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Effect of Heat and Milk Yield on Bovine Plasma Glucocorticoid Levels[1] (38670)

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Glucocorticoids have been shown to be necessary for initiation and maintenance of lactation (1, 2). Previous studies have indicated in other species that adrenal secretions may be rate limiting to milk synthesis during prolonged lactation with corticosterone concentrations reported higher in lactating rats compared to virgin rats (3). Because of the important role of glucocorticoids in lactogenesis and reports of depressed adrenal cortical functions with chronic high environmental temperature exposure (4–6), the objective of this study was to determine possible differences in plasma glucocorticoid levels due to lactational intensity and alterations, if any, due to short-term (18 hr) moderate thermal (30°) exposure in lactating cattle.

Materials and Methods. Lactating Holstein cows (170) at the University of Missouri-Columbia Dairy Farm were used on this study. The cattle were maintained under dry lot management conditions and fed a corn silage *ad libitum* and grain supplement[2] at an average of 6.6 kg per cow per day for the upper 50% (milk yield) of the herd and 2.7 kg per cow per day for the lower 50% (milk yield) of the herd. In the spring (March, 81 cows) and fall (October, 89 cows), the cows were confined to a tie stall barn in groups of 25 each in consecutive days for exposure to control temperature (15°) and heat (30°), 50% relative humidity for 18 hr, at which time blood samples were obtained (2400–0100 hr) via tail vein prior to the morning milking.

The cows were later assigned to their production group (high, middle, low) solely on the basis of milk production (lactational intensity) at the control temperature. Overall (spring and fall) the high, middle, and low production groups comprised 20.5%, 56.5%, and 23% of the total herd, respectively.

Total plasma glucocorticoid levels were determined using competitive protein-binding procedure (7). Plasma samples of 0.5 ml were washed with petroleum ether and extracted with dichloromethane. Assay values were corrected for recovery and expressed as ng/ml. Statistical analyses were performed by analysis of variance, correlation analyses, and covariance analysis using stage of lactation as a covariate.

Results. Plasma glucocorticoid levels between spring (12.8 ± 0.6 ng/ml) and fall (13.1 ± 0.7 ng/ml) trial periods were not different. The high, middle, and low production groups' mean days in lactation were 128.7 ± 19.7 (SEM), 178.1 ± 21.2, and 217 ± 19.4 days, respectively. This indicates that higher producing cows were generally in an earlier stage of lactation compared to the low production group as expected because stage of lactation is a factor in the ability of dairy cattle to produce milk. These data show the relationship of differences ($P < 0.008$) in milk yield among trimesters of lactation (24.5, 20.9, and 17.9 kg/day; respectively); although, a higher level of significance ($P < 0.0001$) was noted between the production groupings (Table I). A 6.6 kg difference in milk production was observed between the first and third trimesters of lactation while the difference between the production groupings was 15.9 kg/day. Overall, no significant correlation was noted among trimesters of lactation and glucocorticoids at 15°, but a significant positive correlation (Table II) was observed after short-term moderate heat (30°) exposure. The means of glucocorticoid levels for trimesters of lactation at 15° and 30° were 12.9 ng/ml, 10.1; 13.2, 14.8; and 8.5, 15.6, respectively (Table

[1] Contribution from Missouri Agriculture Experiment Station Journal Series No. 7125. Approved by the Director.

[2] Grain supplement: 93.5% corn, 2% oats, 2% urea, 1% di-cal-PO_4, 1% limestone, and 0.5% trace mineralized salt (>0.01% iodine).

TABLE I. EFFECT OF HEAT AND MILK YIELD IN SPRING AND FALL ON PLASMA GLUCOCORTICOID (ng/ml) LEVEL.

Temperature	Production group		Milk production kg/day	Glucocorticoids ng/ml adjusted*
Spring				
15°	1 (high) n =	20	28.9[a,1]	14.9[c]
15°	2 (middle)	44	21.3[d]	12.9[bc]
15°	3 (low)	17	14.7[f]	7.6[a]
30°	1 (high)	20	26.3[c]	9.2[ab]
30°	2 (middle)	44	19.8[e]	12.2[bc]
30°	3 (low)	17	14.2[f]	21.3[d]
Fall				
15°	1 (high)	15	30.0[b]	15.4[c]
15°	2 (middle)	52	21.3[d]	12.2[bc]
15°	3 (low)	22	12.3[g]	8.6[a]
30°	1 (high)	15	28.6[a]	9.4[ab]
30°	2 (middle)	52	20.4[e]	12.3[bc]
30°	3 (low)	22	11.5[g]	20.1[d]

* Means adjusted for stage of lactation.
[1] Same letter denotes NS ($P > 0.05$).

TABLE II. CORRELATION COEFFICIENTS (r) AMONG MILK YIELD, PRODUCTION GROUPINGS, STAGE OF LACTATION, AND GLUCOCORTICOIDS IN THE SPRING AND FALL AT 15 OR 30°.

	Milk production	Production groups	Stage of lactation
Spring			
15°	0.307	0.320	−0.197
	$P < 0.0057$	$P < 0.0040$	$P < 0.0790$
30°	−0.493	−0.457	0.338
	$P < 0.0001$	$P < 0.0001$	$P < 0.0022$
Fall			
15°	0.320	0.325	−0.184
	$P < 0.0040$	$P < 0.0039$	$P < 0.1541$
30°	−0.513	−0.520	0.298
	$P < 0.0001$	$P < 0.0001$	$P < 0.0200$

III). The plasma glucocorticoid value (15°) for the open (nonbred) cows was 12.2 ng/ml, with values of 12.7, 10.8, and 13.3 for trimesters of gestation, respectively (Table III).

There is a significant relationship between glucocorticoid levels and lactational

TABLE III. SPRING AND FALL PLASMA GLUCOCORTICOID LEVELS DURING TRIMESTERS OF GESTATION AND LACTATION IN CATTLE

Stage of lactation	Temperature	glucocorticoid (ng/ml)
1st trimester	15°	12.9[b,1]
2nd trimester	15°	13.2[b]
3rd trimester	15°	8.5[a]
1st trimester	30°	10.1[ab]
2nd trimester	30°	14.8[b]
3rd trimester	30°	15.6[c]
Stage of gestation		
Open	15°	12.2[a]
1st trimester	15°	12.7[a]
2nd trimester	15°	10.8[a]
3rd trimester	15°	13.3[a]

[1] Same letter denotes $P > 0.05$.

intensity (Tables I and II). In spring and fall at thermoneutral condition of 15°, the high production group had higher ($P < 0.05$) plasma glucocorticoids compared to the low production group. No significant differences were noted between high and middle production groups, but the high production group had a greater mean. Table II shows significant positive correlation coefficients between plasma glucocorticoid levels and milk production and production groupings. These data indicate that at thermoneutral conditions, plasma glucocorticoid levels are greater in high producing cattle than low producers and appear to be positively correlated with lactational intensity.

The results of short term moderate heat exposure on glucocorticoid levels in both spring and fall indicate that the high production group (7.6 ng/ml, 9.4 ng/ml respectively) exhibited a depression ($P < 0.05$) of plasma levels with exposure to environmental heat; the middle production group (12.9 ng/ml, 12.2 ng/ml) showed no change; and the low production group exhibited a dramatic elevation ($P < 0.01$) of plasma glucocorticoid levels (21.3 ng/ml, 20.1 ng/ml respectively). Positive correlations (Table II) were noted at 15°; however, with short-term thermal exposure, all correlations (spring and fall) were significantly inversely correlated with lactational intensity. These data indicate that with short term (18 hr) thermal (30°) exposure, plasma glucocorticoid levels are markedly lower in high producing cattle compared to low producing cattle; and plasma glucocorticoid levels appear to be negatively correlated with lactational intensity. Figure 1 illustrates this comparison of a positive relationship at 15° and the negative relationship between milk yield and plasma glucocorticoid concentrations at 30°.

Discussion. The findings are not significantly different in either trimesters of gestation or stage of lactation, which is in agreement with Koprowski and Tucker's (8) findings that after the first 12 wk of lactation or as gestation advanced, little change occurred in plasma corticoid concentrations. However, the results of this study show that from the first to the third trimester of lactation, significantly lower milk yields were observed. Associated with this lower milk yield was a corresponding reduction of plasma glucocorticoid concentrations. A possible explanation is that a large difference in milk yield is required to show the relationship between lactational intensity and plasma glucocorticoids. A mean difference of at least 6.6 kg of milk/day was required to show a significant ($P < 0.05$) difference in this study.

Evidence by Thatcher and Tucker (3) has suggested that corticosterone secretion increases markedly from the nonlactating state to early lactation with injections of cortisone acetate (9) causing significant increases in lactational performance. Additional findings (10) suggest that administration of cortisol in rats amplifies insulin effects on lactational performance. Results of this study indicate that higher producing cattle have higher basal levels of plasma glucocorticoids than lower producing cattle; therefore, higher concentrations of glucocorticoids in higher producing cattle may possibly interact with other hormones involved in the lactation processes to assist the animal in efficiently meeting the greater energy demands of lactation.

The shift from a positive relationship between glucocorticoid levels and milk yield at 15° to negative relationship with short term moderate thermal exposure can possibly be explained by high producing cows being more thermally stressed by the short term thermal exposure due to greater energy demands of their higher plane of lactation. In the spring the high production group exhibited a significant (1.4°) elevation in rectal temperature (R.T.) with short term moderate thermal exposure compared to only a 0.9° elevation for the low production group. Similar results were observed in fall with a 1.8° increase in R.T. for the high production group compared to a 1.0°

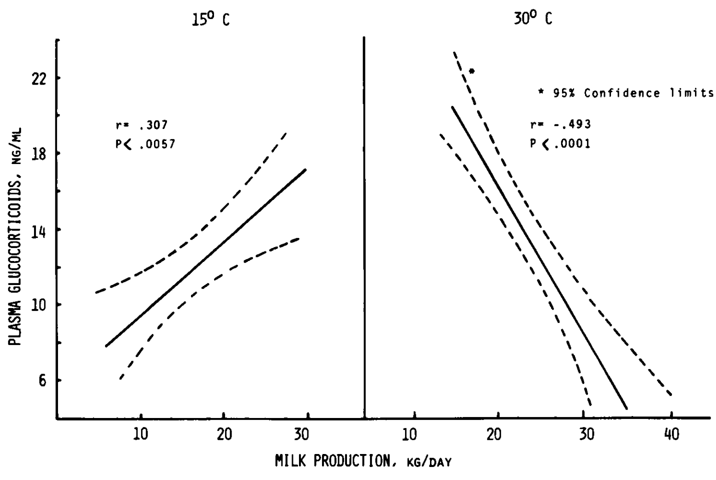

FIG. 1. Relationship of milk yield (kg/day) and plasma glucocorticoids at 15° and short term (18 hr) exposure to 30°C.

elevation in the low production group. Because the high production group may have been more "stressed" by the thermal exposure, they possibly had already attained a maximal plasma cortisol response (5) and were subsequently displaying a depression of plasma glucocorticoids within 18 hr after the initial elevation; whereas, the low production group, being less affected by the thermal exposure, was just attaining maximal or near maximal elevation of plasma glucocorticoids at 18 hrs of thermal exposure. Possibly the positive relationship between corticoids and stage of lactation with acute moderate thermal exposure can be explained by higher producing cows being more thermally stressed because there was a general relationship between level of production and stage of lactation. It appears, as evidenced by the higher producing cattle having the lowest glucocorticoid values following 18 hr moderate thermal exposure, that a production (lactational) component may affect the glucocorticoid response to thermal exposure in cattle.

In view of these findings of a positive relationship between plasma glucocorticoid concentrations and lactational performance at thermoneutral conditions and because plasma levels are only one index of adrenocorticoid activity, further studies should be undertaken to denote free plasma levels and utilization of the hormone by dairy cattle at various levels of milk production.

Summary. This study indicates that at 15° higher producing cattle (milk yield) have higher plasma glucocorticoid concentrations compared to lower producing cattle with glucocorticoid levels appearing to be positively correlated with lactational intensity. Short term thermal (30°) exposure for 18 hr resulted in glucocorticoid levels being markedly lower in high producing cattle compared to low producers. This shift at 30° (after 18 hr) is possibly due to different time sequence of glucocorticoid response to thermal exposure between high and low producing cows. These data support the concept that glucocorticoids assist the animal in efficiently meeting the greater energy demand of lactation and further studies should be undertaken to denote free plasma levels and their utilization by dairy cattle at various levels of milk production.

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