THE INFLUENCE OF EXPOSURE OF BEEF HEIFERS TO WINTER WEATHER PREPARTUM ON CONCENTRATIONS OF PLASMA ENERGY YIELDING SUBSTRATES, SERUM HORMONES AND BIRTH WEIGHT OF CALVES

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

REVIEW OF LITERATURE

Effects of Winter Weather on Animal Production

Almost two-thirds of all livestock in North America are raised in regions where the mean January temperature is below 0 C (Young, 1981). Beef cattle are extremely cold hardy in comparison to other meat animal species and are rarely exposed to ambient weather conditions below their lower critical temperature. However, there are seasonal variations in the level of production of cattle which may be due to hormonal or adaptive changes during occasional cold stress. Primary among these changes are increases in resting metabolic rate, increases in energy requirements for maintenance, and increased rate of passage of digesta which results in reduced digestive efficiency (Young, 1981).

As a result of metabolism, heat is continually released from the animal to the environment. The balance between heat gain and heat loss must be regulated such that the temperature of the body core remains relatively constant (Robertshaw, 1974). The net rate of heat loss depends upon the thermal demand of the surrounding environment and the resistance to heat flow of the outer shell and body covering (Young, 1981).The effective temperature of an animals environment is determined by a combination of air temperature, wind speed, precipitation and radiation from the sun and the surrounding physical environment.

The first responses to a sudden decrease in environmental temperature (eg. shivering) begin within minutes and reach a steady level within hours (Thompson, 1973). Further changes in heat loss may occur after weeks of exposure to cold temperatures such as heavier total hair coat and an increased appetite necessary to accommodate greater maintenance energy needs (Thompson, 1973; Young, 1981). The lowest temperature in the thermoneutral zone is called the 'critical' temperature and below this temperature, an animal must increase its rate of heat production to maintain homothermy. Young (1981) reported the lower critical temperature for a dry pregnant cow at -18C. Other estimates for beef cattle range from 7 to -21 C (National Research Council, 1981). However, the actual temperature for individual animals varies with factors such as size, breed, nutrition, thermal insulation and housing.

Acclimation - Cold Adaptation

Webster et al. (1969a) reported that regulatory nonshivering thermogenesis occurs in a wide range of adult mammals chronically exposed to cold. Although metabolic acclimation to cold has been well established for mammals of less than 500 g body weight (Young, 1975b), in adult mammals greater than 50 kg body weight, there is uncertainty as to the nature or even the occurence of such acclimation (Webster, 1969a; Young, 1975a). However, it has been shown that cattle exposed to naturally occuring cold winter conditions have increased tolerance to cold which is associated with increases in resting metabolic rate, appetite, and thermal insulation (Webster et al., 1970; Young, 1975b).

Shorn sheep exposed to repeated acute cold had an elevated resting heart rate and an increased resistance to body cooling (Slee, 1971). Increased resting metabolic rate has also been shown for sheep acclimated to cold (Webster et al., 1969b). With prolonged exposure to cold, beef cows have shown not only an increase of 30 to 40% in resting metabolic rate independent of physical activity and intake, but also a replacement of shivering thermogenesis with nonshivering thermogenesis (Young, 1975b). Young (1975a) found evidence supporting winter acclimatization and a downward shift in the thermoneutral zone for cows housed outdoors in ambient weather conditions. These findings have significant practical implications to livestock production in cold regions. A decrease in lower critical temperature indicates that the effective environmental temperature can be reduced to a greater extent before the animal needs to increase its heat production to replace that which is lost to the environment. Cows that acclimated to ambient winter weather conditions apparently had a greater capacity to produce heat during periods of severe cold stress (Young, 1975a).

Maternal and Fetal Responses to Exposure to Elevated Ambient Temperature

Mean birth weight of lambs from ewes exposed to heat stress during the last third of gestation was .9 kg less than lambs born from ewes fed restricted diets and 1.4 kg less than ewes fed on range (Brown et al., 1977). Apparently, increased thermal environment can depress fetal growth independently of nutrition of the ewe. Collier et al. (1982) found similar effects of heat stress on birth weights in dairy cattle. Calves born to cows exposed to heat stress during the last trimester of pregnancy were 3 kg lighter than calves born to cows which were not heat stressed. Concentrations of estrone sulfate in the plasma of heat stressed cows were also reduced suggesting that placental function may have been reduced and contributed to reduced birth weight.

Flow of blood to the uterus was also reduced by thermal stress in ovariectomized dairy cows (Roman-Ponce et al., 1978). This decrease in uterine blood flow may elevate the temperature of the reproductive tract and also affect nutrient and hormonal availability to the developing fetus (Roman-Ponce et al., 1978).

Concentrations of catecholamines in plasma increased and remained elevated while concentrations of glucocorticoids increased and then decreased when Holstein cows were exposed to long-term evironmental heat stress (Alvarez and Johnson, 1973). These authors suggest that heat acclimation may be related to a decrease in the sensitivity to physiological actions of catecholamines resulting in depressed heat production.

Profiles of Steroid Hormones and Energy Yielding Substrates During Pregnancy

Estrogens

Concentrations of estradiol in serum of heifers increased steadily until the completion of the fifth month of gestation where they remained at 16.2 pg/ml until the month prior to parturition (Schallenberger et al., 1985). Total estrogens rise rapidly 25 d prepartum and reach maximum concentrations (900 to 1700 pg/ml) 1 to 2 d prior to parturition (Symons, 1973). In cattle, the first major change in steroid hormones is a ten fold increase in the concentration of estrogens in serum during the month prior to parturition (Smith et al., 1973). A marked rise in plasma concentrations of estrogens begins at approximately 20 days prior to parturition and then peaks at the time of parturition (Smith et al., 1973; Symons, 1973; Robertson, 1974; Hunter et al., 1977). During the final two days of pregnancy, there is a precipitous decline in plasma estrogens (Smith et al., 1973; Hunter et al., 1977). The prepartum drop in estradiol may be a direct factor in the initiation of parturition or a result of the first stages of placental death (Smith et al., 1973). Concentrations of estrogens in plasma fall postpartum indicating the placenta is the major source of estrogen prior to parturition (Henricks et al., 1972).

Concentrations of estradiol in plasma were consistently elevated in cows bearing more than one embryo throughout gestation (Adelakoun et al., 1978). But, no differences in concentration of estrogens could be attributed to the sex of the calf (Robertson and King, 1979).

Glucocorticoids

The adrenal cortex is an organ of homeostasis and is involved with metabolic regulation and stress adaptation (Lee et al., 1976) The major glucocorticoids produced by the adrenal are cortisol and corticosterone (Estergreen and Venkataseshu, 1967). Glucocorticoids in serum of heifers averaged 5.0 ng/ml from 26 d to 1 d prior to parturition and increased to 10.3 ng/ml approximately 12 h before parturition (Smith et al., 1973). The rise in glucocorticoids occurred shortly after the fall in progesterone 2 d prior to parturition. Hunter et al. (1977) also showed that maternal plasma corticoids remained fairly constant at 5 to 15 ng/ml during the final 2 wk of gestation.

Increased glucocorticoids near term may be a response to the stress of parturition rather than an initiator of parturition (Smith et al., 1973). Hunter et al. (1977) suggested that normal parturition in the cow, as in the sheep, is initiated by activation of the fetal pituitary-adrenal axis. Robinson et al. (1977) concluded that the fetal adrenal gland requires pituitary trophic hormones such as adrenocorticotropic hormone (ACTH) and possibly prolactin for the normal prepartum surge of cortisol in the fetus.

Ewes exposed to cold weather the last 5 to 6 weeks of pregnancy had increased concentrations of cortisol in plasma and significantly delayed parturition (Samson et al., 1983). Delayed parturition may result from persistent elevations in plasma concentrations of progesterone and a delayed rise in estrogens in ewes exposed to cold stress (Samson et al., 1983). Panaretto and Vickery (1972) also reported that cortisol increased 4-fold in plasma of cold stressed, normothermic sheep over that of the control sheep and 40-fold relative to the controls when they became hypothermic.

Glucose

Fed sheep had plasma concentrations of glucose ranging from 55 to 72 mg/100 ml, then after an overnight fast glucose concentrations dropped to a range of 48 to 64 mg/100ml (Leat, 1974). Pregnant sheep have been reported to have a higher rate of glucose production than nonpregnant sheep and respond to fasting with rapid development of hypoglycemia and ketosis (Hay et al., 1983).

The distribution of maternally produced glucose among nonuterine maternal tissues, the fetus, and placenta was not significantly changed by the onset of hypoglycemia regardless of the reduction in maternal glucose production (Hay et al., 1983). Mellor and Slater (1973) found that mean plasma concentrations of glucose decreased until 112 d of gestation and then remained relatively constant (45 to 55 mg/100 ml) until term.

There is an inverse relationship between ambient temperature and concentrations of glucose in maternal plasma of ewes (Mellor et al., 1975). Halliday et al. (1969) showed that in sheep, concentrations of glucose in plasma increased initially but fell towards the end of acute cold exposure suggesting that less carbohydrate and more fat was utilized as a source of energy under cold conditions. Concentrations of glucose in plasma of sheep averaged 62 mg/100 ml during the period prior to cold exposure and then increased to 115 mg/100 ml after 120 min of cold exposure (Thompson et al., 1978).

Nonesterified Fatty Acids

Nonesterified (free) fatty acids (NEFA) in blood serum are derived mainly from the breakdown of body fats. Circulating concentrations of NEFA are a good indicator of fat currently mobilized for oxidation and energy production (Patterson, 1963; Slee and Halliday, 1968).

Concentrations of NEFA in plasma ranged from 100 to 600 μequiv/l in normal fed cows (Patterson, 1963) and ewes (Patterson, 1963; Leat, 1974) and increased by as much as a 115% as a result of the stress of blood sampling (Patterson, 1963).

During the first 2 mo of pregnancy, ewes had rather constant concentrations of NEFA (430 μequiv/l) followed by a considerable increase after shearing, then a drop and again a rise prior to parturition when concentrations averaged 1893 μequiv/l (Aulie et al., 1971). In cattle, the increase in concentrations of NEFA in plasma during acute cold exposure reflects a substantial mobilization of long-chain fatty acids from the hydrolysis of adipose tissue (Bell and Thompson, 1979). Olsen and Trenkle (1973) reported significant increases in concentrations of NEFA in plasma of cows on the first day of cold exposure followed by a continuous rise with prolonged cold exposure.

A consistent decrease in plasma concentrations of glucose and an increase in NEFA was observed after 18 h of food deprivation in sheep (Leat, 1974). Similar findings have been noted in fasted cows (Patterson, 1963). Slee and Halliday (1968) suggested that pregnancy, shearing, experimental handling and short term fasting all induced an elevation in concentrations of NEFA in plasma. However, these effects were small in comparison to the effects of acute cold exposure. Concentrations of NEFA in serum were 5 to 6 times higher in ewes subjected to cold stress than in thermoneutral control ewes (Halliday et al.,1969). Young (1975b) also reported body weight losses and increased concentrations of NEFA in plasma of cows during cold exposure suggesting that the mobilization and oxidation of NEFA from adipose tissue is a major source of the increased metabolism observed in ruminants during cold exposure.

Aspects of Bovine Dystocia

Parturition is primarily a hormonal process initiated by the fetus when ACTH, glucocorticoids and estrogens are released (Thorburn, 1977). During the last 34 to 48 h of gestation, maternal concentrations of estrogen and prostaglandin in plasma increase while progesterone decreases (Hunter, 1977). Osinga (1978) suggested that fetal hormones influence the maternal endocrine system resulting in the release of prostaglandins and oxytocin and the decrease in maternal progesterone production.

Dystocia is defined as difficult parturition and it is an important economic problem in the beef cattle industry (Laster, 1974). Age of dam and birth weight of calves have been shown to be among the most important factors affecting calving ease. Calving difficulty increased linearly with calf birth weight and for each 1 kg increment in birth weight, calving difficulty increased by 2.6 percentage points (Nelson and Beavers, 1982). Similarly, Bellows et al. (1971) found that length of gestation, sex, and birth weight were important factors affecting dystocia. Calf birth weight ranked first in importance of factors affecting calving difficulty and male calves had a greater frequency of assistance and higher average difficulty score (Notter et al., 1978). In addition, 2 and 3 yr old cows giving birth to male calves had 28% and 16% more dystocia, respectively, than when delivering female calves (Notter et al., 1978). Yet, when calf sex, birth weight, and five calf shape measurements were considered only 39% of the variation in percentage of dystocia was accounted for (Laster, 1974). Therefore, the relationship of dystocia to pelvic size measurements of the cow and weight and shape of the calf is weak and can not be used accurately to predict dystocia.

Although Notter et al. (1978) found the effects of breed of sire of cow and breed of sire and sex of calf had highly significant effects on birth weight of calves, others (Laster, 1974; Burfening et al., 1978) have found that when birth weight was held constant, sex of calf had no effect on calving ease.

Influence of Size and Nutrition

For each 100 kg increase in the weight of the dam, birth weight of calves increased by .9 kg (Nelson and Beavers, 1982). Bellows et al.(1971) suggested that larger dams, as indicated by greater body weight, had larger pelvic areas which were associated with greater body growth early in gestation while weight gains later in gestation were primarily attributable to fetal growth. It was also noted that pelvic area of the dam exerted a significant negative effect on calving difficulty scores. Other authors (Laster, 1974; Notter et al., 1978) found that larger, heavier cows produced calves with heavier birth weights and tended to have more dystocia. These data suggest that the weight of the calf increases at a faster rate than pelvic area of the cow as the weight of the cow increases. Laster (1974) concluded that genetic or environmental factors that affect skeletal dimensions in calves or the condition of the birth canal of the dam, have more impact on calving difficulty than weight gains in the calf associated with soft tissue growth.

Increased intake of energy (4.9, 6.2, or 7.7 kg/hd/d) for a 90 d period before the calving season also increased birth weights of calves for straightbred cows but did not significantly increase the percentage of cows requiring assistance at parturition (Laster, 1974). Similarly, effects of the level of feed during gestation had no effect upon calf birth weight or calving difficulty scores (Hironaka and Peters, 1969; Bellows et al., 1982; Doornbos et al., 1984). In one study, decreasing the precalving feed level was found to decrease weight and condition of the dam and birth weight of the calf but no beneficial effect was observed in reducing calving difficulty (Bellows and Short, 1978).

Dietary protein content did not affect calf birth weight or severity of calving difficulty, but male calves were heavier at birth (37.2 vs 34.3 kg) and had higher calving difficulty scores than female calves (Anthony et al., 1986).

Endocrine Aspects

Defects in at least two hormonal parameters were found during the last 2 d prepartum in 76% of the cows requiring assistance at parturition as compared with 21% who did not experience dystocia (Erb et al., 1981). Concentrations of progesterone in plasma failed to drop to low concentrations 1 d prepartum and concentrations of estradiol tended to be low in cows which had difficult births. The relationship of concentrations of progesterone and estradiol in serum and the patterns of change differ in heifers which experience dystocia (O'Brien and Stott, 1977; Erb et al.,1981). The difference in hormone concentrations and patterns of changes between normal heifers and heifers with dystocia suggests that the timing of hormonal change is late and not as pronounced during the prepartum period in heifers experiencing dystocia (O'Brien and Stott, 1977). Lower concentrations of estradiol in serum were observed in heifers carrying female calves than those carrying male calves, thus the dystocia difference between male and female calves may be due not only to birth weight differences, but endocrine differences as well (Anthony et al., 1986). Osinga (1978) suggested that the relationship between urinary estrogen concentrations and the incidence of dystocia indicates that estrogens from the fetal unit exert a preparative effect on the birth canal and insufficient concentrations may be a factor in dystocia. Concentrations of estradiol in serum were lower 23 to 12 d prepartum in heifers with dystocia as compared to unassisted heifers (O'Brien and Stott, 1977).

Environmental Aspects

The incidence of dystocia differed between seasons, with more occurrences in dairy cattle from December through February than other months (Erb et al., 1981). Similarly, a higher incidence of dystocia and heavier birth weights were observed for cows calving in autumn and winter coinciding with heavier birth weights and low urinary estrogen concentrations (Osinga, 1978). Dystocia was observed less often from February to May when birth weights were lower and urinary estrogen concentrations increased (Osinga, 1978). Caton et al. (1983) also showed that the birth weight of lambs was positively related to mean maternal plasma concentrations of estrone and estradiol and also to the rate of progesterone release from the uterus.

The live weight gain of shorn ewes increased from shearing to the last week of pregnancy and the lambs they produced had heavier birth weights than lambs from unshorn ewes (Austin and Young, 1977). The unshorn ewes had higher respiratory rates and lower voluntary food intake thus, the unshorn ewes may have experienced mild heat stress which may be responsible for the lower birth weights (Austin and Young, 1977). Brown et al. (1977) also reported the birth weight of lambs born to ewes exposed to heat stress was significantly less than controls. Similarly, Collier et al. (1982) found that heat stress had a negative effect on placental function in cows as indicated by a reduction in concentrations of estrone sulfate in plasma and lower birth weight calves.

Ewes exposed to chronic cold conditions which had gross energy intake controlled, had both single and twin lambs that were heavier at birth than lambs from thermoneutral control ewes (Thompson et al., 1982). The length of gestation was significantly longer for ewes that were subjected to chronic cold exposure than for ewes maintained in a thermoneutral environment during the final 5 to 6 weeks of gestation (Samson et al., 1983). In the beef cow, the effects of cold stress appear to be primarily on energy requirements for maintenance and the influence of cold exposure of the dam on development of the conceptus and birth weight of the calf have not been as extensively studied as for the ewe (Hironaka and Peters, 1969; Young, 1981).

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ABSTRACT

The influence of exposure to ambient winter weather conditions (WW) during the final 90 d of gestation on serum hormones, plasma substrates and birth weight of calves was evaluated in spring-calving beef heifers. Data were collected in two consecutive years from primiparous Simmental (n=12) and Polled Hereford (n=17) heifers that were mated to calve at 2 yr of age. At an average of 192 $\pm$ 14 d of gestation, heifers were assigned by expected calving date, breed and sire of fetus to one of two treatments. Thirteen heifers were assigned to thermoneutral environment (TN; 12 C) and housed in temperature controlled rooms. Heifers in WW (n=16) were maintained outdoors in drylot without access to shelter. Additional dietary energy was supplied for WW heifers when average weekly windchill fell below -6.7 C. Body weights, hip-heights and samples of serum and plasma were obtained biweekly until heifers were relocated approximately 7 d prior to expected calving. At calving, weight of calf and calving difficulty score (1 = no assistance; 6 = abnormal presentation) were recorded. Concentrations of estradiol and cortisol in serum and glucose and nonesterified fatty acids (NEFA) in plasma were determined. Polynomial response curves for glucose and NEFA in plasma and cortisol in serum were not influenced by treatment. However, average concentrations of

glucose tended to be elevated ($P<.13$) in WW heifers (87.8 ± 2.4 mg/100 ml) compared to TN heifers (83.3 ± 2.7 mg/100 ml). Average concentrations of NEFA were also increased ($P<.02$) for WW heifers compared to TN heifers (172.5 ± 8.9 vs. 136.9 ± 7.7 μmol/l). Concentrations of cortisol were similar for TN and WW heifers (17.6 ± 2.9 vs. 13.8 ± 2.7 ng/ml). Patterns of concentrations of estradiol in serum ($P<.01$) and time trends for hip-height to weight ratios were different ($P<.05$) for WW and TN. Birth weight of calves from TN heifers were greater ($P<.06$) than calves from WW heifers (42.3 ± 2.0 vs. 36.9 ± 1.8 kg) but average calving difficulty scores were similar for both heifer groups ($3.2 \pm .5$ vs. $2.7 \pm .4$). These data suggest that reduced effective ambient temperatures to which spring-calving cows are exposed during the final third of pregnancy may elevate energy yielding metabolites in plasma and alter endocrine function. These changes may contribute to reduced birth weight of calves.

INTRODUCTION

Dystocia is defined as difficult parturition and it is an important economic problem in the beef cattle industry (Laster, 1974). Bellows et al. (1971) could only account for 44 to 46% of the variation in calving difficulty of first calf heifers and birth weight of calves was the greatest single factor contributing to difficult births. Prepartum concentrations of estrogen have been positively correlated to birth weight of lambs (Caton, 1983). Others have suggested that differences in calf birth weight may be related to endocrine differences (Bellows et al., 1971; Anthony, 1986).

Pregnant ewes subjected to chronic cold exposure had increased concentrations of glucose, NEFA, and corticoids and had significantly heavier lambs at birth than lambs from thermoneutral ewes (Thompson et al., 1978; Thompson et al., 1982). Olsen and Trenkle (1973) found that both concentrations of glucose and NEFA increased significantly when cows were exposed to controlled subzero temperatures. Generally, cows which are mated to calve in the spring experience the final 3 mo of pregnancy during the coldest months of the year. Therefore we questioned the contribution of winter weather to changes in selected serum hormones and plasma energy yielding substrates in beef cattle during this period of gestation and whether such changes might influence the weight of calves at birth.

MATERIALS AND METHODS

Data for this study were collected in two consecutive years from primiparous Simmental (n=12) and Polled Hereford (n=18) heifers that were 2 yr of age and calved between March 31 and May 17, 1985 or March 24 and May 5, 1986. Pregnancies were obtained by embryo transfer or natural mating and heifers were assigned to treatments in pairs so that pairs of either full-sib or half-sib conceptuses were represented in each of the two treatments in order to minimize genetic variation. Breed of heifer (dam), date of expected calving, and sire of the fetus were also used as blocking factors.

Heifers were maintained under pasture conditions and managed as one group until an average of about 160 d of pregnancy. At that time, heifers were grouped in drylot and accustomed to handling. At an average of 192 $\pm$ 14 d (mean $\pm$ sd) of pregnancy, heifers were placed on treatments consisting of exposure to either ambient winter weather conditions (WW) or to a thermoneutral environment (TN) for the final trimester of pregnancy. Heifers in WW were maintained outdoors in drylot without access to shelter while TN heifers were maintained indoors in temperature controlled rooms at 12 C.

Heifers were fed once daily in the evening a complete ration (Appendix Table 2) that was formulated to meet National Research Council (NRC) recommendations (1984). An equation was generated to predict windchill (C) as adapted from data obtained by Ames and Insley (1975). Ambient temperature and wind velocity data were obtained at hourly intervals from a remote weather station located approximately 2.8 km from where WW heifers were maintained.

From these data, an hourly windchill was calculated and then an average windchill was calculated for the entire day (Appendix table 3). Average weekly windchills were calculated for WW heifers and additional dietary energy was added when average windchill of the previous week fell below -6.7 C. The -6.7 C windchill was used since this temperature is within the estimates for the lower critical temperature of beef cattle with either normal or heavy winter hair coats (Ames, 1978). The additional energy was supplied by cracked corn provided at a level to increase energy intake by 1% of the NRC recommendation for each degree windchill below -6.7 C. These dietary energy adjustments were adapted from guidelines suggested by Ames (1978). The ration was formulated to approximate the crude protein content of cracked corn thus, weight for weight substitution of corn for the complete feed increased energy density of the feed but did not substantially changed protein intake.

Body weights, hip-heights and samples of serum and plasma were obtained biweekly until heifers were relocated approximately 7 d prior to expected calving. Samples of blood (60 ml) were collected via puncture of the jugular vein and plasma was obtained by mixing a 20 ml sample of whole blood with 16 mg oxalic acid and immediately placing on ice. Blood samples for plasma were centrifuged within 2 h of collection. Samples of serum were obtained by allowing whole blood (40 ml) to clot and stand at 4 C for 24 h followed by centrifugation. Samples of serum and plasma were frozen and stored a -20 C until serum was analyzed for estradiol-17ß (Skaggs et al., 1986; Lucy and Stevenson, 1986) and cortisol (Skaggs et al., 1986) and plasma was assayed for NEFA (Falholt et al., 1973) and glucose. The assay for glucose was an enzymatic, colorimetric assay performed on a Technicon Autoanalyzer II (industrial method SE4-0036FJ4, Technicon Istruments, Tarrytown, N.Y. 10591). At calving, body weights of calves were obtained within 12 h of birth and a calving difficulty score was assigned (Philipson, 1976). Briefly, scores were: 1) no assistance, 2) an easy assist, 3) a medium pull with minor traction by a mechanical calf puller, 4) a hard pull with moderate to extreme traction, 5) caesarean section, 6) abnormal presentation.

Data obtained for calf birth weight and calving difficulty were analyzed utilizing the General Linear Models procedure of the Statistical Analysis System (SAS, 1979). Effects of treatment, year, sex of calf and the interaction of treatment with year were included as sources of variation in the analysis. Three heifers had breech presentations of the fetus and their calving difficulty scores were not included in the analysis. In addition, one heifer delivered twin calves and data for this animal were eliminated from all analyses. Data for hip-height to weight ratios, concentrations of NEFA and glucose in plasma, and cortisol and estradiol-17ß in serum were characterized by time trends with day of gestation as a continuous independent variable and analyzed by comparing polynomial response curves between treatments. Tests of homogeneity of regression were performed as described by Guilbault et al.(1985). Effects of treatment, year, the treatment by year interaction, the heifer within treatment by year interaction and day of gestation (linear, quadratic, cubic, quartic, or quintic) were included in the model. The heifer within treatment by year interaction mean square was used as an error term to test effects of treatment, year, and the treatment by year interaction. Models used to analyzed hip-height to weight ratios, concentrations of NEFA and glucose in plasma, and concentrations of cortisol and estradiol-17ß in serum had coefficients of determination of .75, .47, .68, .44 and .90, respectively.

RESULTS AND DISCUSSION

Patterns of average weekly windchill (figure 1) were similar for both 1985 and 1986. Supplemental dietary energy was given to WW heifers only during 5 wk of the experiment in 1985 and 2 wk in 1986 and these coldest effective temperatures occured during the month of January and the first half of February. After February 15, the mean weekly windchill remained above -7 C. In neither year did the average weekly windchill exceed the -18 C lower critical temperature for dry, pregnant beef cattle reported by Young (1981).

We evaluated hip-height to weight ratios as an objective measure of body condition of heifers and a significant treatment effect ($P<.01$) was observed for the pattern of changes in this ratio during the final 3 mo of pregnancy (figure 2). Even though heifers on both treatments were managed as a single group prior to the onset of the experiment, heifers in WW began the experiment in slightly thinner body condition (greater hip-height to weight ratio) than TN heifers. As expected, with advancing pregnancy and increased fetal-placental weight, hip-height to weight ratios decreased for heifers on both treatments and by the time of calving, these ratios were similar for both groups of heifers.

Patterns of concentrations of glucose in plasma were similar ($P>.05$) for both groups of heifers (figure 3). However, when averaged across day of gestation WW heifers tended to have increased ($P<.13$) concentrations of glucose (87.8 ± 2.4 vs. 83.3 ± 2.7 mg/100ml) . Glucose concentrations in both heifer groups decreased until the final 2 wk of pregnancy when concentrations began to increase. Others have found an inverse relationship between concentrations of glucose in plasma and ambient temperature in ewes (Mellor et al, 1975). Olsen and Trenkle (1973) reported significant increases in concentrations of glucose in plasma of cows exposed to cold stress. Similarly, concentrations of glucose in sheep averaged 62 mg/100 ml prior to cold exposure and then increased to 115 mg/100 ml after cold exposure (Thompson et al., 1978).

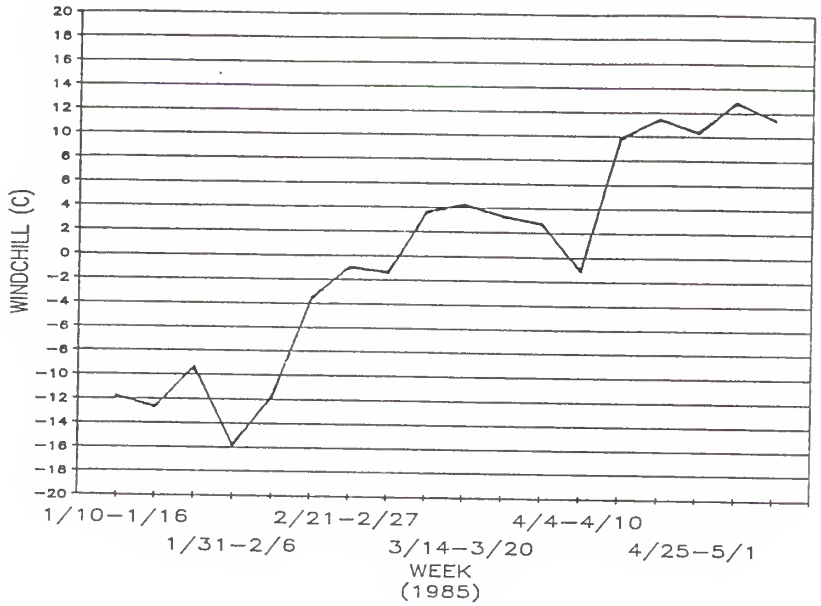
Treatment did not affect (P>.05) time trends of concentrations of NEFA (figure 4) in plasma but, when averaged across day of pregnancy, concentrations of NEFA were increased in WW heifers (P<.02) above TN heifers, perhaps indicating that an increase in energy metabolism may have occured as a result of the winter weather to which these heifers were exposed. Concentrations of NEFA increased steadily from 195 d of gestation until approximately 1 wk prior to parturition when the last blood samples were taken. Others have shown that in sheep (Slee and Halliday, 1968) and cattle (Bell and Thompson, 1979), pregnancy and handling induce an elevation in concentrations of NEFA in plasma yet these effects are relatively small in comparison to the effects of acute cold exposure. Concentrations of NEFA in serum were significantly higher in ewes subjected to cold stress than ewes in a thermoneutral environment (Halliday et al., 1969).

Patterns of concentrations of cortisol in serum during treatment were similar (figure 5; P>.05) for WW and TN heifers (17.5 ± 2.9 vs. 13.8 ± 2.7 ng/ml). In both groups of heifers, cortisol remained relatively stable until the last month of gestation when concentrations began to decrease. The decrease in cortisol during the final month of pregnancy that we observed is similar to the decrease in serum glucocorticoids in the cow from 22 to 9 d prior to parturition (Smith et al., 1973). These concentrations are similar to those reported by Hunter et al. (1977) who found that maternal corticosteroid concentrations ranged from 5 to 15 ng/ml throughout pregnancy until term. The lack of treatment effect on patterns of cortisol in serum would suggest that under the conditions of our experiment, either the effective ambient temperatures to which WW heifers were exposed may not have been severe enough to affect cortisol or intermittent elevations of cortisol occurred in response to abrupt daily changes in ambient temperature but were not evident in our biweekly samples. Although Dantzer and Mormede (1983) suggested that chronic cold exposure might reduce cortisol, the influence of prolonged exposure to cold environments on concentrations of cortisol in serum of beef cattle is not well documented.

Time trends of concentrations of estradiol-17ß in serum differed (P<.01) for heifers in WW and TN (figure 6). This difference may be due to the lower magnitude of the rise in estradiol in WW heifers prior to parturition. Beginning at about d 267 until term, concentrations of estradiol-17ß in serum increased markedly from approximately 39 to 125 pg/ml for TN heifers and from about 32 to 100 pg/ml for WW heifers. These data are consistent with previous observations that demonstrated a rapid rise in concentrations of estrogens beginning at 20 d prior to parturition and peaking at the time of parturition (Smith et al., 1973; Symons, 1973; Robertson, 1974; Hunter et al., 1977). The reason for the difference in profiles of estradiol in serum is not clear but suggest that placental steroidogenesis or metabolism of estradiol was altered in WW heifers.

Heifers calved between March 31 and May 17 in 1985 and March 24 and May 5 in 1986 and the average date of calving was April 18 for both treatments (table 1). Calves born from heifers in TN were heavier (P<.06) than those born from WW heifers (table 1; 42.3 $\pm$ 2.0 vs. 36.9 $\pm$ 1.8 kg) but calving difficulty scores were similar for heifers on both treatments. We eliminated scores of 6 from the analysis since abnormal presentations probably do not reflect dystocia births attributable to treatment or weight of the calf. As expected, male calves were heavier ($P<.05$) than female calves (40.8 ± 1.6 vs. 36.7 ± 1.7 kg) and approximately equal proportions of male calves were born within each treatment (54% bulls from TN, 56% bulls from WW). The lower birth weights and calving difficulty scores observed in the WW heifers are similar to the findings by Osinga (1978) where calf birth weight and the occurrence of dystocia decreased for heifers calving between the months of February and May (Netherlands).

The results from this study indicate that reduced ambient temperatures to which spring-calving cows were exposed, although relatively mild, increased concentrations of glucose and NEFA in plasma. These findings are consistent with the results of others for acutely cold stressed ruminants (Olsen and Trenkle, 1973; Young, 1975; Thompson et al., 1978; Bell and Thompson, 1979). Estrogen secretion or metabolism was also altered in WW heifers which may suggest altered placental function in cold stressed heifers and may be associated with reduced weight of calves. We can not attribute lighter calves from the WW heifers to differences in energy requirements for heifers outdoors since these animals received additional dietary energy in an attempt to meet this increased demand. In fact, WW heifers increased in body condition at a faster rate than TN heifers (figure 1). Elevated concentrations of energy yielding substrates in serum of WW heifers and reduced weights of calves in the present experiment are difficult to reconcile. Although human babies born to diabetic mothers tend to be heavier at birth (Liggins, 1972), weights of fetal pigs were not increased by elevated maternal glucose (Ezekwe and Martin, 1978). Even so, other endocrine secretions not evaluated in our study are known to affect fetal growth in beef cattle (Etherton and Kensinger, 1984). Taken together, our data suggest that the thermal environment to which spring-calving beef cows are exposed during the final third of pregnancy can alter plasma constituents and endocrine function. In addition, even relatively mild winter weather can be associated with reduced weight of calves at birth.



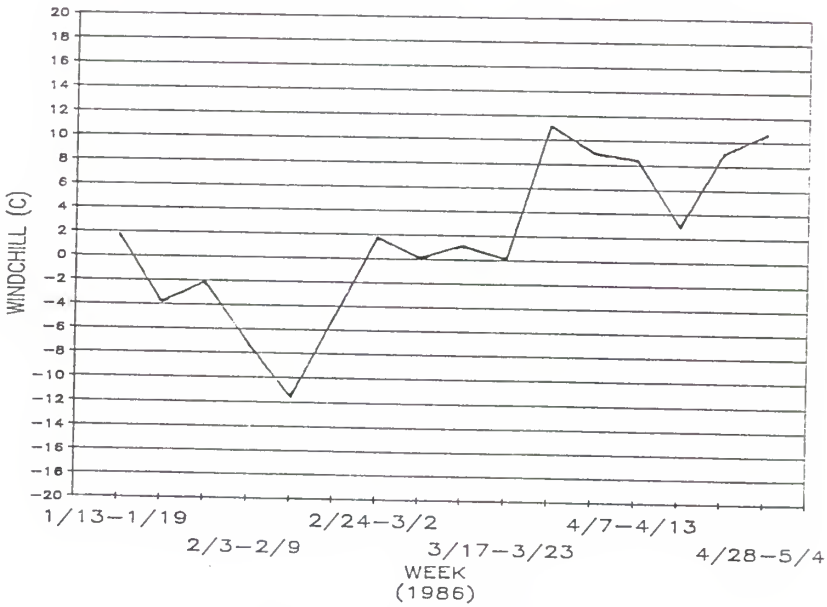


Figure 1. Average weekly windchill throughout the experiment.

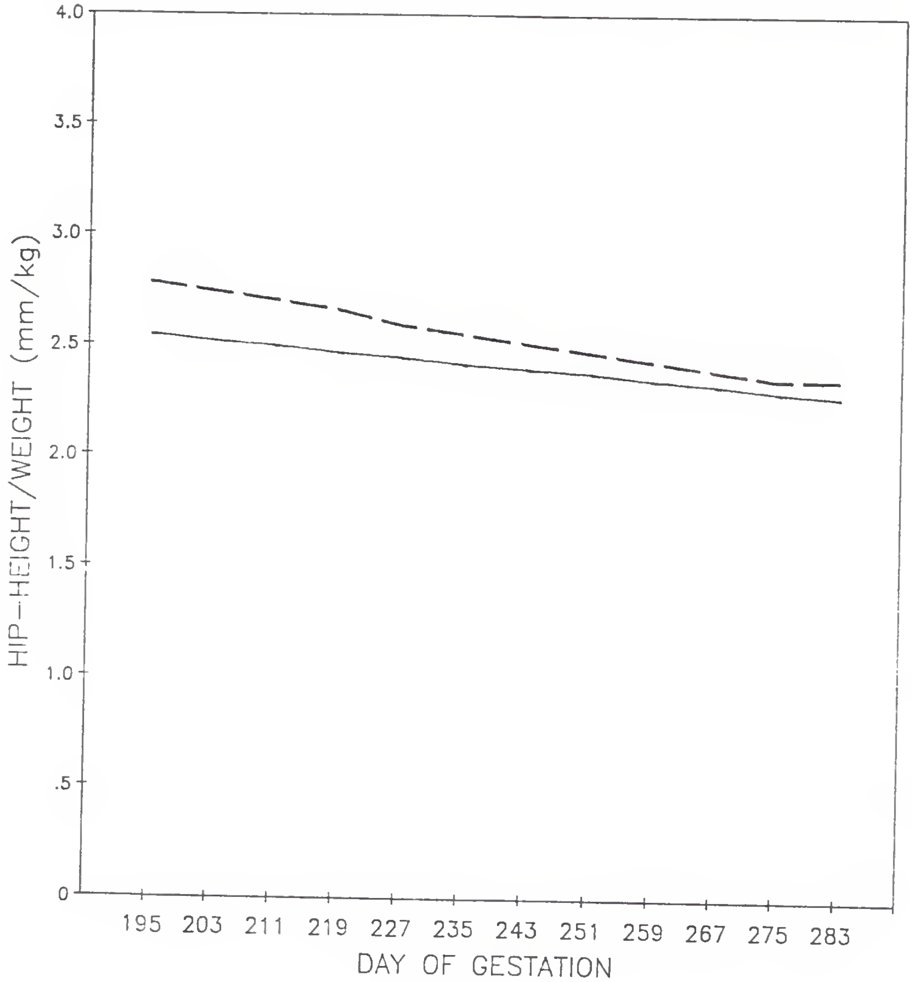


Figure 2. Hip-height to weight ratios of heifers exposed to winter weather conditions (WW ----) or thermoneutral environment (TN ——).

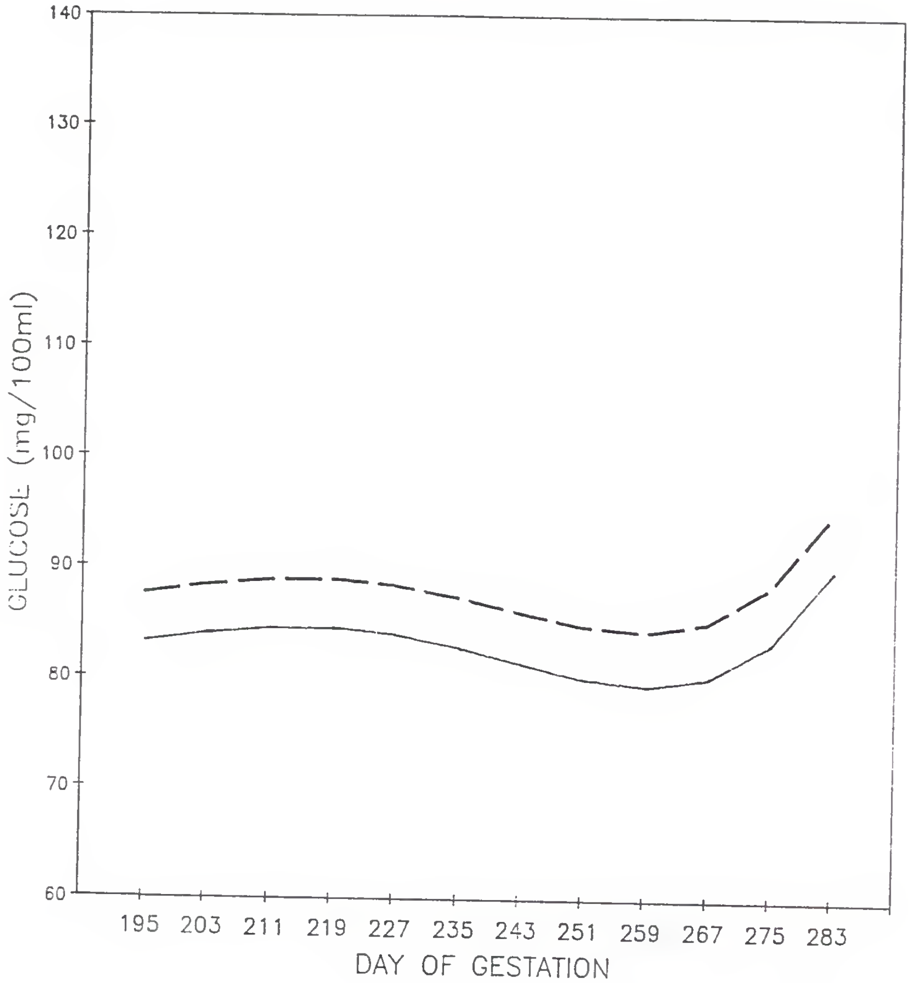


Figure 3. Plasma glucose concentrations of heifers exposed to winter weather conditions (WW ---) or thermoneutral environment (TN ——).

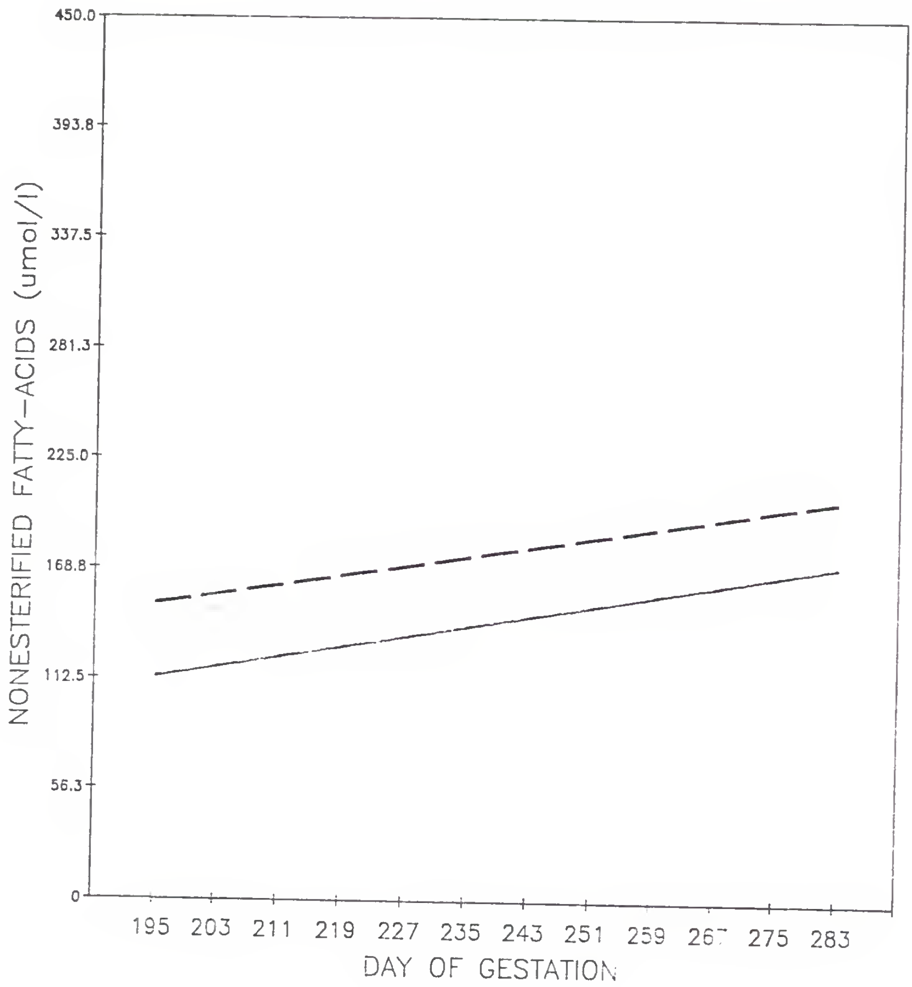


Figure 4. Plasma nonesterified fatty acid concentrations of heifers exposed to winter weather conditions (WW ----) or thermoneutral environment (TN ——).

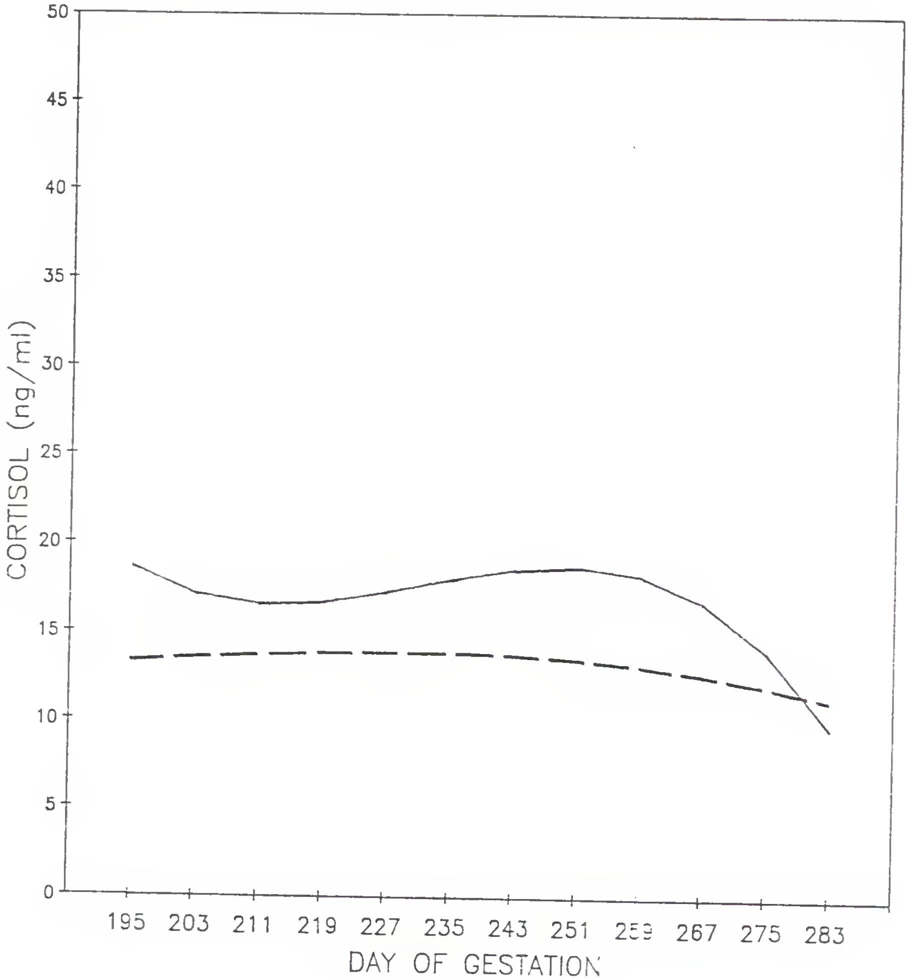


Figure 5. Serum cortisol concentrations of heifers exposed to winter weather conditions (WW ----) or thermoneutral environment (TN ——).

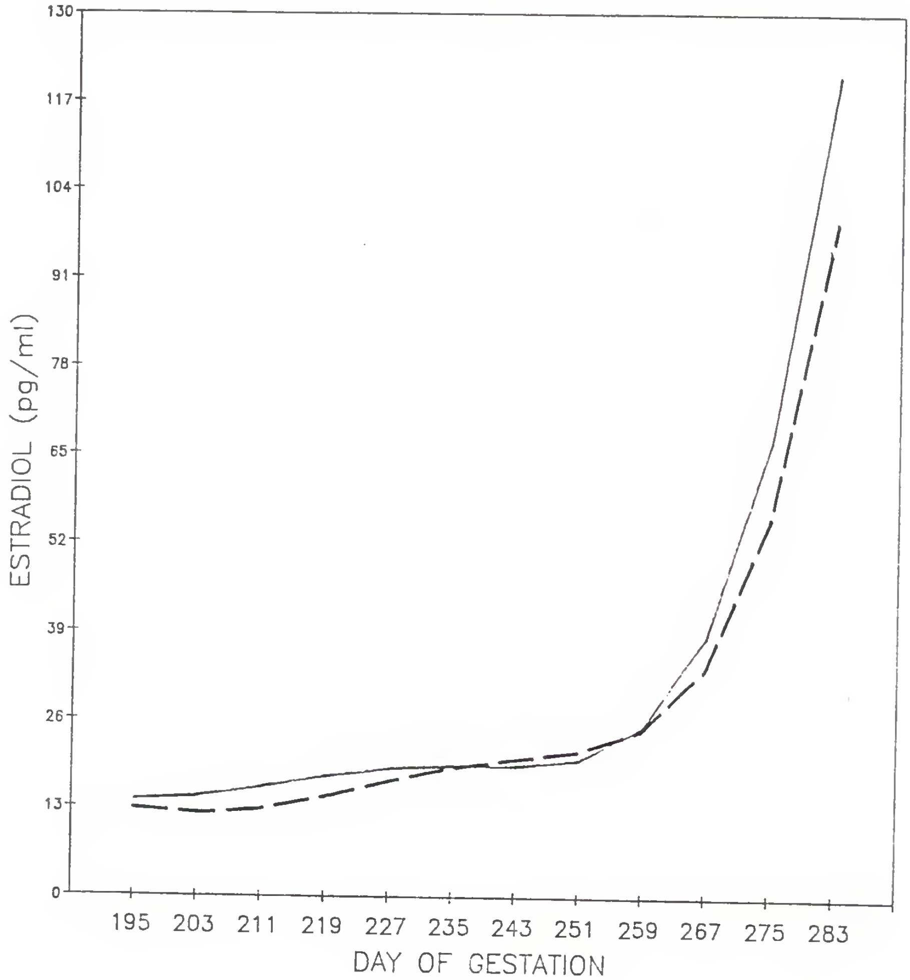


Figure 6. Serum estradiol 17-ß concentrations of heifers exposed to winter weather conditions (WW ----) or thermoneutral environment (TN ——).

TABLE 1. Birth weights of calves, calving difficulty scores and calving dates for heifers exposed to winter weather (WW) or thermoneutral environment (TN).

Treatment	n	Birth weight (kg)	Calving difficulty[b]	Calving date[c]
TN	13	42.3 ± 2.0[a,d]	3.2 ± 0.5	107.5 ± 3.9
AW	16	36.9 ± 1.8[e]	2.7 ± 0.4	107.8 ± 3.6

[a]Mean ± SEM.

[b]1 = no assistance; 6 = abnormal presentation.

[c]Day 108 = April 18.

[d,e]Means with different superscripts differ ($P<.06$).

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APPENDIX

TABLE 2. Ration formulation.

Components	International Feed Number	Percentage[a]
Corn	4-02-931	52
Cottonseed hulls	1-01-599	28
Dehydrated alfalfa	1-00-023	10
Dehydrated molasses	4-04-695	5
Soybean meal	5-20-637	2.9
Fat, animal-poultry	4-00-409	1.0
Limestone	6-02-632	.5
Trace mineral salt		.5
Vitamin premix		.1

[a]Dry matter basis.

TABLE 3. Average weekly windchill.

Year 1 (1985)		Year 2 (1986)	
Week	Windchill (C)	Week	Windchill (C)
1/10 - 1/16	-11.84	1/13 - 1/19	1.67
1/17 - 1/23	-12.76	1/20 - 1/26	-3.89
1/24 - 1/30	-9.39	1/27 - 2/2	-2.22
1/31 - 2/6	-15.89	2/3 - 2/9	-7.22
2/7 - 2/13	-11.79	2/10 - 2/16	-11.67
2/14 - 2/20	-3.61	2/17 - 2/23	-5.00
2/21 - 2/27	-1.01	2/24 - 3/2	1.67
2/28 - 3/6	-1.46	3/3 - 3/9	0
3/7 - 3/13	3.57	3/10 - 3/16	1.11
3/14 - 3/20	4.21	3/17 - 3/23	0
3/21 - 3/27	3.26	3/24 - 3/30	11.11
3/28 - 4/3	2.67	3/31 - 4/6	8.89
4/4 - 4/10	-1.15	4/7 - 4/13	8.33
4/11 - 4/17	9.82	4/14 - 4/20	2.87
4/18 - 4/24	11.43	4/21 - 4/27	8.93
4/25 - 5/1	10.29	4/28 - 5/4	10.61
5/2 - 5/8	12.82		
5/9 - 5/15	11.36		

THE INFLUENCE OF EXPOSURE OF BEEF HEIFERS TO WINTER WEATHER PREPARTUM ON CONCENTRATIONS OF PLASMA ENERGY YIELDING SUBSTRATES, SERUM HORMONES AND BIRTH WEIGHT OF CALVES

by

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ABSTRACT

The influence of exposure to ambient winter weather conditions (WW) during the final 90 d of gestation on serum hormones, plasma substrates and birth weight of calves was evaluated in spring-calving beef heifers. Data were collected in two consecutive years from primiparous Simmental (n=12) and Polled Hereford (n=17) heifers that were mated to calve at 2 yr of age. At an average of 192 $\pm$ 14 d of gestation, heifers were assigned by expected calving date, breed and sire of fetus to one of two treatments. Thirteen heifers were assigned to thermoneutral environment (TN; 12 C) and housed in temperature controlled rooms. Heifers in WW (n=16) were maintained outdoors in drylot without access to shelter. Additional dietary energy was supplied for WW heifers when average weekly windchill fell below -6.7 C. Body weights, hip-heights and samples of serum and plasma were obtained biweekly until heifers were relocated approximately 7 d prior to expected calving. At calving, weight of calf and calving difficulty score (1 = no assistance; 6 = abnormal presentation) were recorded. Concentrations of estradiol and cortisol in serum and glucose and nonesterified fatty acids (NEFA) in plasma were determined. Polynomial response curves for glucose and NEFA in plasma and cortisol in serum were not influenced by treatment. However, average concentrations of

glucose tended to be elevated (P<.13) in WW heifers (87.8 ± 2.4 mg/100 ml) compared to TN heifers (83.3 ± 2.7 mg/100 ml). Average concentrations of NEFA were also increased (P<.02) for WW heifers compared to TN heifers (172.5 ± 8.9 vs. 136.9 ± 7.7 μmol/l). Concentrations of cortisol were similar for TN and WW heifers (17.6 ± 2.9 vs. 13.8 ± 2.7 ng/ml). Patterns of concentrations of estradiol in serum (P<.01) and time trends for hip-height to weight ratios were different (P<.05) for WW and TN. Birth weight of calves from TN heifers were greater (P<.06) than calves from WW heifers (42.3 ± 2.0 vs. 36.9 ± 1.8 kg) but average calving difficulty scores were similar for both heifer groups (3.2 ± .5 vs. 2.7 ± .4). These data suggest that reduced effective ambient temperatures to which spring-calving cows are exposed during the final third of pregnancy may elevate energy yielding metabolites in plasma and alter endocrine function. These changes may contribute to reduced birth weight of calves.