rate - taken at the coccygeal artery.

iii. Rectal temperature - measured by placing the thermocouple 6 cm in the rectum using digital thermometer (Digitron).

iv. Ambient temperature and relative humidity - using a Whirling Hygrometer.

Three times daily at 0900,1200 and 1500 hours, skin temperatures on the left and right flank,forehead, left and right pinna,rump and the perineal region were determined by contact thermocouple (Digitron).

To minimize error due to the excitation of the animals,the respiratory rates were first determined followed by pulse rate,rectal and skin temperatures.

Blood samples were collected from the jugular vein using heparinized tubes,three times daily,at 0900, 1200 and 1500 hours on the first,middle and last day of the week,for the determination of:-

i. Blood pH,pO_2,pCO_2 and HCO_3^- concentration (CORNING pH/Blood Gas 165/2)

ii. Total erythrocyte (Coulter counter model ZF)

iii. Hemoglobin (Coulter Hemoglobinometer)

iv. Packed cell volume (Microhematocrit method)

v. Erythrocyte indices; MCV,MCHC (Calculation)

vi.Calcium (Beckman Spectrophotometer)

Total daily milk production for each breed was recorded during the duration of the study.

RESULTS AND DISCUSSION

The weather during the study is shown in Figure 1.

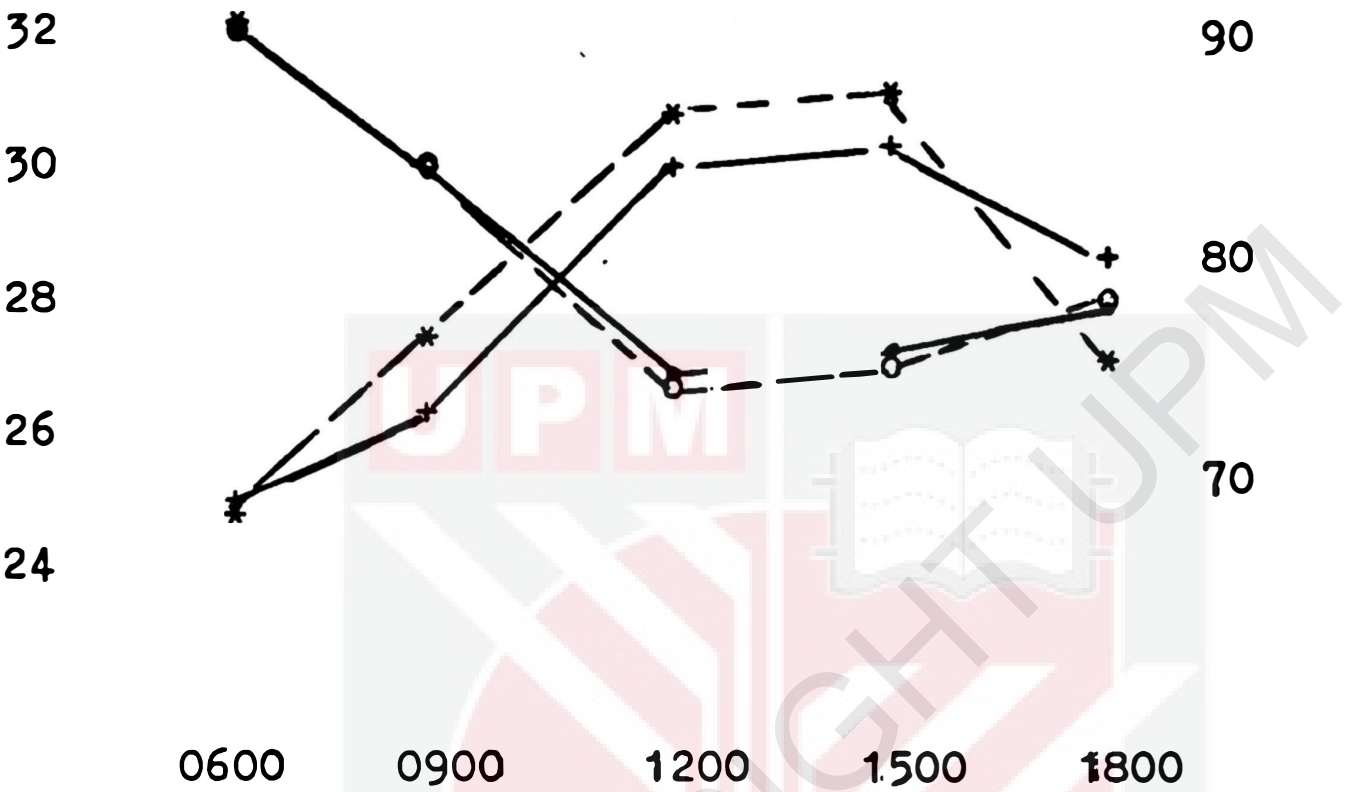

FIGURE 1 : AVERAGE THREE-HOURLY AMBIENT TEMPERATURE AND RELATIVE HUMIDITY IN THE SHED AND IN THE OPEN CORRAL.

RECTAL TEMPERATURE

The average rectal temperature(T_{re}) for both breeds in the shed and in the open corral is presented in Table 1.

BREED	FRIESIAN		FRIESIAN X L.I.D	
TREATMENT	SHADED	NONSHADED	SHADED	NONSHADED
HOURS OF DAY	(MEAN ± S.D)	(MEAN ± S.D)	(MEAN ± S.D)	(MEAN ± S.D
0600	39.4±0.09	38.3±0.06	38.4±0.09	38.2±0.13
0900	39.8±0.05	40.5±0.13	38.9±0.22	39.6±0.12
1200	39.7±0.15	41.0±0.12	39.8±0.08	41.7±0.13
1500	39.3±0.22	40.2±0.21	39.6±0.25	40.7±0.17
1800	39.2±0.29	39.3±0.08	39.1±0.14	38.2±0.13

TABLE 1 : AVERAGE RECTAL TEMPERATURE OF THE SHADED AND NONSHADED FRIESIAN AND FRIESIAN X L.I.D .

For both breeds, T_{re} increased significantly with the increase in the ambient temperature.This indicates that under heat stress,thermal balance could not be maintained since heat production is greater than heat dissipation.Under high temperatures,the nonevaporative cooling mechanisms become very inefficient since the difference of temperature between the body and the air is greatly reduced.This was more apparent under direct solar radiation,where in addition to the ineffective nonevaporative cooling mechanisms,the cows were gaining radiant heat from the solar radiation.

Under direct solar radiation, the purebreds experienced earlier and more rapid rise in T_{re}. At 0900 hours, the average T_{re} for the purebreds was 40.5° C which was higher ($P < 0.001$) than the crossbreds' 39.6° C. This could be due to the low critical temperature of the purebreds. Similar observations were made by Kamal (1965) in European evolved cattle with T_{re} beginning to rise at ambient temperatures above 23.9° C.

RESPIRATORY RATE

The average respiratory rate (f) for the two breeds in the shade and in the open corral is presented in Table 2.

BREED	FRIESIAN		FRIESIAN X L.I.D	
TREATMENT	SHADED	NONSHADED	SHADED	NONSHADED
HOURS OF DAY	(MEAN±S.D)	(MEAN±S.D)	(MEAN±S.D)	(MEAN±S.D)
0600	60±6.85	52 ± 6.48	23 ± 1.26	23 ± 1.29
0900	41 ± 8.37	62 ± 1.29	29 ± 1.63	35 ± 1.0
1200	71 ± 14.84	106± 6.13	35 ± 1.50	72 ± 0.82
1500	65 ± 10.47	98 ± 6.06	33 ± 1.73	88 ± 7.27
1800	73 ± 14.22	66 ± 3.0	28 ± 1.26	23 ± 1.29

TABLE 2: AVERAGE RESPIRATORY RATES OF THE SHADED AND NONSHADED FRIESIANS AND FRIESIAN X L.I.D.

The general trend of f were similar for both breeds.Generally the average f increased significantly with the increase in the ambient temperature,the increase being more pronounced in the nonshaded animals.This agrees with the findings of Allen (1962); Johnston and Branton (1952);and Ingraham (1974).Animals increase f under heat stress to dissipate about 30 per cent of its body heat by respiratory vapprization (Mclean,1963).

In the nonshaded Friesians,the per cent increase in f was 70 per cent between 27.3° C to 30.5° C and 19 per cent between 24.4° C to 27.3° C. Similar responses were observed in the crossbreds but the per cent increase was greater,that is 50 and 105 per cent respectively.This probably indicates that the crossbreds were more sensitive than the purebreds to the rise in ambient temperature under direct solar radiation.However the actual values of f were significantly higher for the crossbreds.This finding disagrees with the observations made by Kamal (1965). They observed that the per cent increase in f in the Friesian was much greater at lower temperatures.This could be due to the fact that the Friesians used in the present study were born and raised under the Malaysian environment had,to a certain degree,adapted to the climate.However beyond 30.9° C,unlike the crossbreds,the Friesians were unable to further increase their f.This diminished res-

ponse was similarly shown by Kamal (1969) but they observed that this phenomenon occured beyond the ambient temperature of 42.0° C.

PULSE RATE

The average pulse rate for the two breeds in the shade and in the open corral is presented in Table 3.

BREED	FRIESIANS		FRIESIAN X L.I.D	
TREATMENT	SHADED	NONSHADED	SHADED	NONSHADED
HOURS OF DAY	(MEAN ± S.D)	(MEAN ± S.D)	(MEAN ± S.D)	(MEAN ± S.D)
0600	64 ± 4.86	60 ± 9.20	56 ± 3.30	55 ± 0.50
0900	63 ± 9.64	76 ± 3.87	59 ± 1.41	59 ± 2.22
1200	77 ± 4.50	76 ± 9.24	64 ± 2.45	77 ± 2.58
1500	75 ± 8.46	67 ± 3.59	62 ± 5.12	74 ± 1.91
1800	77 ± 7.75	71 ± 3.09	61 ± 2.08	55 ± 0.50

TABLE 3 : AVERAGE PULSE RATE OF THE SHADED AND NONSHADED FRIESIAN AND FRIESIAN X L.I.D.

Generally pulse rates for both breeds increased significantly with the increase in ambient temperature. Similar finding was made by Rees (1964).Although cattle is a poor sweating animal,studies have shown that heat loss by vaporization of sweat does occur.Under heat stress

the blood flow in increased to the surface by peripheral vasodilation where cooling is by the vaporization of the sweat.The internal defficiency resulting therefrom is compensated by increasing the pulse rate.

The purebreds showed no significant difference in the pulse rate with or without shade,but for tthe crossbreds,the pulse rate was significantly higher when under long exposure to direct solar radiation.This may indicate that the crossbreds have a greater capacity of elevating the pulse rate so that excess body heat could be dissipated by vaporization of sweat.

SKIN TEMPERATURE

The average skin temperature (T_{skin}) at various sites of the body is presented in Appendix 1.

The general trend of respomse of T_{skin} towards the increasing ambient temperature were similar for both breeds. T_{skin} increased significantly with the increase in the ambient temperature,the increase being more pronounced in the nonshaded animals.Under solar radiation,T_{skin} of the crossbreds were significantly higher than those of the purebreds.This may be brought about by the nature of the hair coat of these animals.The shining glossy hair coat of the purebreds might repel some of the radiation and this protected them to some extent from the influence of

radiant heat,and also the presence of thick hair coat will form a barrier for heat transfer as such certain amount of cooling prevails on the skin.The dull coarse coat of the crossbreds might absorb more radiant heat and this explained for the higher T_{skin}.

MILK PRODUCTION

The total milk production for four Friesians and three Friesian X L.I.D is presented in Figure 2.

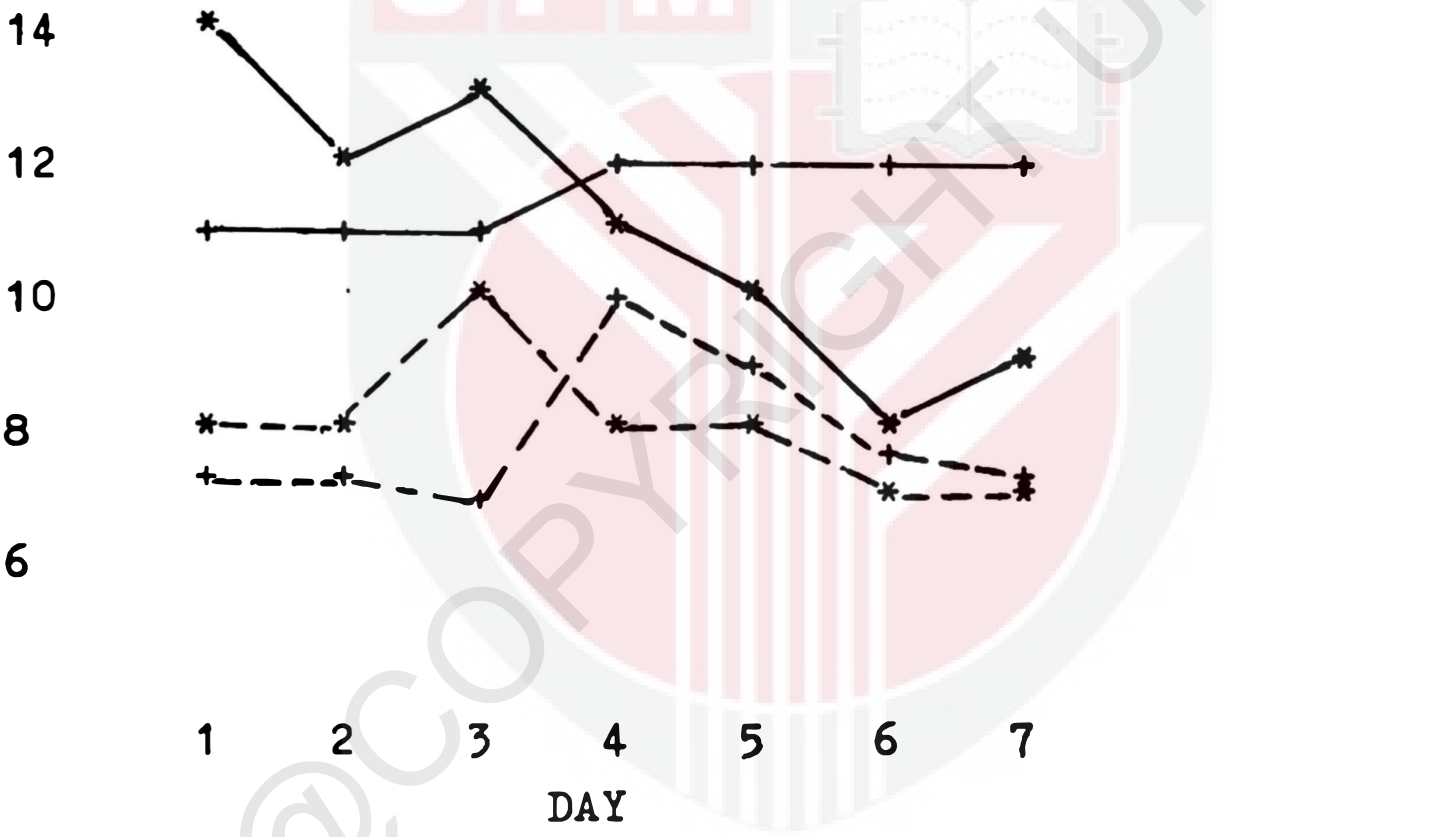

FIGURE 2 : THE TOTAL DAILY MILK PRODUCTION OF THE SHADED AND NONSHADED FRIESIAN AND FRIESIAN X L.I.D.

Both breeds showed significant reduction in milk production when they were exposed to direct solar radiation.This agrees with the observations made by Johnson (1965) who observed a marked decline in milk yield when temperate dairy cows were exposed to ambient temperatures beyond 27° C.

Environmental temperature may modify the ability of cows to secrete milk.Negative effects of thermal stress on milk yield have been reported by Harris et al(1960). It is recognized that temperature and climate have direct and indirect effects in altering lactation.Studies revealed that milk synthesis depends on a continuous supply of various metabolites and hormones to the mammary gland from the blood,and presumably are dependant on optimum temperature for the enzymatic activity in the mammary gland.Both of these requirements are disrupted with the exposure of the mammary gland to high environmental temperature.

Indirectly,temperature alters appetite or nutrient intake of the animals and thus providing less substrate or less available milk precursors for the mammary gland (Johnson,1965).However data Wayman et al(1962) indicated that despite of controlled feeding by rumen fistula,milk production dropped consistently at high ambient temperatures.This indicates that elevation of body temperature,

including the mammary gland,depress milk yield of dairy cows even with adequate supply of nutrients.

HEMATOLOGICAL PARAMETERS

The average values for all hematological parameters are presented in Appendix 2.

ERYTHROCYTE

Only the crossbreds showed significant reduction in the average erythrocyte count when exposed to direct solar radiation for a week.Similar observation was made by Razdan(1969) who showed significant decline in erythrocyte count at noon.This reduction might be due to the lowering of mitotic rate concerned with hemopoesis.Even with the reduction,there was no significant breed difference in the erythrocyte count.

HEMOGLOBIN

Both breeds showed general reduction in the hemoglobin concentration when exposed to solar radiation but the reduction was significant only for the crossbreds. This showed that hemoglobin level was regulated by changing environmental conditions..

The mechanism whereby high temperatures affect hemoglobin level is not clearly apparent.Due to the short

duration of the study,the likely mechanism for this reduction is as explained by Pal *et al*(1945).They said this could be due to hemodilution of blood resulting from tissue fluid being transferred to blood for efficient dissipation of heat by evaporation from body surface.

PACKED CELL VOLUME

Under direct solar radiation,the PCV of the crossbreds decreased significantly with increasing temperature.Similar response was reported by Razdan(1969).The decrease in the PCV was due to the reduction in erythrocyte number.The PCV of the Friesians did not show significant reduction and this was in accordance to the reports made by Gutierrez(1968) who reported no temperature effect on the PCV of Hereford under thermal stress.

MEAN CORPUSCULAR HEMOGLOBIN CONCENTRATION

Under direct solar radiation,both breeds showed no significant change in the MCHC.However,comparatively the values were higher for the crossbreds.Similar reports were made by Razdan(1969) in Tharparkar cattle.MCHC remained unchanged to maintain adequate oxygen carrying capacity.

BLOOD pH

Blood pH increased significantly with the incr-

ease in ambient temperature.This was due to the increased respiratory activity following exposure to high environmental temperatures.The increased respiratory rate lead to a 'washing out' of carbon dioxide from the lungs,as indicated by the rise in blood pH.This finding supports that made by Bianca and Findlay(1962).

CONCLUSION

From the study,it was observed that the purebreds are more susceptible to heat stress,especially with the exposure to direct solar radiation.Provision of shade could alleviate the effect of heat stress and it is recommended to dairy cattle,especially during hot days.As far as dairy industry in Malaysia is concerned,crossbreds with their greater heat tolerance have great potential in becoming important dairy animals here.

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APPENDIX 1: AVERAGE SKIN TEMPERATURES AT VARIOUS SITES OF THE BODY AT DIFFERENT OF DAY FOR THE SHADED AND NONSHADED FRIESIAN AND FRIESIAN X L.I.D.

SITE	FLANK				PERINEAL				RUMP				FOREHEAD				PINNA			
BREED	F		F X LID		F		F X LID		F		F X LID		F		F X LID		F		F X LID	
TREATMENT	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
HOURS OF DAY	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.	- X + ± S.D.
0900	34.7 ± 0.52	36.4 ± 0.37	33.8 ± 0.39	36.5 ± 0.22	36.0 ± 0.26	36.9 ± 0.17	35.0 ± 0.10	37.4 ± 0.49	34.1 ± 0.70	36.3 ± 0.77	33.0 ± 0.32	36.5 ± 0.42	34.0 ± 0.43	35.7 ± 0.46	33.3 ± 0.39	36.3 ± 0.29	34.9 ± 0.46	36.4 ± 0.33	33.1 ± 0.14	36.5 ± 0.16
1200	36.3 ± 0.29	37.4 ± 0.37	34.1 ± 0.33	38.3 ± 0.16	37.3 ± 0.29	37.9 ± 0.09	35.3 ± 0.08	38.9 ± 0.68	35.9 ± 0.28	37.7 ± 0.19	34.0 ± 0.45	38.1 ± 0.24	35.7 ± 0.37	36.8 ± 0.41	33.7 ± 0.31	38.0 ± 0.09	36.6 ± 0.39	37.7 ± 0.26	33.7 ± 0.17	38.0 ± 0.24
1500	36.2 ± 0.31	37.5 ± 0.39	34.2 ± 0.25	38.6 ± 0.21	36.8 ± 0.43	38.3 ± 0.29	35.4 ± 0.08	39.5 ± 0.79	35.5 ± 0.18	38.1 ± 0.23	33.9 ± 0.27	38.3 ± 0.24	34.9 ± 0.13	37.1 ± 0.64	33.9 ± 0.24	38.2 ± 0.15	35.9 ± 0.13	38.1 ± 0.24	33.8 ± 0.21	38.3 ± 0.15

F = Friesian

F X LID = Friesian X L.I.D.

NONSHADED FRIESIANS AND FRIESIAN X L.I.D.

PARAMETERS (MEAN ± S.D.)	FRIESIANS						FRIESIAN X L.I.D.					
	SHADED			NONSHADED			SHADED			NONSHADED		
	0900	1200	1500	0900	1200	1500	0900	1200	1500	0900	1200	1500
RBC cmm x 10^6	5.13 ± 0.44	5.63 ± 1.05	5.28 ± 0.63	5.38 ± 0.35	5.18 ± 0.39	5.03 ± 0.36	5.90 ± 1.06	5.35 ± 0.67	5.98 ± 0.71	7.18 ± 0.72	6.10 ± 0.74	5.08 ± 0.91
Hb g%	7.95 ± 0.58	9.25 ± 2.46	7.95 ± 0.58	8.68 ± 0.57	8.30 ± 0.58	8.20 ± 0.37	9.28 ± 1.37	9.10 ± 2.02	10.13 ± 2.09	12.93 ± 2.32	9.6 ± 0.56	8.78 ± 2.62
PCV %	24.50 ± 2.08	25.75 ± 6.29	24.75 ± 2.50	25.25 ± 0.96	23.75 ± 1.50	22.75 ± 1.5	25.75 ± 4.19	27.50 ± 4.65	27.75 ± 5.12	34.25 ± 4.79	26.25 ± 1.26	25.0 ± 6.38
MCV u^3	48.3 ± 4.92	45.75 ± 5.25	47.50 ± 4.79	47.0 ± 3.46	46.75 ± 4.27	45.50 ± 3.32	44.25 ± 4.56	47.0 ± 7.16	46.0 ± 4.39	48.0 ± 3.74	44.0 ± 5.59	48.75 ± 3.59
MCHC %	33.0 ± 0.82	36.0 ± 1.41	32.50 ± 1.29	34.75 ± 0.96	34.75 ± 0.96	35.75 ± 0.96	36.0 ± 2.16	34.0 ± 2.71	36.0 ± 1.15	38.0 ± 2.0	37.25 ± 0.96	35.0 ± 1.41
Calcium mg%	8.78 ± 0.34	9.08 ± 0.79	8.75 ± 0.29	8.43 ± 0.26	8.28 ± 0.61	8.33 ± 0.49	9.55 ± 0.51	9.95 ± 0.38	9.40 ± 0.43	9.88 ± 0.33	10.18 ± 0.39	10.95 ± 1.43
pH	7.44 ± 0.22	7.47 ± 0.005	7.45 ± 0.01	7.44 ± 0.02	7.48 ± 0.01	7.46 ± 0.02	7.41 ± 0.02	7.39 ± 0.03	7.40 ± 0.30	7.40 ± 0.01	7.45 ± 0.01	7.43 ± 0.01
pCO_2 mm Hg	39.20 ± 1.06	37.10 ± 0.3	35.73 ± 2.94	38.28 ± 1.39	34.70 ± 3.29	36.50 ± 1.79	40.33 ± 0.49	42.23 ± 3.36	38.68 ± 2.65	44.15 ± 2.85	42.9 ± 3.33	41.8 ± 3.83
pO_2 mm Hg	38.65 ± 3.1	36.80 ± 7.09	37.13 ± 2.73	34.58 ± 4.02	32.08 ± 1.60	37.43 ± 6.57	31.10 ± 3.24	32.08 ± 2.62	36.03 ± 3.89	33.0 ± 3.69	30.18 ± 1.37	33.7 ± 5.24
HCO_3^- m Eq/litre	24.13 ± 1.01	24.43 ± 0.82	22.93 ± 1.03	23.08 ± 1.14	21.98 ± 0.85	23.03 ± 1.28	24.98 ± 4.91	23.10 ± 1.09	23.25 ± 2.16	24.25 ± 1.59	26.5 ± 0.67	24.18 ± 1.34
TOTAL	25.43 ±	26.25 ±	24.20 ±	23.66 ±	22.98 ±	24.15 ±	24.18 ±	24.6 ±	23.03 ±	25.68 ±	27.98 ±	25.20 ±