THE INFLUENCE OF PREPARTUM NUTRITION ON BLOOD

CONSTITUENTS AND POSTPARTUM REPRODUCTIVE

PERFORMANCE OF BEEF COWS

By

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CHAPTER I

INTRODUCTION

Reproductive performance of cows is a major factor affecting biological efficiency of a cow-calf production system. To improve economic efficiency, suckled cows were allowed to accumulate body reserves of fat during the grazing season at relatively low cost. These energy reserves are subsequently mobilized during the winter to supply a proportion of the cow's nutrient requirements during gestation. Such a feeding scheme results in a reduction in the amount and cost of winter feed required. If spring calving cows are not managed to minimize losses of weight and body condition during late gestation, postpartum reproductive efficiency is reduced. To maintain a 365-day calving interval, cows should conceive by 85 days after parturition. Nutrition has a major role on reproduction because cows must have a minimum amount of body reserves of energy and protein, which is visible as adequate body condition, before estrous cycles are reinitiated after calving and conception can occur.

Energy and protein supplementation late in gestation influence subsequent postpartum reproductive performance. Prepartum weight loss is usually the criterion used to determine if sufficient supplemental feed is supplied. However, weight loss in late gestation is confounded with fetal growth. Energy reserves of the cow, reflected in the amount of body fat, has an important role in supplying nutrients to the fetus.

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Depletion of body reserves and loss of weight in late gestation increase the postpartum anestrous interval. Although it is recognized that prepartum nutrition influences postpartum reproduction, the mechanism of action is not clear. In addition to prepartum nutrition, suckling intensity, age and breed of cow influence postpartum reproduction.

During the last trimester of pregnancy the fetal calf grows rapidly and many fetal and placental endocrine changes occur. The nutritional regime may influence compounds in the blood that are related to energy metabolism. These metabolic changes may occur in response to energy demands by tissue that are essential for the maintenance of pregnancy. However, metabolic changes late in gestation may dictate subsequent postpartum reproductive endocrine functions. Therefore, the objectives of this study were to determine the influence of prepartum nutrition of range beef cows on concentrations of glucose, proteins and total esterified fatty acids in plasma during late gestation and to relate these constituents to rebreeding performance.

CHAPTER II

LITERATURE REVIEW

Postpartum Reproduction in the Beef Cow

A postpartum interval in any species is a period from the expulsion of the fetus until the occurrence of a specific event. Events ending a postpartum interval include first estrus, first ovulation, completion of uterine involution and first breeding or conception (Casida et al., 1968). These designated end points may occur singly or in combination with one or more events. For example, the interval may be from parturition to first estrus or the interval from parturition to first estrus accompanied with ovulation. The most commonly studied postpartum interval is the interval from parturition to first estrus. Numerous studies have been conducted to elucidate this important event. Decreasing the interval to first estrus will insure increased production of product in most farm animals.

The length of the postpartum interval to first estrus, commonly referred to as the postpartum anestrus interval, varies between species. It has also been demonstrated that the postpartum anestrus interval varies between breeds within species, but the variation may be due to management practices. For example, the postpartum anestrus interval for dairy cows ranges between 30 to 72 days, compared to 46 and 104 days in beef cattle (Casida et al., 1968). The postpartum anestrus period in the ewe usually extends from lambing, which occurs in early spring, to

late fall when estrous activity resumes. In the sow, there is usually complete anestrous during lactation and ovarian activity usually resumes within a week after weaning.

Uterine and Ovarian Characteristics Postpartum

Ovarian follicular activity in cows usually occurs shortly after regression of the corpus luteum of pregnancy (Labhsetwar et al., 1964; Saiduddin et al., 1968; Wagner and Hansel, 1969; Wagner and Oxenreider, 1971). Postpartum regression of the corpus luteum is very rapid in the cow. It is difficult to palpate the corpus luteum of pregnancy between days 4 and 7 postpartum. This observation is confirmed by direct measurement which indicated average corpora lutea diameters of 16 mm at day 2, 15 mm at day 4 and 11 mm at day 11 postpartum (Morrow et al., 1966). Wagner and Hansel (1969) reported that the corpora lutea of pregnancy had regressed to 12.7 mm on day 7 postpartum and to 9.3 mm by day 14 postpartum. They also noted very little change in size of corpora lutea from day 14 to day 30 postpartum (8.5 mm) and that corpora lutea on day 7 had no viable or functional luteal cells. Labhsetwar et al. (1964) were unable to detect progesterone in corpora lutea at parturition. Therefore, postpartum anestrus is probably not a result of prolonged maintenance of the corpus luteum of pregnancy.

Graafian follicles are present by day 21 postpartum (Labhsetwar et al., 1964). Wagner and Hansel (1969) observed that the largest follicles present on days 7, 14 and 30 postpartum were 9.6 mm, 11.3 mm and 13.1 mm in diameter, respectively. In addition, suckled cows killed on day 30 postpartum had follicles with a mean diameter of 12.1 mm.

Suckling and postpartum nutrition influence follicular formation.

The numbers of days from parturition to the presence of a follicle greater than 10 mm in dairy cows fed 66 or 133 percent of N.R.C. recommended levels of energy were 16 and 10 days, respectively (Oxenreider and Wagner, 1971). In addition, the numbers of days from parturition to presence of a follicle greater than 10 mm for suckled and nonlactating dairy cows were 16 and 9 days, respectively. These data suggest effects of nutrition and suckling on follicular development. However, suckled and nonsuckled dairy cows slaughtered between 10 and 30 days postpartum had similar numbers of follicles greater than 5 mm, follicular fluid weights and fluid volumes of the largest follicles (Saiduddin et al., 1968). Graves et al. (1968) observed similar follicular fluid weights, numbers of follicles and fluid volume of the largest follicles for suckled and nonsuckled beef cows slaughtered on either day 3 or 15 after breeding.

First ovulation after calving has been reported to occur as early as 11 days (Oxenreider, 1968), 14 days (Wagner and Hansel, 1969) or 19 days (Morrow et al., 1966) in dairy cows. However, estrus does not necessarily preceed the first ovulation. The incidence of ovulation not preceeded by behavioral estrus appears greater in suckled than nonsuckled cows (Wiltbank and Cook, 1958; Graves et al., 1968). Therefore, in some cases, sufficient hormones to cause follicular growth and ovulation are secreted but behavioral estrus is not induced.

Uterine involution after parturition is variable and can range from 26 to 56 days (Oxenreider, 1968; Kiracofe, 1980). Completion of uterine involution is difficult to evaluate. Rectal palpation reveals information on size and tone of the uterus but does not indicate the amount of epithelial regrowth. Gier and Marion (1968) described uterine involution

with three overlapping processes: (1) reduction in uterine size, (2) loss of tissue, and (3) repair. Histological examination suggests that the interval from parturition to complete uterine involution occurs in 25 to 30 days for most cows (Gier and Marion, 1968; Wagner and Hansel, 1969). The influence of body condition on uterine involution has not been evaluated. The variation in time required to complete uterine involution may be due, in part, to the animal's ability to regenerate endometrial tissue. Energy reserves may be devoted to lactation and not uterine repair and subsequent support of a pregnancy. Wording et al. (1972) observed no differences in the gross histology of uteri from control and undernourished heifers post estrus and after first breeding but did indicate some biochemical differences in the uteri from undernourished heifers.

<center>Endocrine Profiles During the Pre- and
Postpartum Periods in Cows</center>

Progesterone

The ovary is the major source of progesterone during late pregnancy in the cow (Gorski et al., 1958; Fairclough et al., 1975). However McDonald et al. (1953) demonstrated that pregnancy could be maintained for up to 70 days when ovariectomy occurred after day 200 of gestation, illustrating that progesterone required to maintain pregnancy in late gestation can be from a nonovarian source. Low concentrations of progesterone in plasma necessary to maintain pregnancy may be of placental origin. Bovine placental preparations are capable of producing progesterone in vitro (Ainsworth and Ryan, 1967) but Gorski et al. (1958) were unable to find detectable amounts of progesterone in bovine placenta. The

maternal adrenal gland is also capable of producing progesterone (Balfour et al., 1957; Gorski et al., 1958; Wagner et al., 1969) and may be involved in maintenance of pregnancy during late gestation. In addition, pregnancy was maintained when either ovaries or the adrenal glands were removed at 215 days of gestation, but pregnancy was terminated after removal of both the adrenal glands and ovaries (Wendorf et al., 1983).

Peripheral concentrations of progesterone during early pregnancy are similar to concentrations (4-6 ng/ml) during the luteal phase of the estrous cycle (Pope et al., 1969; Donaldson et al., 1970; Edgerton and Hafs, 1973). Concentrations of progesterone decline during midgestation then increase (7-8 ng/ml) to about 220 days of gestation (Donaldson et al., 1970). Beginning 40 to 60 days prepartum, concentrations of progesterone decrease gradually with a further decrease 24 to 48 hours before delivery (Echternkamp and Hansel, 1973; Arije et al., 1974; Fairclough et al., 1975; Edqvist et al., 1978). For example, serum progesterone concentrations averaged 10.1 ng/ml from day 26 to 9 days prepartum, gradually declined from day 15 to day 3 prepartum and at 2.5 days prepartum progesterone averaged 8.0 ng/ml; then concentrations of progesterone declined precipitously to .6 ng/ml at parturition (Smith et al., 1973).

During the postpartum period, concentrations of progesterone remain low (< 1 ng/ml) until ovarian activity resumes (Smith et al., 1973; Edgerton and Hafs, 1973; Arije et al., 1973; Corah et al., 1974; Rawlings et al., 1980). Systemic progesterone concentrations greater than 1 ng/ml are associated with presence of a corpus luteum or a luteinized follicle (Swanson et al., 1972). Transient increases in

concentrations of progesterone occur about 4 days before the first observed behavioral estrus (Donaldson et al., 1970; Arije et al., 1974; Rawlings et al., 1980; Humphrey et al., 1983). For example, Donaldson et al. (1970) observed a small but significant increase in progesterone that reached a maximum of 1.0 ng/ml 3 to 4 days before the first observed estrus after parturition. A similar increase in plasma pro- gesterone precedes the first estrus in heifers (Gonzalez et al., 1975; Cartenson et al., 1976; Berardinelli et al., 1979). The progesterone increase in plasma before the postpartum estrus appears to come from luteinized follicles (Donaldson et al., 1970; Castenson et al., 1976; Rawlings et al., 1980). The importance of this progesterone increase is unclear but may be necessary to initiate resumption of behavioral estrus post partum. Chang et al. (1981) demonstrated that suckled cows exhibited estrus within 2 days after removal of progesterone releasing intravaginal devices and none of the nontreated suckled cows showed behavioral estrus.

Estrogens

The bovine placenta is the major source of estrogen during gestation (Gorski and Erb, 1959; Hoffmann et al., 1979). In vitro perfusion studies with placental tissue identified the fetal part of the placentome, the cotyledon, as the major source of estrogen (Hoffmann et al., 1979). The supply of precursors for estrogen production by the cotyledon remains unclear. Hoffmann et al. (1979) demonstrated that the fetus is not the source of needed precursors. For example, concentrations of estrone, the major unconjugated estrogen in peripheral plasma during pregnancy (Tsang et al., 1975; Eley et al., 1981), declined only slightly during

the first 30 hours after removal of the fetus (1570 to 1200 pg/ml), and at 4 days after fetectomy, concentrations of estrone were 800 pg/ml (Hoffmann et al., 1979).

Although estrone is the major unconjugated estrogen produced by the cotyledon, estrone sulfate (E_1SO_4) is the major estrogen in the maternal circulation (Tsang et al., 1975; Robertson and King, 1979; Eley et al., 1981; Mobley, 1982). Thus, E_1SO_4 may be the estrogen of choice for evaluating placental production of estrogen. As early as day 72 of gestation E_1SO_4 is detectable in maternal plasma (Robertson and King, 1979). Concentrations of E_1SO_4 in plasma increase at about 100 days of gestation (Eley et al., 1979; Robertson and King, 1979) and increase further during the last 40 days of gestation to maximum concentrations around the time of parturition (Robertson and King, 1979; Thatcher et al., 1980; Mobley, 1982). For example, concentrations of E_1SO_4 in plasma on days 72, 147, 213 and 270 of gestation were 114, 3,655, 3,836 and 5,653 pg/ml, respectively (Robertson and King, 1979). However, Thatcher et al. (1980) indicated tremendous variability in concentrations of E_1SO_4 48 to 76 days prepartum and just prior to parturition $(E_1SO_4$ ranged from 250 to 7,000 pg/ml). Such variability may represent differences in hormonal production by the cotyledon due to availability of precursors or differences in rate of metabolism.

Estrone is the primary unconjugated estrogen during gestation in the cow (Smith et al., 1973; Hoffmann et al., 1979; Mobley, 1982). For example, concentration of estrone and estradiol 17-B averaged 218 and 32 pg/ml, respectively, 26 days prepartum and 2,256 and 293 pg/ml, respectively, 2 days prepartum (Smith et al., 1973). In addition, Robertson (1974) found estrone concentrations of 2 ng/ml compared to

150 pg/ml for estradiol 17-B at eight days before parturition.

Total estrogens in plasma increase dramatically as parturition approaches (Smith et al., 1973; Robertson, 1974; Arije et al., 1974; Mobley, 1982). Concentrations of estradiol increase by 50 percent between day 4 prepartum and parturition with similar changes, but of a smaller magnitude, occurring in concentration of estrone (Robertson, 1974) and E_1SO_4 (Thatcher et al., 1980; Eley et al., 1981). Thus, the dramatic increase in concentration of estrogens in plasma during the last month before parturition is the first major change in steroid hormones in advance of parturition.

Following parturition maternal concentrations of estrogens decrease rapidly (Arije et al., 1974; Hoffmann et al., 1979; Humphrey et al., 1983) and remain at low concentrations until first estrus and/or ovulation (Echternkamp and Hansel, 1973; Arije et al., 1974; Humphrey et al., 1983). Estradiol 17-β is the major conjugated estrogen during the postpartum period (Smith et al., 1973) and concentrations in plasma range between 5 and 7 pg/ml (Corah et al., 1974; Humphrey et al., 1983). Concentrations of estradiol 17-β begin to increase a few days prior to first estrus and attained a maximum at estrus when amounts range from 10 to 15 pg/ml (Echternkamp and Hansel, 1973; Corah et al., 1974; Humphrey et al., 1983).

The involvement of estrogen in the postpartum anestrus period remains unanswered. Walters et al. (1982a) demonstrated that concentrations of estradiol 17-β during the first 25 days postpartum were similar for suckled and weaned cows. However, in postpartum dairy cows, LH after GnRH increased with increasing estradiol concentrations (Kesler et al., 1977; Fernandes et al., 1978). In addition, Beck and

Convey (1977) demonstrated positive feedback effects of estradiol
on LH secretion. Thus, before behavioral estrus and subsequent post-
partum ovulation can occur, endogenous estrogens may be needed to
increase GnRH receptor numbers, affinity, availability and/or
releasable LH stores in the pituitary.

Prolactin

Concentrations of prolactin in serum of cattle are influenced by
season of the year (Schams, 1972) and ambient temperature (Wettemann
and Tucker, 1974). There are greater concentrations of prolactin during
the summer and at higher temperatures than during the winter and lower
temperatures. Therefore, when interpreting prolactin results these
factors must be considered and probably account for much of the variation
in prolactin concentrations during pregnancy and the postpartum period.

The broad diversity of functions of prolactin within animals
leads to discrepency as whether to classify this hormone as a metabolic
hormone or a gonadotropin. Prolactin is luteotropic and luteolytic in
rats and luteotropic in mice and hamsters (Hillard, 1973). The luteo-
tropic function of prolactin in larger domestic animals is questionable
(Hansel et al., 1973). Prolactin is a primary hormone necessary for
lactogensis in cattle and causes secretory cell proliferation during
late pregnancy (Baldwin, 1969).

As is the case with many reproductive hormones, concentrations of
prolactin in plasma differ between beef and dairy cows during late
gestation and the postpartum period. Concentrations of prolactin vary
between 15 and 50 ng/ml during late gestation (Ingalls et al., 1973;
Edgerton and Hafs, 1973; Arije et al., 1974), increase to a maximum of

about 250 ng/ml one or two days prepartum (Ingalls et al., 1973; Arije et al., 1974; Eley et al., 1981) and decrease slightly at parturition (Ingalls et al., 1973; Arije et al., 1974; Eley et al., 1981).

During the postpartum period, concentrations of prolactin fluctuate above 30 ng/ml (Ingalls et al., 1973; Arije et al., 1974). For instance, prolactin in plasma averaged 143 ng/ml in beef cattle between days 22 and 25 postpartum (Walters et al., 1982a). Similarly, Arije et al. (1974) reported that concentrations of prolactin in beef cows were about 150 ng/ml from 30 days postpartum to first estrus. Prolactin in serum increases as estrus approaches and subsequently declines after estrus (Edgerton and Hafs, 1973; Arije et al., 1974; Humphrey et al., 1983).

Suckled cows have greater concentrations of prolactin in serum than do nonsuckled cows (Han and Moody, 1974; Chang et al., 1981) and suckled cows also have longer postpartum anestrus intervals (Short et al., 1972; LaVoie et al., 1981). However, administration of ergot alkaloids, that suppress peripheral concentrations of prolactin, did not affect the postpartum anestrus interval of suckled cows (Gimenez et al., 1980; Williams and Ray, 1980). Concentrations of prolactin during a 35 day period averaged .9 ng/ml for heifer treated with an ergot alkaloid and 19.2 ng/ml for control heifers, yet the days to first estrus were 46 and 45 days for treated and control heifers, respectively (Williams and Ray, 1981). In other studies, basal concentrations of LH did not differ between suckled and nonsuckled cows (Chang et al., 1981), and prolactin did not affect the episodic release of LH (Carruthers and Hafs, 1980; Chang et al., 1981) but mean concentrations of LH released during spikes were greater for cows that were not suckled (Chang et al., 1981). In contrast, high serum concentrations of prolactin during

lactation in women have been related with decreased gonadotropin secretion, suggesting that prolactin may delay postpartum ovarian activity. Suppression of prolactin release in postpartum suckled women with an ergot alkaloid caused early restoration of ovulatory cycles (Varga et al., 1972).

In summary, prolactin does not have an inhibitory role on the hypothalamus or anterior pituitary gland in the suckled postpartum cow.

Corticoids

Reproductive processes are influenced by the adrenal gland. Injections of corticoids during late gestation will induce parturition in cattle, sheep and swine (Wagner et al., 1974) and corticoids may reduce gonadotropin secretion in cattle (Wagner and Oxenreider, 1972; Wagner et al., 1977; Dunlap et al., 1981a; Dunlap et al., 1981b; Wettemann et al., 1981).

During gestation, concentration of corticoids averaged 2.3 ng/ml from insemination to 20 days postinsemination (Edgerton and Hafs, 1973). There appears to be more variation in concentrations of corticoids in bovine plasma as parturition approaches and this variation may be related to breed differences. At four weeks prepartum, concentrations of corticoids ranged from 3 to 7 ng/ml (Edgerton and Hafs, 1973; Humphrey et al., 1983). Concentration of corticoids increase two weeks prepartum and range between 10 and 70 ng/ml (Adams and Wagner, 1970; Arije et al., 1974; Humphrey et al., 1983). Concentration of corticoids are increased by 5 days prepartum and attain a maximum at parturition between 9 and 100 ng/ml (Adams and Wagner, 1970; Smith et al., 1973; Arije et al., 1974).

Concentration of corticoids decrease to between 4 and 38 ng/ml by one week postpartum (Echternkamp and Hansel, 1973; Arije et al., 1974; Stevenson and Britt, 1979; Humphrey et al., 1983). Concentration of corticoids tend to increase a few days before estrus (Echternkamp and Hansel, 1973; Arije et al., 1974; Humphrey et al., 1983). Suckled and milked cows have greater average systemic concentration of corticoid than do nonlactating cows (Wagner and Oxenreider, 1972; Dunlap et al., 1981a).

The influence of corticoids on the postpartum anestrus period remains unclear. A suckling event increases concentrations of corticoids in serum within 15 minutes (Wagner and Oxenreider, 1972; Ellicott et al., 1981; Dunlap et al., 1981a; Dunlap et al., 1981b) and Dunlap et al (1981b) observed that LH peaks did not occur within 45 minutes after the initiation of a suckling event. In addition, ACTH administration which is followed by an increased concentration of corticoids in plasma, decreases the number of cows exhibiting episodic LH secretion (Dunlap et al., 1981a). In contrast, under physiological situations concentrations of corticoids appear to be greatest a few days prior to estrus (Arije et al., 1974; Humphrey et al., 1983), a time when LH concentrations are greatest and the number of peaks are greatest (Humphrey et al., 1983). Walters et al. (1982b) have recently demonstrated that pituitary tissue from suckled cows did not release as much LH in vitro in response to treatment with GnRH as did tissue from recently weaned or nonlactating cows. However, in vivo experiments do not confirm these results (Williams et al., 1982). Although treatment of cows with ACTH or corticoids suggest that increased concentrations of corticoids in plasma could decrease the number of LH spikes and therefore influence the postpartum anestrus period, evidence that corticoids are involved in postpartum anestrus is limited.

Prostaglandin $F_{2\alpha}$

Prostaglandin $F_{2\alpha}$ secretion can be estimated since the advent of a radioimmunoassay to measure the main metabolite of $PGF_{2\alpha}$, 15-keto-13, 14-dihydro-$PGF_{2\alpha}$ (PGFM). This breakthrough allows sampling over prolonged periods without problems of surgical intervention and cannulation. Kindahl et al. (1976) demonstrated that PGFM has a half-life of approximately eight minutes in the cow, compared to the 30-second half-life for $PGF_{2\alpha}$.

Peripheral plasma concentrations of PGFM are low ($<$ 200 pg/ml) and are constant from 60 to 5 days prepartum (Edquist et al., 1978; Thatcher et al., 1980). Then concentrations of PGFM increase expotentially to about 1200 pg/ml at parturition (Thatcher et al., 1980). Similarly, concentrations of $PGF_{2\alpha}$ in utero-ovarian venous plasma are relatively constant until 5 to 7 days before term, then concentrations increase gradually to about 1.5 ng/ml at 24 to 48 hours before parturition and increase to a maximum of 5.5 to 9.0 ng/ml at delivery (Fairclough et al., 1975). The increase in $PGF_{2\alpha}$ in utero-ovarian venous plasma and PGFM in peripheral plasma occurs prior to or simultaneous with the decline in peripheral concentrations of progesterone that immediately precede parturition (Fairclough et al., 1975; Edquist et al., 1978; Thatcher et al., 1980). This relationship suggests that the increase in $PGF_{2\alpha}$ causes luteolysis and the rapid reduction in plasma concentrations of progesterone that precede delivery. The ovary is the major source of progesterone during late gestation (Fairclough et al., 1975) and exogenous injections of $PGF_{2\alpha}$ are luteolytic in pregnant cows (Lauderdale et al., 1972).

Concentrations of PGFM continue to increase after parturition (Edquist et al., 1978), average 3,400 pg/ml by 2 days postpartum and remain high until 4 days postpartum (Thatcher et al., 1980). Beginning 5 days postpartum, peripheral concentrations of PGFM gradually decrease and are less than 100 pg/ml by day 20 postpartum (Edquist et al., 1978; Thatcher et al., 1980). During the early postpartum period, $PGF_{2\alpha}$ secretion can be altered by amputating the uterus (Guilbault et al., 1981). In addition, Eley et al. (1981) also suggested a uterine source of $PGF_{2\alpha}$, since prepartum increases were coupled closely with delivery of the calf and placenta and the postpartum decrease in PGFM concentrations was correlated ($r = .68$) with diameter of the previously gravid uterine horn. Regression analysis of concentrations of PGFM and progesterone until 20 days postpartum indicated that a subtle but perhaps important, increase in progesterone in plasma (>1 ng/ml) did not occur until concentrations of PGFM decreased to less than 100 pg/ml (Thatcher et al., 1980). This suggests that the onset of ovarian activity during the early postpartum period may be related to changes in peripheral concentrations of PGFM.

Luteinizing Hormone

Concentrations of luteinizing hormone in serum are minimal ($\sim .6$ ng/ml) and relatively constant throughout pregnancy and at parturition (Ingalls et al., 1973; Edgerton and Hafs, 1973; Arije et al., 1974; Peters et al., 1981). Arije et al. (1974) reported concentrations of LH during late gestation in three beef cows between 0.4 and 1.4 ng/ml.

Following parturition, concentrations of LH are minimal for about the first week (Ingalls et al., 1973; Peters et al., 1981), then concen-

trations increase throughout the postpartum period (Kesler et al., 1977; Rawling et al., 1980; Dunlap et al., 1981b). For example, in dairy cows, concentrations of LH on 3, 10, 20, 30 and 40 days postpartum were .32, .98, .60, 1.05 and 1.08 ng/ml, respectively (Fernandes et al., 1977). In addition, Arije et al. (1974) reported that average concentration of LH in serum during the first 21 days postpartum was 1.3 ng/ml and during the next 51 days concentration of LH averaged 1.6 ng/ml. The increase in concentrations of LH is due to an increase in the number and magnitude of LH peaks preceding the first postpartum ovulation (Stevenson and Britt, 1979; Rawlings et al., 1980; Humphrey et al., 1983). On the day of the first postpartum estrus, concentrations of LH exceded 10 ng/ml (Echtern-kamp and Hansel, 1973; Arije et al., 1974; Stevenson and Britt, 1978) and returned to less than 2 ng/ml following estrus (Echternkamp and Hansel, 1973).

The involvement of LH in the reestablishment of postpartum estrous cycles remains unresolved. Pituitary content of LH increases linearly from 10 to 30 days postpartum (Saiduddin et al., 1968) and there are no significant differences in pituitary content of LH between suckled and nonsuckled cows (Saiduddin et al., 1968; Wagner et al., 1969). Pituitary responsiveness of dairy cows to GnRH, as evidenced by concentrations of LH in serum, appears to be similar to that of the normal cyclic cow by day 10 postpartum (Fernandes et al., 1977; Kesler et al., 1977). Thus, the ability of the pituitary to release LH in lactating cows does not appear to be the limiting factor in reestablishment of cyclic ovarian activity. However, suckled cows have reduced basal serum LH (Radford et al., 1978; Dunlap et al., 1981a,b) compared to nonsuckled cows which probably results from a reduction in frequency and amplitude

of episodic LH peaks in suckled cows (Carruthers and Hafs, 1980; Carruthers et al., 1980; Dunlap et al., 1981a). In contrast, Chang et al. (1981) reported that basal concentrations of LH were not different between suckled and nonsuckled cows, nor was the number of LH spikes different. However, the mean concentration of LH released during a spike was greater in cows not suckled. Cows that ovulate early after parturition have more LH peaks and greater average serum LH during the early postpartum period than cows that ovulated later (Stevenson and Britt, 1979). Removal of the suckling stimulus increased pituitary responsiveness to GnRH and increased concentrations of basal LH in serum which may increase LH receptors in the largest follicles (Walters et al., 1982b). Riley et al. (1981) significantly reduced the number of days to the first progesterone increase in plasma by treating suckled cows 20 to 40 days postpartum with small doses of GnRH. Webb et al. (1977) were unable to induce normal ovarian activity by administration of 500 ug of GnRH to suckled cows 13 to 32 days postpartum. However, a small transient increase in progesterone followed GnRH injection. Administration of 500 ug of GnRH to suckled cows 20 to 30 days postpartum and a second injection 10 days later induced normal cyclic activity at 35 days postpartum compared to 70 days for untreated controls (Webb et al., 1977). Inconsistant ovarian and behavioral response to treatment of postpartum anestrous cows with GnRH (Echternkamp et al., 1978; Fonseca et al., 1980; Wettemann et al., 1982) may be related to other factors such as nutrient intake and/or body condition.

Blood Metabolites During the Pre-

and Postpartum Periods

Undernutrition of commercial beef herds is of great importance as farmers and ranchers attempt to minimize production costs by reducing the plane of nutrition during pregnancy. In pregnant cows, change in body weight has been used as a criterion for evaluation of the adequacy of the diet. However, change in weight of the fetus sometimes confuses interpretation of change in weight of the dam. Since most physiological processes involve transport of substrates and metabolites by the blood, measurement of specific blood constituents should indicate changes in types or rates of biochemical processes related to growth or productivity. Quantities of nutrients consumed are associated with variation in metabolism of fat in the body, especially the mobilization of fat depots during low intake. Changes in concentrations of esterified and nonesterified fatty acids, ketone bodies (acetoacetate, B-hydroxy-butyrate and acetone) and glucose in blood are related to changes in energy reserves in the body.

Glucose

Restriction of energy intake can reduce concentrations of glucose in the blood of ruminants (Patterson et al., 1964; Howland et al., 1966; Wagner and Oxenreider, 1971; Coggins and Field, 1976). Limited information on plasma glucose during gestation of ruminants is available and very seldom is body condition of the cow mentioned. In general, concentrations of glucose increase until parturition (Horrocks and Paterson, 1957, 1960) and in ewes the increase in concentrations of glucose is not related to prepartum nutrition (Patterson et al., 1964).

For example. Horrocks and Paterson (1957) observed concentrations of glucose in blood of 47 mg percent in dairy cows about 65 days prepartum and 52 mg percent at the time of parturition.

Concentrations of glucose decline after parturition in cows (Horrocks and Paterson, 1957, 1960) and then amounts appear to be influenced by intake of energy and lactational status (Wagner and Oxenreider, 1971; Coggins and Field, 1976; Downie and Gelman, 1976). Wagner and Oxenreider (1971) fed low (66% N.R.C.), medium (100% N.R.C.) or high (133% N.R.C.) energy diets during the postpartum period and plasma glucose concentrations for cows fed the low energy diet (61.9 mg%) were significantly reduced compared to cows fed the medium (66.8 mg%) or high (69.0 mg%) energy diets. Suckled (64.9 mg%) and milked (64.1 mg%) cows had significantly reduced concentrations of glucose in plasma compared to nonlactating cows (69.1 mg%).

Hypoglycemia might be the primary biological problem occurring in lactating or suckled cows losing excessive amounts of weight. During the breeding season concentrations of glucose in blood of infertile dairy cows were decreasing and were reduced compared to fertile cows that had increasing blood concentrations of glucose (McClure, 1965, 1968). Cows with reduced blood glucose and body weights may not exhibit estrus within 90 days after parturition (Patil and Deshpande, 1979). Although weight change has been related to fertility (McClure et al., 1970) and number of days from parturition to first estrus (Wettemann et al., 1982), the correlation is moderate. Likewise, mean plasma concentrations of glucose for a 56 day period postpartum is negatively correlated with the interval to the presence of a 10 mm follicle $(r=-.50)$ and with the interval from parturition to first ovulation $(r=-.62)$ (Wagner and

Oxenreider, 1971). Decreasing weight at the same time that concentrations of glucose in blood are decreasing appears detrimental to fertility (McClure et al., 1970; Downie and Gelman, 1976). However, McClure et al. (1970) observed that fertility remained normal in some cows that were losing weight but whose blood glucose was constant. This suggests a possible influence of body condition and the effect of weight loss on reproductive performance.

Induction of hypoglycemia is detrimental to normal reproductive processes. Acute fasting or insulin treatment of mice, both of which caused hypoglycemia, or administration of 2-deoxy-D-glucose, a glucose metabolic inhibitor, caused alterations which varied from embryonic death to failure of ovarian follicular development (McClure, 1966, 1967a,b). In addition, treatment of cows with insulin beginning on day 18 of the cycle through day 20 lengthened the estrous cycle to an average of 34 days compared to an average cycle length of 24 days for control cows (McClure, 1968). Treatment of cows with insulin four times daily starting the day of or the day after insemination resulted in pregnancy rate of 18 % at eight weeks after breeding compared to 75 % for control cows.

Feeding of grain compared to hay to ewes caused increased glucose in blood and heavier adrenal glands, pituitaries, follicular fluid, greater pituitary LH and ovulation rates and an increased number of large follicles (Howland et al., 1966). Ovine brains cannot use volatile fatty acids as an energy source and blood glucose becomes the limiting factor for cellular activity (McClymont and Setchell, 1956). A high energy ration for ruminants causes an abundance of propionic acid, which through gluconeogenisis results in elevated blood glucose levels. Elevated concentrations of glucose in blood could provide a stimulus to

hypothalamic centers in the brain which control gonadotropins and result in greater secretion of gonadotropic hormone and subsequent ovarian activity. Infusion of propionate into the abomasum of prepuberal heifers enhanced the ability of heifers to respond to a GnRH challenge (Rutter et al., 1983). In addition, treatment with metabolic inhibitors that altered glycolysis and oxidative phosphorylation retard the ability of rats to respond to a GnRH challenge (Sen et al., 1979).

Nonesterified Fatty Acids, Ketones and
Total Esterified Fatty Acids in Plasma

Nonesterified fatty acids (NEFA) are released into blood plasma when adipose tissue is mobilized to supply energy. Although the quantity of NEFA in the blood of ruminants is small, it is an important factor in caloric homeostasis of the body. Total esterified fatty acids (TEFA) are long chain fatty acids attached to a glycerol backbone. TEFA are greatest in blood plasma when the animal is in a positive energy balance and these fats are incorporated into the lipid stores. Ketone bodies are a product of NEFA that have been split into acetyl Co-A which in turn are condensed to a form one molecule of acetoacetic acid in the liver. A large part of the acetoacetate is converted to B-hydroxy-butyrate and a minute quantity to acetone. These products then enter the blood and are available for tissue use.

The increased energy requirements of pregnancy and lactation usually result in an increase in concentration of NEFA in plasma. Quantities of plasma NEFA during late pregnancy in ewes fed similar amounts of feed are highly correlated with total fetal weight per unit of maternal weight (Reid and Hinks, 1962). Amounts of blood NEFA

increased at parturition in cows (Randloff et al., 1966). Nonesterified fatty acids in plasma averaged 290 µeq/l 2 weeks prior to calving and increased to 723 µeq/l at parturition. During lactation, concentrations of NEFA vary with the greatest values usually at the time of maximum milk production (Radloff et al., 1966; Head et al., 1976).

Concentrations of NEFA and ketones in the blood of ruminants are usually negatively related to concentrations of glucose (Annison, 1960). Concentration of ketones or glucose in pregnant ewes with increased feed intake 2 weeks before parturition were not significantly different from those for ewes on constant feed intake (Reid and Hinks, 1962). Ewes on ad libitum feed had lower NEFA and greater glucose levels than ewes on restricted intake during late pregnancy.

Concentrations of NEFA in plasma could be a useful indicator to predict the nutrient status of ruminants (Annison et al., 1960; Reid et al., 1964; Russel et al., 1967). Reid and Hinks (1962) concluded that concentrations of NEFA in plasma were more sensitive indicators of undernourishment during pregnancy in ewes than blood glucose or ketones. They observed that blood glucose and ketone concentrations underestimate the additional feed requirements needed during late pregnancy. It was also apparent that when fat, pregnant ewes were subjected to under-nutrition, they were better able to maintain blood glucose and blood ketones in the "normal" range than ewes in medium condition.

Concentrations of ketones in plasma increase slightly prior to calving and increase further during the postpartum period (Horrocks and Paterson, 1957, 1960). Ketones in plasma of cows, expressed as mg of acetone per 100 ml of blood, averaged 3.9, 6.1 and 13.2 mg percent at 7 days prepartum, at parturition and at 8 days postpartum, respectively,

and ketones in plasma remained elevated until 56 days postpartum (Horrocks and Paterson, 1960).

Data are not available on concentrations of TEFA in the blood of prepartum cows. Concentration of TEFA decrease from parturition through 24 weeks of lactation and then concentrations gradually increase to 44 weeks of lactation (Head et al., 1976). They also observed greater concentrations of TEFA during the summer months.

Plasma Protein

Concentrations of protein in blood plasma are fairly stable and have not been related to fertility (Treacher et al., 1976). Concentrations of protein in plasma were similar for lactating beef cows fed low (90 % A.R.C.) medium (125 % A.R.C.) or high (175 % A.R.C.) energy diets and averaged 7.3, 7.8 and 7.4 percent, respectively (Coggins and Field, 1976).

<center>Influence of Prepartum Nutrition on

Postpartum Reproduction</center>

Amounts of energy fed during gestation can have a marked effect on postpartum ovarian activity in the sow (Robertson et al., 1951; Self et al., 1959) and ewe (El-Sheilk et al., 1955; Foote et al., 1959). The onset of puberty can be delayed by underfeeding heifers (Joubert, 1954; Reid, 1960). If pregnant first calf heifers are fed reduced amounts of energy prior to parturition, they have increased intervals from calving to first estrus (Joubert, 1954; Turman et al., 1964; Dunn et al., 1969; Bellows and Short, 1978; Dunn and Kaltenbach, 1980). Sixty-nine percent of the heifers fed a high energy diet before calving

were in estrus by 60 days postpartum compared to only 44 percent of the heifers fed a low energy diet prepartum (Dunn et al., 1969). A similar situation occurs when mature pregnant beef cows are fed restricted amounts of energy prior to calving (Wiltbank et al., 1962, 1964; Hight, 1968; Dunn and Kaltenbach, 1980). For example, cows fed one-half the N.R.C. recommended energy level prior to calving and 100% of the energy level after calving had postpartum intervals to first estrus of 65 days compared to 48 days for cows fed recommended N.R.C. energy levels both pre- and postpartum (Wiltbank et al., 1962). In contrast, Corah et al. (1975) found no significant influence of prepartum energy level on the postpartum interval to first estrus in either heifers or cows. However, cows in that study were in good body condition, which may have influenced the response to nutrition. In many studies, weight change has been used as an indicator of body condition at calving. However, weight change does not always reflect changes in body condition. The responses during the postpartum period to prepartum nutrition depends on body condition of the cow at parturition (Dunn and Kaltenbach, 1980).

Influence of Postpartum Nutrition on Reproduction

Reduced energy intake following parturition delays the onset of estrus in dairy cows (Reid, 1960; Gardner et al., 1969). Beef cows fed restricted energy diets post partum experience a similar response (Wiltbank et al., 1964; Summerville et al., 1979; Lowman et al., 1979). However, the response to postpartum energy level is dictated by prepartum energy level and body condition (Wiltbank et al., 1962; Dunn and Kaltenbach, 1980). For example, cows fed 100% N.R.C. before calving then fed either 100% or 50% N.R.C. post partum had similar intervals

from calving to first estrus (48 and 43 day). Likewise, cows fed 50% N.R.C. before calving then fed either 100% or 50% N.R.C. post partum had longer but similar postpartum intervals to first estrus (65 and 52 days) (Wiltbank et al., 1962).

Wiltbank et al. (1964) fed cows one-half or 100 % of the recommended N.R.C. energy level beginning 140 days prepartum then fed either 75, 100 or 150 % of the N.R.C. requirement post partum. More cows fed 100 % N.R.C. throughout the experiment exhibited estrus by 50 and 70 days post partum and they had a significantly shorter interval from calving to first estrus. However, the number of cows pregnant by the end of the breeding season were similar for all groups. Feeding 150 % of the N.R.C. requirement postpartum exerted a favorable $(P > .05)$ influence on conception. Bellows and Short (1978) observed that a high postcalving feed level was slightly advantageous to subsequent reproductive performance when precalving feed level was high, but a high postpartum diet was detrimental when precalving feed level was low. The cause for this interaction was not elucidated but it is possible that the additional feed that cows were fed on the low prepartum energy level stimulated milk production and not replenishment of body reserves that are vital to promotion of satisfactory postpartum reproductive activity.

The amount of energy and/or protein fed postpartum influences reproductive performance of fall calving cows (Lowman et al., 1979; Cantrell, 1982; Rakestraw et al., 1983). Cows fed to maintain their postcalving body weight had a postpartum interval about 22 days shorter and a conception rate 12 % greater compared to cows fed to lose 10 % of their body weight by the start of the breeding season (Cantrell, 1982).

Influence of Body Condition on

Postpartum Reproduction

Reproductive performance post partum is increased when heifers are fed to minimize weight loss pre- and post partum (Dunn et al., 1969). However, changes in body condition in response to weight loss were not assessed. Wiltbank et al. (1962) and Whitman et al. (1975) demonstrated that weight change pre- and post calving accounted for a significant portion of the variation in the percentage of cows in estrus by 40 to 50 days postpartum. In addition, as body condition of cows at calving improved from thin to moderate to good, the likelihood of estrus between 60 and 90 days postpartum increased significantly (Whitman et al., 1975).

Wettemann et al. (1981) illustrated that body weight change or body condition score change during gestation can be used to estimate rebreeding performance. For example, a 20 percent decrease in body condition score from November to calving in the spring was associated with an additional 15 days to first estrus after calving compared to cows that maintained body condition. Similarly, a 20 percent decrease in body weight from November to calving in the spring resulted in an additional 17 days to first estrus. Concentrations of hormone in plasma may be altered due to prepartum supplementation rate. Cows that lost weight and body condition during the prepartum period had altered concentrations of progesterone, estrone and estrone sulfate in plasma compared to cows that maintained or gained weight (Mobley, 1982).

In summary, cows that lose weight prior to and after calving tend to have longer postpartum anestrus intervals compared to cows that maintain or gain weight. Cows that calf in moderate or good body

condition have a reduced interval to first postpartum estrus compared to cows that calve in a thin body condition. If weight loss occurs prepartum, the animal has utilized body tissue stores to provide nutrients for the developing conceptus. Weight gain prepartum indicates that a cow consumed sufficient nutrients to meet the demands for body maintenance plus enough nutrients to support growth of the fetus. Thus less body tissues were mobilized. Maintaining weight prepartum does not necessarily mean the dam is not mobilizing body reserves. Cows maintaining weight prepartum are actually experiencing some weight loss but this weight change is undetected because the fetus is growing and gaining weight.

Factors Influencing Postpartum Reproduction

Suckling

The suckling stimulus increases the interval from parturition to first estrus in both beef (Wiltbank and Cook, 1958; Graves et al., 1968; Oxenreider, 1968; Short et al., 1972; Bellows et al., 1974; LaVoie et al., 1981) and dairy (Saiduddin et al., 1968; Oxenreider and Wagner, 1971) cows. Beef cows that have their calves removed at birth or shortly thereafter have shorter postpartum intervals to first estrus than cows that are allowed to nurse their calves (Graves et al., 1968; Oxenreider and Wagner, 1971; Short et al., 1972; Bellows et al., 1974; LaVoie et al., 1981). For example, cows that had calves removed at parturition had a postpartum anestrus interval of 25 days compared to 65 days for cows suckling a calf (Short et al., 1972).

Ovulation without behavioral estrus does not necessarily precede the first postpartum ovulation but many cows do not exhibit behavioral

estrus until after one or more ovulatory periods. This situation appears more prevalent in suckled than nonsuckled cows (Wiltbank and Cook, 1958; Graves et al., 1968). However, the incidence of ovulation without estrus tends to decrease as days postpartum increase. Graves et al. (1968) observed that 70% of the suckled compared to 42% of the nonsuckled cows had silent first estruses, and at the second estrus, 50 % of the suckled and 26 % of the nonsuckled cows had silent estruses. Smith and Vincent (1972) demonstrated that hormone therapy, consisting of a progesterone implant combined with injections of FSH and estradiol 17-B initiated 30 days postpartum resulted in increased ovarian activity in suckled cows. Ninety-four percent of the treated suckled cows compared to 71 % of the nontreated suckled cows exhibited estrus by 100 days postpartum. This suggests that treatment returned suckled cows to a normal endocrine balance sooner than untreated cows.

The average interval from calving to first estrus is longer for nursed than for milked cows (Wiltbank and Cook, 1958; Oxenreider and Wagner, 1971; Carruthers and Hafs, 1980). Furthermore, cows rearing twins had extended periods of anestrus when compared to cows suckling one calf (Wettemann et al., 1978). Once-daily-suckled cows (Reeves and Gaskins, 1981; Randel, 1981) or cows suckled 2 times daily (LaVoie et al., 1981) had shorter periods from parturition to first estrus than did cows suckled ad libitum. This indicates that the frequency that milk is removed from the mammary system and intensity of mammary stimulation influences postpartum ovarian activity. Wyatt et al. (1977) observed that cows suckling twin calves produced more milk (9.2 kg vs 6.6 kg) were nursed more frequently (4.3 vs 3.4 times per day) and suckled for a longer period of time (46.1 vs 32.4 minutes) compared to cows suckling

a single calf. By 90 days postpartum, 71% of the cows rearing single calves displayed estrus compared to only 43% of the cows rearing twins. Mastectomy also shortens the postpartum anestrous interval (Short et al., 1972) but denervation of the mammary gland failed to alter the interval to first estrus (Short et al., 1976).

The effect of suckling on the postpartum anestrus interval is generally confounded with nutrition because of the increased nutrients required to meet the demands for lactation. In studies where the nutritional regime was adjusted for lactational status, suckling delayed postpartum estrual activity independent of nutrient intake (Short et al., 1972; Kaiser, 1975; Wettemann et al., 1978). As days postpartum increase, fertility increases in suckled cows (Graves et al., 1968; Wettemann et al., 1978). This indicates that the energy demands for lactation have decreased or that the hypothalamic-pituitary-gonadal axis has become refractory to the suckling stimulus.

Management of cows to reduce the suckling stimulus may be helpful to shorten the postpartum anestrus interval when this period becomes excessively long. Early weaning or temporary calf separation can be used to decrease the interval from parturition to first estrus. At parturition there is reduced secretory activity by the ovary and minimal follicular growth occurs. But these processes increase as days post partum increase (Saiduddin et al., 1968; Graves et al., 1968). Though ovulation may occur as early as 11 days postpartum (Oxenreider, 1968) in cows having their calves weaned at birth, uterine environment may not be conducive for embryo survival. A review by Kiracofe (1980) indicates that uterine involution and repair post partum requires between 27 and 56 days.

Weaning calves early will significantly decrease the postpartum anestrus interval of beef cattle (Smith and Vincent, 1972; Bellows et al., 1974; Lusby et al., 1981). When calves were weaned 30 days postpartum the average interval from calving to conception was decreased by 13 days (Smith and Vincent, 1972). Early weaning appears to be more beneficial with younger cows compared to mature cows (Laster et al., 1973; MacPherson et al., 1976). Weaning one week prior to a 42 day breeding season increased the percentage of 2- and 3-year-old cows exhibiting estrus during the first 21 days of the breeding season but had no influence on mature cows (Laster et al., 1973). In addition, the proportion of 2 and 3-year-old cows conceiving during the breeding season was also increased.

Once-daily-suckling can also be used to shorten the postpartum anestrus period. Once-daily nursing beginning 21 or 30 days postpartum significantly decreases days to first estrus (Reeves and Gaskin, 1981; Randel, 1981). However, alteration of the suckling intensity may increase the incidence of short estrous cycles (< 11 days) (Reeves and Gaskin, 1981)

Age and Breed of Cow

The interval from parturition until cows are reproductively functional varies with age and breed (Laster et al., 1973; Davis et al., 1977; Inskeep and Lishman, 1979). Inskeep and Lishman (1979) observed that Angus and exotic (crosses of Angus or Hereford with Charolais, Simmental, Brown Swiss or Holstein) heifers with their first calves are more likely to have a corpus luteum at a given stage postpartum than Herefords or crosses of other British breeds. In addition, mature

Angus cows were reproductively active earlier in the postpartum period than Hereford and exotic cross cows (Inskeep and Lishman, 1979).

A summary by Casida et al. (1968) indicated only a 4-day advantage for Angus cows compared to Hereford cows in interval from parturition to first estrus. Similarly, Angus cows suckling calves displayed estrus 4 to 7 days earlier than suckled Hereford cows (Laster et al., 1973). When Hereford and Angus 2-year-old heifers were maintained on a low energy ration following calving, 30% of the Hereford heifers failed to show estrus compared to only 9% of the Angus heifers (Dunn et al., 1969). Dairy cows ovulate earlier in the postpartum period than do beef cows (Graves et al., 1968; Saiduddin et al., 1968). This difference between dairy and beef cows may be due to breed but is most likely influenced by nutritional management.

Many studies indicate the influence of age of cow on postpartum reproduction. In a review by Tervit et al. (1977), two-year-old heifers had an average postpartum anestrous interval of 85 days compared to 63 and 58 days for 3- and 4-year-old cows, respectively.

In summary, postpartum reproductive function can be influenced by age and breed of the female but both of these factors can be altered by nutritional regime and lactational status.

CHAPTER III

THE INFLUENCE OF PREPARTUM NUTRITION ON BOOOD CONSTITUENTS AND POSTPARTUM REPRODUCTIVE· PERFORMANCE OF BEEF COWS[1,2]

Summary

Sixty-eight mature, spring calving Hereford cows were used to
determine the effect of prepartum nutrition on concentrations of glucose,
protein, total esterified fatty acids in blood plasma and packed cell
volume in blood. About 120 days before calving (November 19, 1980) 12
cows were assigned to a moderate (M) supplemental feeding regime so as
to maintain their November weight until calving and 56 cows were
assigned to a low (L) supplemental regime so as to lose 5% of their
November weight by 60 days precalving. On January 22, 1981 the supple-
mental rate of the L cows was altered. One group (n =19) was fed to
return to their November weight by calving (LH) another group (n=20)
was fed to maintain their weight until calving (LM). A third group
(n=17) was fed to continue to lose weight, so that approximately 10% of
the November weight was lost by the time of calving (LL). All animals
were treated alike after parturition. Body condition scores and plasma
samples were obtained every two wk from 60 d prepartum until calving.
Percentage body weight changes from November 19 to March 19, the average

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calving date for all cows, were -3.0%, -4.4%, -6.2% for M, LL, LM and LH cows, respectively. Body condition scores were similar for cows on all treatment groups at the start of the experiment (6.5 ± .1) and were reduced, but not significantly influenced by treatments, on March 19 (6.0 ± .1). Concentrations of glucose in plasma were similar for cows in all treatment groups on the day of nutrition change (January 22). However, concentrations of glucose in plasma increased in LH and LM cows by February 5 (P <.005) and remained greater (P <.05) on February 19, March 5 and March 19 when compared to cows in the LL treatment group. Concentrations of protein in plasma were reduced in cows on the LL treatment (P <.05) on the day of nutrition change and remained reduced until calving. Concentration of total esterified fatty acids in plasma were not affected by treatments. Packed cell volumes increased for all cows between January 22 and March 19. However, the volume of blood cells was lower (P <.05) for cows in the LL and LM treatment groups compared to cows on the LH and M treatments from February 5 to March 19. Pregnancy rates were 92%, 77%, 94% and 90% for M, LL, LM and LH cows, respectively. We conclude that the nutritional regime during late gestation influences concentrations of glucose and protein plasma and the packed cell volume in blood of beef cows.

Introduction

Prepartum nutrition influences postpartum reproductive performance of beef cows (Wiltbank et al., 1962; Wiltbank et al., 1964; Dunn et al., 1969). Cows that lose weight and body condition prior to calving have extended intervals from parturition to first estrus (Dunn and Kaltenbach, 1980; Wettemann et al., 1982). Undernutrition in commercial beef herds

is of great importance as farmers and ranchers attempt to minimize pro-
duction costs by reducing the amount of supplemental feed purchased.
Reduced nutritional intake causes a depletion of body reserves. Deter-
mination of specific blood constituents that reflect nutritional intake
could be useful indicators of nutrient adequacy of the diet of ruminants
(Annison et al., 1960; Reid et al., 1962; Russel et al., 1967). Feeding
regime (Reid and Hink, 1962; Howland et al., 1966; Wagner and Oxenreider,
1971) and lactational status (Wagner and Oxenreider, 1971) alter concen-
trations of glucose in blood.

Physiological processes involve substrates and metabolites that are
transported by the blood. Ovine brain tissue is totally dependent on
glucose as an energy source (McClymont and Setchell, 1956) and reduced
glucose in blood may affect hormone production (Howland et al., 1966).
Administration of glucose metabolic inhibitors decrease the ability of
rats to release LH in vitro in response to GnRH (Sen et al., 1979) where-
as abomasal infusion of propionate increases blood glucose and enhanced
the ability of prepuberal heifers to respond to a GnRH challenge
(Rutter et al., 1983).

Weight loss coupled with a reduction in concentration of glucose in
blood are associated with long postpartum anestrus periods (McClure,
1968; Patil and Deshpande, 1979) and low fertility (McClure et al., 1970;
Downie and Gelman, 1976). Independent of nutritional treatment, concen-
trations of blood glucose in dairy cows increased up to parturition then
decreased slightly after calving (Horrocks and Paterson, 1957; 1960).

The effect of nutrition, as reflected in body condition, on specific
blood constituents prepartum may influence subsequent endocrine function
during the postpartum period of beef cows. Restriction of energy intake

by cows during pregnancy can alter concentrations of hormones in blood (Donaldson et al., 1970; Mobley, 1982). Therefore, the objective of this study was to determine the influence of prepartum nutrition on specific blood constituents and reproductive performance of beef cows.

Materials and Methods

Sixty-eight mature Hereford cows that calved in March and April were used to determine the influence of nutrition during late gestation on hematocrit, concentrations of glucose, proteins and total esterified fatty acids (TEFA) in plasma, postpartum ovarian activity and reproductive performance. Cows were maintained during the winter on dry native range. Animals were blocked and assigned to four nutritional regimes based on body weight and condition, age and expected calving date. Cows on each treatment were fed in a group and nutrient intake was regulated by alteration in the amount of supplement feed offered (Table I).

On November 19, 1980, one-fourth of the cows were assigned to a moderate (M) level of nutrition so as to maintain their fall weight (the November 19th weight) until parturition. The remaining cows were assigned to a low (L) level of nutrition with the intent that they would lose 5% of their fall weight by January 22, 1981 (approximately sixty days prepartum). On January 22, 1981 one-third of the L cows remained on the low plane of nutrition with the intent for them to lose 10% of their fall weight by calving (low-low; LL group). Another one-third of the L cows were fed the same amount of supplemental feed as the M group up until calving (low-moderate; LM group). The remaining one-third of the L cows were fed 140% of the amount of supplemental protein and energy that was fed the M treatment group, (low-high; LH group). It

TABLE I

FEEDING PROGRAM

Date	Nutritional Treatment		
	Moderate	Low	High
November 19, 1980	9.5 kg of 41 % protein CSM[a] pellets/week	2.3 kg of 41 % protein CSM pellets/week	
January 22, 1981	9.5 kg of 41 % protein CSM pellets/week	2.3 kg of 41 % protein CSM pellets/week	3.6 kg of 41 % protein CSM pellets/week
Postpartum	12.7 kg of 41 % protein CSM pellets/week		

[a]41 % protein cottonseed meal pellet.

was anticipated that during the last 60 days of gestation, M cows would maintain their fall weight, LL cows would lose weight, and LM and LH cows would gain weight. All cows were managed in the same pasture and group fed supplemental feed after calving.

Cows were weighed biweekly, after 15 hours without feed and water from November 19, 1980 until calving. Body condition scores were determined independently by at least two individuals when cows were weighed. Body condition scores were based on a scale from 1 to 9 and a condition score of 1 was a very thin and emaciated animal and a cow that scored 9 was extremely fat and obese. Samples of blood plasma were collected biweekly during late gestation from January 22, 1981 until calving. About 40 ml of blood were obtained by jugular puncture. The blood was transferred to tubes containing 32 mg of oxalic acid and cooled immediately to 5 C. Sodium fluoride (.1 ml per 10 ml blood of a 16 gr NaF/100 ml oxalic acid solution) was added to blood to inhibit metabolism of glucose in samples used to estimate concentrations of glucose in plasma. Then samples were centrifuges (5,000 xg for 15 min) and plasma was decanted and stored at -10 C until analyzed.

Within 30 min after collection of blood, protein in each plasma sample was quantified using a refractometer and packed cell volume was determined by centrifugation of blood in hematocrit tubes. Concentrations of glucose in plasma were determined by an enzymatic colormetric procedure (Sigma Chemical Company, No. 510, St. Louis). Within each assay, standard curves were developed with 0, 25, 50, 100 and 150 mg % glucose solutions for calculation of concentrations in unknown samples. The between assay coefficient of variation for glucose in plasma was 1.0% and the within assay coefficient of variation was 2.8%. When 50 mg of

glucose was added to 1 ml samples of plasma from cows, 90 ± 1 % (n=5) was recovered. A colormetric assay (Stern and Shapiro, 1953) was used to determine TEFA in plasma samples after storage. A standard curve was developed for each assay using 0, 14.54, 29.08, 43.62, 58.16 and 72.70 mg % triacetin solutions. The between assay coefficient of variation for TEFA in plasma was 13.5% and the within assay coefficient of variation was 2.7%. When 19.38 mg of triacetin was added to 1.5 ml samples of plasma from cows, 105 ± 4 % (n=10) was recovered.

Blood samples (20 ml) were obtained weekly by tail vein puncture between 15 to 85 days postpartum. Oxalic acid (16 mg) was added to tubes, samples were cooled, centrifuged and plasma was decanted and stored. Concentrations of progesterone in plasma were quantified by a double antibody radioimmunoassay. The specificity and validation of the assay in our laboratory has been described (Lusby et al., 1981). The between assay coefficient of variation was 11.6% and the within assay coefficient of variation was 6.6%. When 5 ng of progesterone were added to 1 ml samples of plasma from steers, 104 ± 4 % (n=11) was recovered. Concentrations of progesterone in plasma were used to determine the onset of ovarian activity. Ovarian activity was considered to be initiated when concentrations of progesterone in plasma were equal to or greater than 1 ng/ml for 2 weeks in succession.

Sterile bulls were used to detect estrous activity from parturition until the start of the breeding season. Cows were exposed to fertile bulls equipped with chinball markers from May 1, 1981 to August 1, 1981.

Polynomial curves were used to describe the influence of nutritional treatment on concentrations of glucose, TEFA and proteins in plasma, packed cell volume in blood, prepartum percentage weight change and

body condition score of cows. Fit of the response curve (linear, quadratic, cubic, quartic or quintic) was determined by using the curve with the highest significant R^2. If the R^2 for the next highest order of fit was less than a 2% increase, although the fit was significant, it was not used. Tests of heterogeneity of regression coefficients were used to determine whether time trends among groups were not parallel. Cow within treatment was included in the model adjusting means for stage of gestation at each date sampled. Reproductive performance data were analyzed by chi-square and analysis of variance.

Results

Body weights of cows prepartum are summarized in Table II. On November 19 body weights were similar for cows on all treatments and averaged 459 ± 12 kg. Percentage weight changes from November 19 to the day of nutrition change (January 22) were similar for cows assigned to M, LL, LM and LH treatments (Figure 1). Winter nutritional treatments influenced percentage body weight change ($P < .05$) between November 19, 1980 and February 19, 1981 and changes averaged .5 ± 1.5 %, -5.2 ± 1.4 %, .3 ± 1.1 % and 3.1 ± 1.2 % for cows on the M, LL, LM and LH treatment groups, respectively. Cows on the LL treatment weighed 434 ± 12 kg on February 19 ($P < .05$) compared to 442 + 11 kg for LM cows and 463 ± 17 and 467 ± 12 kg, respectively, for M and LH cows. On March 19, the average calving date for all cows, percentage prepartum weight change for all the four treatment groups were similar. A third order polynomial regression equation best described percentage prepartum weight change from November 19, 1980 to March 19, 1981 (Table III). The percentage weight change for M cows was different ($P < .05$) from that for cows on

TABLE II

INFLUENCE OF NUTRITION ON PREPARTUM BODY
WEIGHTS[a] (kg) OF RANGE COWS

Date	Weeks Before or After Change in Nutrition	Nutritional Treatment			
		M	LL	LM	LH
November 19, 1980	-9	462 ± 10 (12)[b]	455 ± 12 (17)	443 ± 10 (20)	460 ± 17 (19)
December 18, 1980	-5	454 ± 16 (12)	457 ± 13 (17)	443 ± 12 (20)	462 ± 12 (19)
January 22, 1981	0	470 ± 16 (12)	467 ± 13 (17)	445 ± 12 (20)	459 ± 12 (19)
February 19, 1981	+4	463 ± 17 (11)	434 ± 12 (17)	442 ± 11 (20)	467 ± 12 (19)
March 5, 1981	+6	441 ± 14 (10)	430 ± 11 (15)	419 ± 10 (17)	437 ± 12 (13)
March 19, 1981	+8	432 ± 21 (5)	418 ± 13 (11)	407 ± 13 (10)	414 ± 14 (10)

[a] Least square means ± S.E.

[b] No. in parenthesis equals no. of cows.
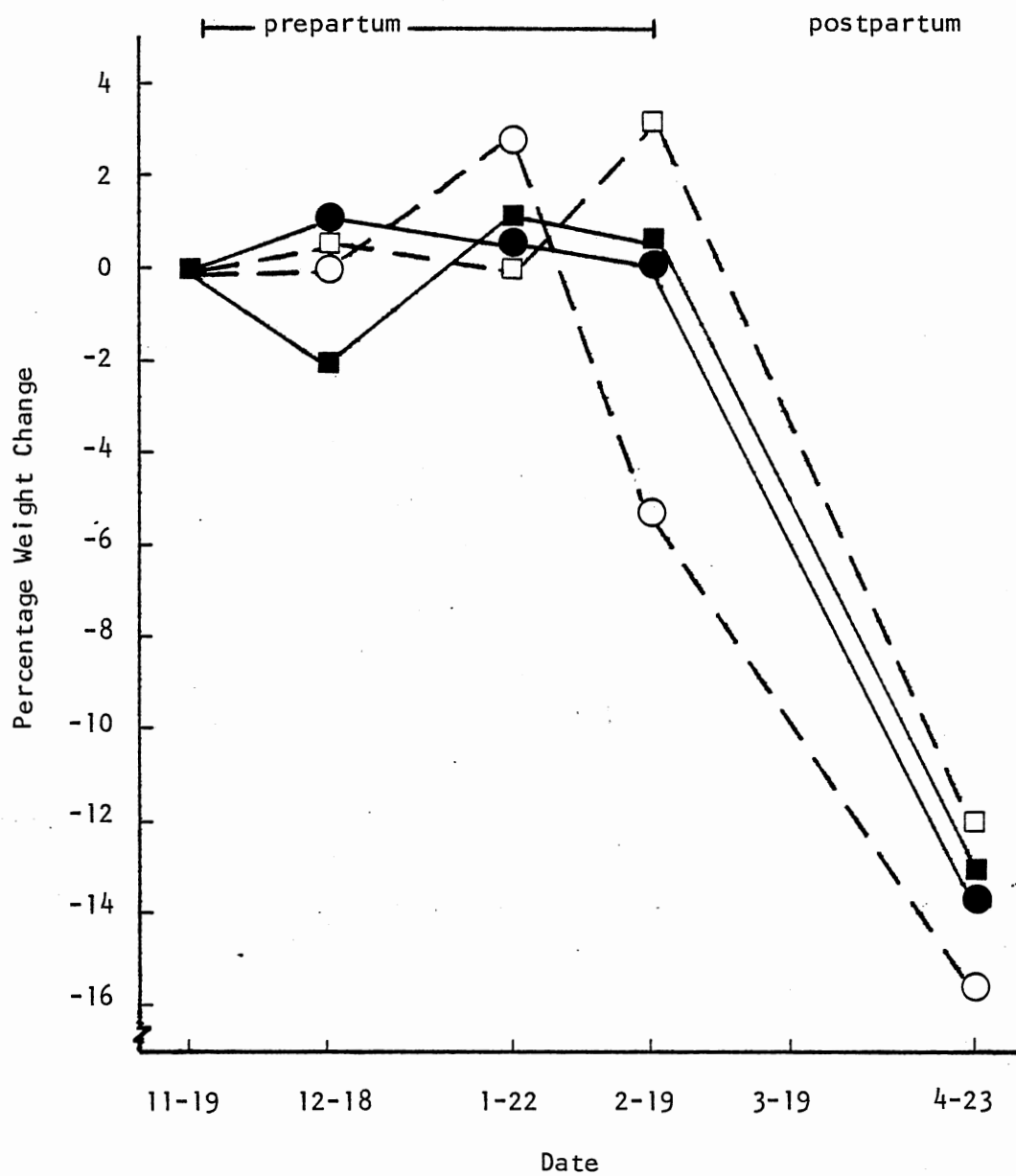
Figure 1. Percentage Weight Change of Moderate (■), Low-Moderate (●),
Low-High (□), and Low-Low (○) Range Cows.

TABLE III

R^2 AND PROBABILITY LEVELS OF POLYNOMIAL
REGRESSION EQUATIONS FOR PREPARTUM
PERCENTAGE CHANGE IN BODY WEIGHT
AND BODY CONDITION SCORE

Order	Percentage Change in Body Weight	Body Condition Score
Linear	.542[a] <.001[b]	.576 <.001
Quadratic	.653 <.001	.586 <.039
Cubic	.711[c] <.001	.619[c] <.001
Quartic	.717 <.008	.622 <.244
Quintic	.718 <.865	.622 <.395

[a] R^2 value.

[b] Probability level.

[c] Curve used in analyses.

TABLE IV

ORTHOGONAL COMPARISONS USED TO TEST FOR HETERO-
GENEITY OF REGRESSION COEFFICIENTS FOR
POLYNOMIAL RESPONSE CURVES TO DETERMINE
WHETHER TIME TRENDS FOR PREPARTUM
PERCENTAGE CHANGE IN BODY WEIGHT
AMONG GROUPS WERE NOT PARALLEL

	M versus LH, LM, LL			
Error	D.F.	S.S.	M.S.	F
LH, LM, LL	274	1677.1441		
M	48	168.0298		
Total	322	1845.1739	5.7304	
M, LH, LM, LL	326	1951.8338		
Difference	4	106.6599	26.6650	4.65*
	LL versus LH, LM			
LH, LM	190	928.3727		
LL	80	396.5400		
Total	270	1324.9127	4.9071	
LH, LM, LL	274	1677.1441		
Difference	4	352.2314	88.0579	17.95**
	LH versus LM			
LM	96	351.9143		
LH	90	430.8417		
Total	186	782.7560	4.2084	
LH, LM	190	928.3727		
Difference	4	145.6167	36.4042	8.65**

** $P < .001$.
 * $P < .05$.

the LH, LM and LL treatments (Table IV). The response for cows on the LL treatment was different (P < .001) from that for LM and LH cows. In addition, the response for percentage weight change of LH cows was different (P< .001) from that for cows on the LM treatment.

Body condition scores were similar for cows in the four treatment groups on November 19 and averaged 6.5 + 1 (Figure 2). On January 22, the day of change in nutrition, body condition scores were lower but similar for all treatment groups (range 5.7 to 6.0). Body condition scores were similar for cows in all treatment groups at calving. A third order polynomial regression equation best described the response curve for body condition from November 19, 1980 to March 19, 1981 (Table III). Response of body condition score for LL cows was different (P < .001) from that for cows on the LH and LM treatments (Table V). In addition, the response for cows on the LH treatment was different (P < .05) from that for LM cows.

Concentrations of glucose in plasma of cows from January 22 to March 19 were best described by a second order polynomial response curve (Table VI). Concentrations of glucose during the sampling period were similar for cows on the LH and LM treatments (Table VII). However, glucose concentrations for M cows were different (P< .05) from those cows on the LH, LM and LL treatments. Moreover, the response for cows on the LL treatment was different (P< .05) from that for cows on LH and LM treatments.

Concentrations of glucose in plasma were similar for cows assigned to all treatment groups on the day of nutrition change (January 22) and averaged 55.1 ± .7 mg/100 ml (Table VIII). Least square means for glucose in plasma adjusted for stage of gestation indicated that concen-
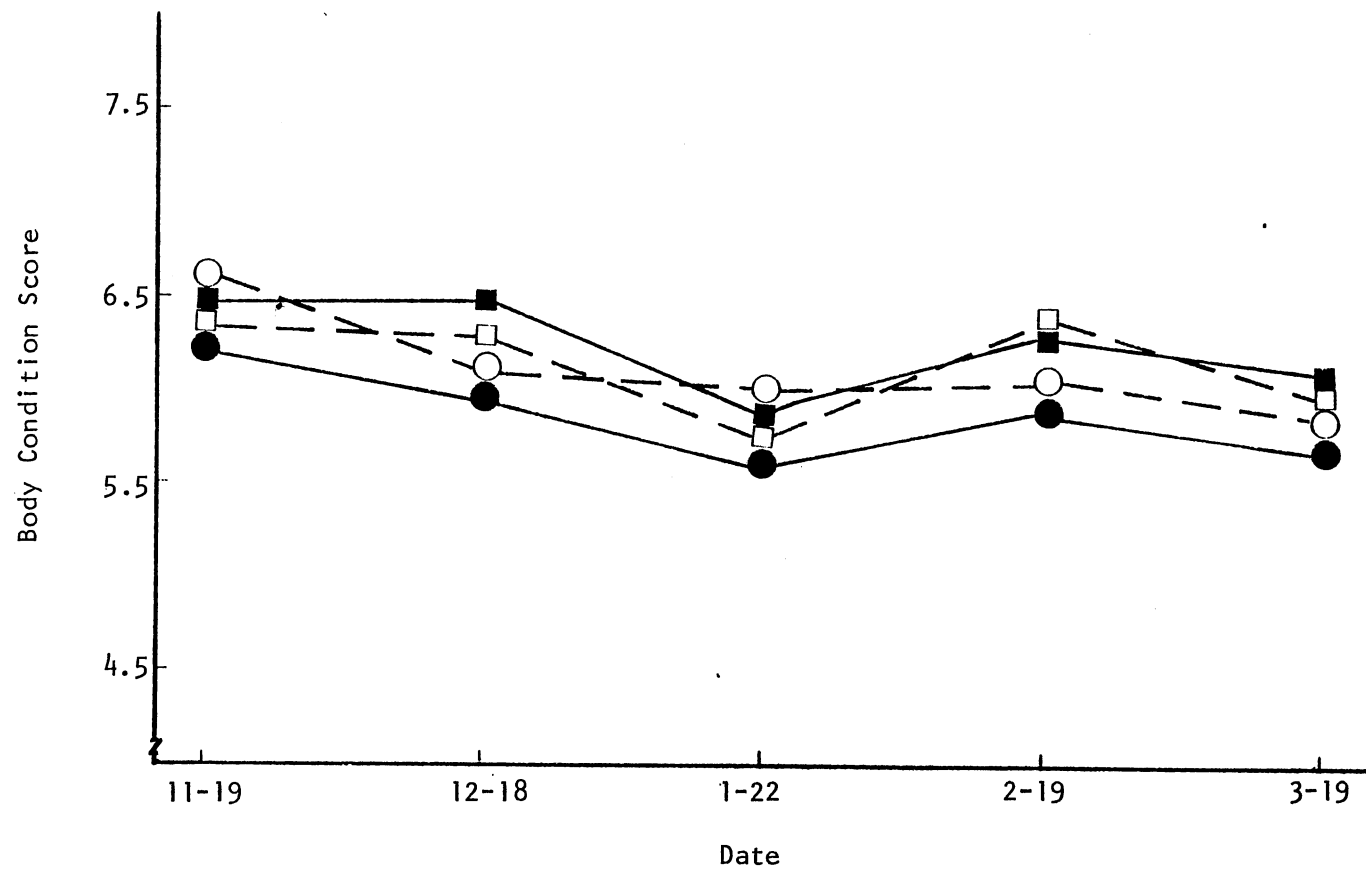
Figure 2. Body Condition Scores of Moderate (■), Low-Moderate (●), Low-High (□)
and Low-Low (○) Range Cows.

TABLE V

ORTHOGONAL COMPARISONS USED TO TEST FOR HETERO-
GENEITY OF REGRESSION COEFFICIENTS FOR
POLYNOMIAL RESPONSE CURVES TO DETERMINE
WHETHER TIME TRENDS FOR PREPARTUM
BODY CONDITION AMONG GROUPS
WERE NOT PARALLEL

	M versus LH, LM, LL			
Error	D.F.	S.S.	M.S.	F
LH, LM, LL	152	24.2717		
M	24	1.3980		
Total	176	25.6697	.1459	
M, LH, LM, LL	180	26.2052		
Difference	4	.5355	.1339	.92
	LL versus LH, LM			
LH, LM	104	15.4905		
LL	44	3.3941		
Total	148	18.8846	.1276	
LH, LM, LL	152	24.2717		
Difference	4	5.3871	1.3468	10.55**
	LH versus LM			
LM	50	6.9865		
LH	50	6.1550		
Total	100	13.1415	.1314	
LH, LM	104	15.4905		
Difference	4	2.3490	.5873	4.47*

** P < .001.
 * P < .05.

TABLE VI

R^2 AND PROBABILITY LEVELS OF POLYNOMIAL
REGRESSION EQUATIONS FOR CONCENTRATIONS
OF BLOOD CONSTITUENTS

| Order | Blood Constituent | | | |
	Glucose	Protein	Esterified Fatty Acid	Packed Cell Volume
Linear	$.516^a$ $.925^b$	$.842^c$ .097	.587 .446	.566 .001
Quadratic	$.525^c$ .027	.842 .528	$.616^c$ .001	.579 .005
Cubic	.525 .956	.842 .950	.617 .745	.603 .001
Quartic	.528 .216	.842 .532	.617 .622	$.620^c$ .008

[a] R^2 value.

[b] Probability level.

[c] Order of response curve used.

TABLE VII

ORTHOGONAL COMPARISONS USED TO TEST FOR HETERO-
GENEITY OF REGRESSION COEFFICIENTS FOR
POLYNOMIAL RESPONSE CURVES TO DETERMINE
WHETHER TIME TRENDS FOR GLUCOSE AMONG
GROUPS WERE NOT PARALLEL

		M versus LH, LM, LL		
Error	D.F.	S.S.	M.S.	F
LH, LM, LL	219	7019.8001		
M	38	1755.2690		
Total	257	8775.0691	34.1443	
M, LH, LM, LL	260	9223.9795		
Difference	3	448.9105	149.6368	4.38*
		LL versus LH, LM		
LH, LM	152	5502.2356		
LL	64	1112.0682		
Total	216	6614.3038	30.6218	
LH, LM, LL	219	7019.8001		
Difference	3	403.4963	135.1654	4.41*
		LH versus LM		
LM	77	3527.5120		
LH	72	1899.0863		
Total	149	5426.5983	36.4201	
LH, LM	152	5502.2356		
Difference	3	75.6373	25.6373	0.02

* P < .05.

TABLE VIII

INFLUENCE OF NUTRITION ON CONCENTRATIONS OF
GLUCOSE (mg/100 ml) IN PLASMA OF
RANGE COWS

Date	Weeks After Change In Nutrition	Nutritional Treatment[a]			
		M	LL	LM	LH
January 22	0	55.7 ± 1.6	55.2 ± 1.3	55.9 ± 1.2	53.2 ± 1.2
February 5	2	52.2 ± 2.5^b	53.3 ± 2.1^b	61.4 ± 1.9^c	57.9 ± 1.9^{bc}
February 19	4	54.9 ± 1.8^{de}	51.4 ± 1.5^d	58.9 ± 1.3^e	59.6 ± 1.4^e
March 5	6	56.3 ± 2.6^{de}	55.2 ± 2.1^d	57.5 ± 2.0^{de}	61.5 ± 2.3^e
March 19	8	64.5 ± 3.3^d	52.8 ± 2.2^e	60.0 ± 2.3^d	62.2 ± 2.3^d

[a] Least square means ± S.E. adjusted for stage of gestation.

[bc] Means in a row with different superscripts differ ($P < .005$).

[de] Means in a row with different superscripts differ ($P < .05$).

trations of glucose in plasma two wk postnutritional change (February 5) were greater (P < .005) for LM and LH cows compared to cows on the LL treatment. By four wk after nutrition change cows that were fed either moderate or high amounts of supplemental feed after a low amount previously (LH and LM treatments) had greater (P < .05) concentrations of glucose in plasma than LL or M cows. Concentrations of glucose in plasma on February 19 averaged 54.9 ± 1.8, 51.4 ± 1.5, 58.9 ± 1.3 and 59.6 ± 1.4 mg/100 ml for cows on the M, LL, LM and LH treatments, respectively. At six weeks after the change in nutrition, concentrations of glucose in plasma remained greater (P < .05) in LH cows compared to cows on the LL treatment. In addition, on March 19 (8 weeks after the change in nutrition), glucose concentrations were reduced (P < .05) in LL cows compared to the other three treatments. During the first six wk after the nutritional change, concentrations of glucose in plasma of cows on the LL and M treatments remain essentially unchanged and range between 52 and 56 mg/100 ml while concentrations of glucose in plasma of cows on the LH and LM treatments increased.

A linear regression equation best described concentrations of protein in plasma from January 22 to March 19 (Table VI). Concentrations of protein in plasma were similar for cows on all treatments during the sampling period (Table IX).

Least square means adjusted for stage of gestation for concentrations of protein in plasma were less (P < .05) for LL cows compared to cows in the M and LM treatments on the day of nutrition change (January 22) (Table X). At two wk and six wk after nutrition change, protein in plasma was reduced in cows on the LL treatment compared to cows on the other treatments. Concentrations of protein in plasma increased in cows

TABLE IX

ORThOGONAL COMPARISONS USED TO TEST FOR HETERO-
GENEITY OF REGRESSION COEFFICIENTS FOR
POLYNOMIAL RESPONSE CURVES TO DETERMINE
WHETHER TIME TRENDS FOR PROTEIN AMONG
GROUPS WERE NOT PARALLEL

		M versus LH, LM, LL		
Error	D.F.	S.S.	M.S.	F
LH, LM, LL	214	9.2808		
M	39	1.8326		
Total	253	11.1134	.0439	
M, LH, LM, LL	255	11.1470		
Difference	2	.0336	.0168	.38
		LL versus LH, LM		
LH, LM	147	6.4966		
LL	65	2.6850		
Total	212	9.1816	.0433	
LH, LM, LL	214	9.2808		
Difference	2	.0992	.0496	1.15
		LH versus LM		
LM	74	3.3437		
LH	71	3.0622		
Total	145	6.4059	.0442	
LH, LM	147	6.4966		
Difference	2	.0907	.0454	1.03

TABLE X

INFLUENCE OF NUTRITION ON CONCENTRATIONS OF
PROTEIN (PERCENT) IN PLASMA OF RANGE COWS

Date	Weeks After Change In Nutrition	Nutritional Treatment[a]			
		M	LL	LM	LH
January 22	0	$7.0\pm.1^b$	$6.7\pm.1^c$	$7.0\pm.1^b$	$6.9\pm.1^{bc}$
February 5	2	$7.1\pm.1^b$	$6.8\pm.1^c$	$7.2\pm.1^b$	$7.1\pm.1^b$
February 19	4	$7.1\pm.1$	7.1 ± 1	$7.2\pm.1$	$7.3\pm.1$
March 5	6	$7.3\pm.1^b$	$7.0\pm.1^c$	$7.4\pm.1^b$	$7.4\pm.1^b$
March 19	8	$7.7\pm.2^b$	$7.2\pm.1^c$	$7.3\pm.1^{bc}$	$7.6\pm.2^{bc}$

[a] Means $\pm$ S.E. adjusted for stage of gestation.

[bc] Means in a row with different superscripts differ (P<.05).

TABLE XI

ORTHOGONAL COMPARISONS USED TO TEST FOR HETERO-
GENEITY OF REGRESSION COEFFICIENTS FOR
POLYNOMIAL RESPONSE CURVES TO DETERMINE
WHETHER TIME TRENDS FOR TOTAL
ESTERIFIED FATTY ACIDS AMONG
GROUPS WERE NOT PARALLEL

M versus LH, LM, LL

Error	D.F.	S.S.	M.S.	F
LH, LM, LL	219	2677.1269		
M	38	488.4553		
Total	257	3165.5822	12.3174	
M, LH, LM, LL	260	3181.0274		
Difference	3	15.4452	5.1484	.42

LL versus LH, LM

Error	D.F.	S.S.	M.S.	F
LH, LM	152	1876.0429		
LL	64	578.2639		
Total	216	2454.3068	11.3625	
LH, LM, LL	219	2677.1269		
Difference	3	222.8201	74.2734	6.54*

LH versus LM

Error	D.F.	S.S.	M.S.	F
LM	78	707.9848		
LH	71	921.9931		
Total	149	1692.9779	11.3623	
LH, LM	152	1876.0429		
Difference	3	183.065	61.0217	5.37*

* P < .05.

on all treatments from January 22 to March 19 but cows on the LL

treatment   lower protein concentrations on all dates sampled.

A second order polynomial regression equation best described con-

centrations of total esterified fatty acids (TEFA) in plasma of cows

from January 22 to March 19 (Table VI). Concentrations of TEFA for

cows on the LL treatment responded differently (P < .05) to treatment

change than did cows on the LH and LM treatments (Table XI). In addition,

the response curve for TEFA of cows on the LH treatment was different

(P < .05) from that for cows on the LM treatment. Treatment least

square means adjusted for stage of gestation were similar for all

treatments at all dates sampled and averaged 25.3 ± .3 mg/100 ml

(Table XII).

A fourth order regression equation best described the response for

packed blood cell volume due to treatment from January 22 to March 19

(Table VI). The response curve for volume of cells in blood of cows

on the LH treatment was different (P < .05) than for cows on the LM

treatment (Table XIII). Treatment least square means for hematocrit

adjusted for stage of gestation were similar for cows on all treatments

on January 22 (Table XIV). At two, four, six and eight wk after

nutrition change, cows on the LL treatment had reduced (P < .05) hemato-

crits compared to cows on the M treatment. In addition, cows on the

LM treatment had reduced (P < .05) hematocrits at two, four and six wk

after change in nutrition compared to cows on the M treatment. Cows

on the LH treatment had hematocrits that were intermediate between cows

on LL and M treatments. In general hematocrits increased for all cows

between January 22 and March 19.

Postpartum reproductive performance is summarized in Table XV.

TABLE XII

INFLUENCE OF NUTRITION ON CONCENTRATIONS OF TOTAL ESTERIFIED FATTY ACIDS (mg/100 ml, TRIACETIN BASIS) IN PLASMA OF RANGE COWS

Date	Weeks After Change In Nutrition	Nutritional Treatment			
		M	LL	LM	LH
January 22	0	24.9 ± 1.2[a]	22.7 ± 1.0	$23.4\pm.9$	25.1 ± 1.0
February 5	2	26.9 ± 1.3	26.6 ± 1.1	25.6 ± 1.0	23.9 ± 1.0
February 19	4	26.2 ± 1.1	$26.3\pm.9$	$24.7\pm.8$	$26.8\pm.9$
March 5	6	26.6 ± 1.9	25.2 ± 1.5	26.6 ± 1.5	23.9 ± 1.7
March 19	8	26.4 ± 2.1	23.5 ± 1.4	23.8 ± 1.4	26.7 ± 1.5

[a] Least square means ± S.E. adjusted for stage of gestation.

TABLE XIII

ORTHOGONAL COMPARISONS USED TO TEST FOR HETERO-
GENEITY OF REGRESSION COEFFICIENTS FOR
POLYNOMIAL RESPONSE CURVES TO DETERMINE
WHETHER TIME TRENDS FOR PACKED CELL
VOLUME AMONG GROUPS WERE
NOT PARALLEL

Error	D.F.	S.S.	M.S.	F
		M versus LH, LM, LL		
LH	214	1288.5736		
M	35	116.4048		
Total	249	1404.9784	5.6425	
M, LH, LM, LL	254	1416.4175		
Difference	5	11.4391	2.2878	.41
		LL versus LH, LM		
LH, LM	147	1069.7937		
LL	62	179.1758		
Total	209	1248.9695	5.9759	
LH, LM, LL	214	1288.5736		
Difference	5	39.6041	7.9208	1.3255
		LH versus LM		
LM	74	497.0388		
LH	64	422.2854		
Total	142	919.3242	6.4741	
LH, LM	147	1069.7937		
Difference	5	150.4695	30.0939	4.65*

* $P < .05$.

TABLE XIV

INFLUENCE OF NUTRITION ON PACKED BLOOD CELL
VOLUME (PERCENT) IN RANGE COWS

Date	Weeks After Change In Nutrition	Nutritional Treatment[a]			
		M	LL	LM	LH
January 22	0	35±.8	33±.7	35±.6	33±.6
February 5	2	35±.7^b	33±.6^c	32±.5^c	34±.5^{bc}
February 19	4	36±.7^d	35±.6^e	34±.5^e	36±.5de
March 5	6	37±1.0^d	34±.8^e	35±.7^e	35±.8de
March 19	8	40±1.7^d	36±1.1^e	38±1.2^{de}	40±1.2^d

[a] Least square means ± S.E. adjusted for stage of gestation.

[bc] Means in a row with different superscripts differ (P<.01).

[de] Means in a row with different superscripts differ (P<.05).

TABLE XV

INFLUENCE OF PREPARTUM NUTRITION ON POSTPARTUM
REPRODUCTIVE PERFORMANCE OF RANGE COWS

| Criteria | Nutritional Treatment | | | |
	M	LL	LM	LH
No. of Cows	12	17	19	19
Estrus by 85 Days (%)	66.7	41.2	52.6	79.0
First Estrus for Cows Cycling During the Breeding Season (d)	71 ± 8[a] (10)[b]	67 ± 8 (9)	73 ± 6 (15)	62 ± 6 (16)
Ovarian Activity[c] 85 Days (%)	58.3	52.9	52.6	52.6
Onset of Ovarian Activity (d)	68 ± 7	71 ± 6	60 ± 6	61 ± 5
Pregnant[d] During the Breeding Season (%)	91.7	76.5	94.7	89.5
Parturition to Conception[e] (d)	78 ± 9	83 ± 8	90 ± 7	83 ± 7

[a] Means $\pm$ S.E.

[b] No. in parenthesis equals no. of cows if less than total no. of cows studied.

[c] The onset of avarian activity was characterized by concentration of progesterone in plasma equal to or greater than 1 ng/ml for two weeks in succession.

[d] Determined by rectal palpation 75 days after the end of the breeding season.

[e] Date of conception was calculated by subtracting 282 days from the calving date in 1982.

This experiment utilized cows for one year of a four year study to determine the influence of nutrition on reproductive performance. Although treatments did not significantly influence the reproductive criteria, some trends emerged. Fewer cows on the LL treatment exhibited estrus by 85 day after calving. The average number of days until the onset of ovarian activity, for cows with activity by 85 days postpartum, were 71, 68, 60 and 61 for cows on LL, M, LM and LH treatments, respectively. In addition, only 77 percent of the cows on the LL treatment became pregnant compared to 92, 95 and 90 percent for cows on M, LM and LH treatments, respectively. The interval from parturition to conception was slightly shorter for cows on the M treatment compared to cows on the other treatments. Birth weights of calves were similar for cows in all treatment groups (Table XVI).

Discussion

Due to favorable conditions for forage growth during the fall, abundant dormant native range was available and the desired weight losses at nutrition change and at calving were not achieved. Cows on all treatments essentially maintained their November 19, 1980 weight until change in nutrition on January 22, 1981, by calving percentage weight changes were in the desired direction. Average percentage prepartum weight changes at parturition were -3.0%, -4.4%, -6.2% and -2.6% for cows on the M, LL, LM and LH treatments, respectively. Body condition scores were relatively unchanged throughout the prepartum period. At calving, body condition scores were 6.1, 5.8, 5.7 and 6.0 for cows on the M, LL, LM and LH treatments, respectively.

In previous studies, (Wiltbank et al., 1962; Hight, 1968; Corah

TABLE XVI

BIRTH WEIGHT OF CALVES (kg) FROM COWS
ON FOUR NUTRITIONAL TREATMENTS
DURING GESTATION

Treatment	Birth Weight
Moderate	36.7 ± 1.1^a
Low - Low	$39.1 \pm .6$
Low - Moderate	$36.8 \pm .9$
Low - High	36.8 ± 1.2

[a]Least square means ± S.E.

et al., 1975) weight changes are reported without data on changes in body condition (fat reserve). Interpretation of these data are difficult since there could be differences in cow response to treatment due to the amount of fat reserve. Consideration of body condition of cows is important when nutritional treatments are studied. Restriction of energy intake (Donaldson et al., 1970) and reduction in body condition of cows (Mobly, 1982) can alter hormones during gestation. However, Corah et al. (1975) found that nutrition had no effect on endocrine function, but fat reserves may have been ample to negate the effect of limited nutrient intake.

Energy deprivation may alter blood constituents necessary for normal endocrine function. Cows on restricted energy diets post partum had lower concentrations of glucose in plasma (Wagner and Oxenreider, 1971). Ewes fed grain had increased glucose in plasma and improved reproductive performance which indicated increased endocrine function compared to ewes fed hay (Howland et al., 1966). Our research indicates that animals subjected to increased energy and protein intakes during the last 60 days of gestation, after a previous reduction in intake, have significantly increased concentrations of glucose in plasma by two weeks after the change in nutrition and this increase continues for the next eight weeks. Concentrations of glucose in plasma of cows increase during late gestation (Horrocks and Paterson, 1957; Horrocks and Paterson, 1960). However, in ewes, increases in concentration of glucose in plasma during gestation were not related to nutrition (Patterson et al., 1964).

Concentrations of protein in plasma are usually constant and have not been related to fertility (Treacher et al., 1976) or energy content

of the diet (Coggins and Field, 1976). Our findings indicate that concentrations of protein in plasma of cows on a low level of nutrition are reduced during the prepartum period.

Concentrations of blood constituents could be useful indicators to predict nutrient status of ruminants (Annison et al., 1960; Reid et al., 1962; Russel et al., 1967). Amounts of TEFA in blood plasma are greatest when animals are in a positive energy balance. The cows on all treatments in our study were on maintenance or sub-maintenance diets. Our results indicate no difference in concentrations of TEFA in plasma due to treatment at each date sampled. However, the response of LL cows to treatment over the sampling period was different ($P < .05$) than LH and LM cows and LH cows responded different ($P < .05$) than did LM cows. M and LH cows had greater concentrations of TEFA in plasma at calving than did LL and LM cows. The cause of the difference in response curves is not clear.

Packed red blood cell volumes were reduced for LL and LM cows compared to cows on the moderate treatment. All treatment groups had greater volumes of packed red blood cells at calving than on the day of nutrition change. This indicates that blood fluids changed as parturition approached and could be related to physiological changes associated with late gestation and environmental changes such as warm temperatures.

Prepartum nutrition influences postpartum reproductive performance of beef cows (Wiltbank et al., 1962; Wiltbank et al., 1964; Dunn et al., 1969). Although not significant, reproductive performance of LL cows was reduced in this experiment. Fewer LL cows exhibited estrus by 85 days after calving, they needed more days before ovarian activity resumed and fewer cows became pregnant during the breeding season.

Prepartum changes in specific blood constituents may influence subsequent endocrine function after calving. Cows with reduced concentrations of glucose in plasma and decreasing body weights after parturition may have extended intervals from parturition to first estrus (Patil and Deshpande, 1979). Infertility has been related to low amounts of glucose in plasma (McClure, 1965; McClure, 1968). Problems in fertility during the breeding season may be caused by prepartum changes in concentrations of metabolites such as glucose and precursors of glucose that are vital for cellular activity.

The mechanism by which prepartum nutrition and body condition at calving influence postpartum reproductive performance is unclear. Once the cell is deprived of energy, endocrine activity may be reduced. Elevated concentrations of blood glucose increase endocrine function (Rutter et al., 1983) and decreased glucose availability retards endocrine function (Sen et al., 1979). Ewes that are in good condition when diet is not adequate are better able to maintain the concentrations of glucose in blood (Reid and Hinks, 1962) and usually don't experience reduced endocrine function. Therefore, it is possible that nutritional alterations before calving in concentrations of compounds in blood involved in energy metabolism may have a carry over effect into the postpartum period and result in reduced endocrine function.

In conclusion, this study indicates that prepartum nutrition influences the concentrations of glucose and protein in plasma and hematocrit and suggest that these prepartum changes may be related to subsequent endocrine function during the postpartum period in beef cows.

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TABLE XVII

BODY CONDITION SCORE[a] FOR COWS ON DIFFERENT
PREPARTUM NUTRITIONAL TREATMENTS

Date	Weeks Before or After Change In Nutrition	Nutritional Treatment			
		M	LL	LM	LH
November 19, 1980	-9	6.5 ± .2	6.5 ± .1	6.4 ± .1	6.5 ± .2
December 18, 1980	-5	6.5 ± .2	6.1 ± .2	6.1 ± .2	6.3 ± .2
January 22, 1981	0	5.9 ± .3	6.0 ± .2	5.7 ± .2	5.8 ± .2
February 19, 1981	+4	6.3 ± .2	6.1 ± .2	6.1 ± .1	6.4 ± .1
March 19, 1981	+8	6.1 ± .2	5.9 ± .1	5.8 ± .1	6.0 ± .2

[a]1 = very thin, 9 = very fat.

VITA

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Master of Science

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